

Sultanate of Oman
Ministry of Environment and Climate Affairs (MECA)

**The Qurm Environmental Information
Center Project**

Technical Document

March 2014

Japan International Cooperation Agency (JICA)

Ides Inc.

Appropriate Agriculture International Co., Ltd. (AAI)

Contents

Technical Document 1	Training plan and materials
Technical Document 2	Mangrove Monitoring Guideline
Technical Document 3	Mangrove Plantation Guideline
Technical Document 4	Mangrove Protection Guideline
Technical Document 5	Guideline for Development of Environmental Education Program

The Qurm Environmental Information Center Project

Technical Document 1

Training plan and materials

March 2014

JICA Expert Team

Contents

1	Introduction	1
2	List of training course	2
3	List of module and material of each training course	3
4	Outline of training program	5
5	Trainer's manual.....	19
6	List of materials	41

Attached CD: Soft copy of the training materials

1 Introduction

As one of the various functions of the Qurm Environmental Information Center (QEIC), it is expected that the QEIC would be a center for training programmes related to mangrove ecosystem conservation.

The targeted trainees will be the staff of the QEIC (Qurm Environmental Information Center), the Ministry of Environment and Climate Affairs (MECA), research organizations, schools, NGOs, local communities and private sectors.

Since the training course will consist of various topics and target groups, the trainers (i.e. lecturers) would be not only the QEIC staff but also be recruited from available local human resources (e.g. university professor, expert from other ministries).

The contents of the training course, therefore, shall be shared within the trainers to understand the contents of the training course. This material was prepared based on the viewpoint mentioned above.

Each training course consists of several modules, and information regarding each training course are described through following.

- List of training courses: general information about the training course, including the course title, target group, learning goal, location, duration, number of module and lecturer
- List of module and material of each training course: break down of each training course, including the contents of each module, location duration and contents of training material
- Outline of training course: outline of the training course
- Trainer's manual: procedures and methods of the training course, which are referred by the trainer
- List of training material: list of document materials to be used by trainer to explain the details on the training course

2 List of training course

Traning courses are listed in the Table 1, including the course title, target group, learning goal, location, duration, number of module and lecturer.

Table 1 List of training course

Category	Course title	Target Group						Learning Goals	Location		Duration (day)	No. of modules	Lecturer	
		QEIC/MECA staff	Research organizations	Students	NGO	Local community	Private sector		Lecture room	Field				
I	General	1. Function of QEIC	x	x	x	x	x	x	To introduce activities, facilities and equipment of QEIC, as well as case studies of similar institutions.	x		1.5	6	Q
		2. Introduction on mangrove ecosystem	x	x	x	x	x	x	To obtain a basic understanding on mangrove ecosystem, importance of conservation and the various threats.	x	x	1.0	2	Q
II	Monitoring	1. Introduction on Mangrove Ecosystem Monitoring Program	x		x	x	x		To learn how to monitor and assess the status of mangrove ecosystem.	x	x	4.0	4	Q, E
		2. Introduction on mangrove health assessment using remote sensing	x		x				To learn how to monitor and assess mangrove forest health with remote sensing technology.	x	x	3.0	3	Q, E
		3. Introduction on Transplanted-seedling Monitoring Program	x		x	x	x		To learn how to monitor the growth and health status of transplanted seedling.	x	x	1.0	2	Q
III	Plantation	1. Method of mangrove tree plantation	x			x	x	x	To learn necessary processes for mangrove tree plantation such as site selection, seed collection/treatment, nursery operation and transplanting procedure. The course also covers landownership issues for plantation.	x	x	3.0	4	Q
IV	Protection	1. Introduction on mangrove ecosystem protection	x			x	x	x	To learn practical and regulatory measures to protect mangrove ecosystem.	x		0.5	1	Q
V	Database	1. Introduction of QEIC database	x						To learn the structure and how to use QEIC database.	x		0.5	1	Q
VI	Education	1. Producing education materials	x			x			To learn how to produce education materials.	x		2.0	7	Q
		2. Implementing education programs	x			x			To learn how to implement education programs.	x	x	1.0	2	Q
VII	Exhibition	1. Introduction of QEIC exhibition	x			x			To learn about the QEIC exhibition, as well as methods to enhance visitors understanding. The course also introduces examples of other similar exhibitions.	x		0.5	3	Q, E

E: Expert from outs E: Expert from outside organization, Q: QEIC staff (incl. MECA staff)

Prepared by JICA Expert Team

3 List of module and material of each training course

List of module and material of each training course is shown in Table 2. Break down of each training course, including the contents of each module, location duration and contents of training material are summarized in the table.

Table 2 List of module and material of each training course

Category	Course title	Module			Location	Duration (day)	Contents of the material	
		No	Mode	Contents				
I	General	1. Function of QEIC	1	Lecture	Introduction of QEIC functions and activities	Lecture room	0.2	PPT
			2	Lecture	Introduction of case studies of similar institutions in the world	Lecture room	0.3	PPT
			3	Lecture	Introduction of facilities of QEIC	Lecture room	0.2	PPT
			4	Quick tour:	Visual tour of facilities, mangrove nursery and Qurm Nature Reserve	QEIC, QNR	0.3	DM
			5	Tour	Laboratory tour	Lecture room, laboratory	0.2	PPT
				Lecture	Detailed introduction of the laboratory, equipment and available parameters, necessary maintenance			
		6	Tour	Introduction of field equipment	Lecture room, storage	0.3	PPT	
			Lecture:	Detailed introduction of the field equipment, necessary maintenance				
		2. Introduction on mangrove ecosystem	1	Lecture	Introduction on mangrove ecosystem	Lecture room	0.5	PPT
			2	Field visit	Observation of mangrove ecosystem	Field	0.5	DM
II	Monitoring	1. Introduction on mangrove ecosystem monitoring program	1	Lecture	Introduction on mangrove ecosystem monitoring program	Lecture room	0.5	PPT
			2	Practice	Monitoring of mangrove	Field & Lecture room	0.5	GL
			3	Practice	Monitoring of fauna	Field & Lecture room	1.5	GL
			4	Practice	Monitoring of environmental condition	Field & Lecture room	1.5	GL
		2. Introduction on mangrove health assessment using remote sensing	1	Lecture	Introduction on mangrove health assessment using remote sensing	Lecture room	0.5	PPT
			2	Practice	Mangrove health assessment using image processing software	Lecture room	2.0	GL
			3	Practice	Field verification	Lecture room	0.5	GL
		3. Introduction on "Transplanted-seedling Monitoring Program"	1	Lecture	Introduction on "Transplanted-seedling Monitoring Program"	Lecture room	0.5	PPT
			2	Practice	Monitoring of seedling growth and health	Field & Lecture room	0.5	GL
		III	Plantation	1. Method of mangrove tree plantation	1	Lecture	Significance of mangrove plantation and selection of suitable site	Lecture room	1.0	PPT, GL
2	Lecture & practice				Seed collection methods and treatment of collected seeds	Field & Lecture room	0.5	DM, PPT, GL
3	Lecture & practice				Operation of nursery for proper seedling production	Field & Lecture room	0.5	DM, PPT, GL
4	Lecture & practice				Transplanting procedure and maintenance of planted trees	Field & Lecture room	1.0	DM, PPT, GL
IV	Protection	1. Introduction on mangrove ecosystem protection	1	Lecture	Introduction on mangrove ecosystem protection	Lecture room	0.5	PPT, GL
V	Database	1. Introduction of QEIC database	1	Lecture	Introduction of database available in the QEIC	Lecture room	0.5	PPT
VI	Education	1. Producing education	1	Lecture	Different type of education materials	Lecture room	0.2	PPT

Technical Document 1 Training plan and materials

Category	Course title	Module			Location	Duration (day)	Contents of the material		
		No	Mode	Contents					
	materials	2	Lecture & discussion	Necessary contents of education materials for environment education of mangroves and mangrove ecosystem	Lecture room	0.4	PPT, discussion		
		3	Lecture & practice	Preparation of education materials	Lecture room	0.4	practice		
		4	Lecture	Factors to be considered in designing education programs	Lecture room	0.2	PPT		
		5	Lecture	Goals of education programs and suitable education materials to be used	Lecture room	0.2	PPT		
		6	Lecture and Practice	Preparing activity sheet of the education program	Lecture room	0.4	practice		
		7	Lecture and Practice	Evaluation of the education program	Lecture room	0.2	PPT, practice		
		2. Implementing education programs	1	Lecture & practice	How to use education materials to implement education programs	Lecture room	0.3	PPT, practice	
	2		Lecture & practice	How to implement education programs based on the activity sheet	Lecture room	0.7	practice		
	VII		Exhibition	1. Introduction of QEIC exhibition	1	Lecture	Importance of story line in designing exhibition plan	Lecture room	0.2	PPT
	2	Lecture & practice			Preparing work sheet on exhibition articles	Lecture room	0.2	PPT, practice	
3	Lecture & discussion	Lessons learnt from other organization			Lecture room	0.1	PPT, discussion		

Note: PPT: Microsoft Power Point material, DM: Document material, GL: Guideline

4 Outline of training program

Outline of each training course, including the course title, objectives of the training, expected output, expected participants, trainers, syllabus (training modules), schedule and necessary equipment, are summarized in a table respectively.

Outline of Training Course

1. Course Title:	
Function of QEIC	
2. Objectives of the Course	
This training course aims to introduce the trainees of activities and function of the QEIC, case studies of similar institutions in the world and to introduce facilities of QEIC, including laboratory, equipment, mangrove nursery and Qurm Nature Reserve.	
3. Expected Output (skills to be acquired by participants)	
By the end of this training course, participants should;	
<ul style="list-style-type: none"> ● understand the functions and activities of the QEIC, ● understand world trend of similar institutions, and thus grasp brief idea for nature conservation for further dissemination to those who are interested. ● understand world trend of similar institutions, and thus grasp brief idea for nature conservation for further dissemination to those who are interested. ● understand facilities in QEIC, Qurm Nature Reserve, function of the laboratory, available field and laboratory equipment, and necessary maintenance of the equipment 	
4. Expected Participants (minimum required level for entry if any)	
All targeted groups	
5. Trainers	
QEIC Staff	
6. Syllabus	
Module 1	Lecture : Introduction of QEIC functions and activities (0.2day)
Module 2	Lecture : Introduction of case studies of similar institutions in the world (0.3day)
Module 3	Lecture : Introduction of facilities of QEIC
Module 4	Quick tour: Visual tour of facilities, mangrove nursery and Qurm Nature Reserve Tour: Laboratory tour
Module 5	Lecture: Detailed introduction of the laboratory, equipment and available parameters, necessary maintenance
Module 6	Tour: Introduction of field equipment Lecture: Detailed introduction of the field equipment, necessary maintenance
7. Schedule	
Module 1 : anytime (duration: 0.2 day)	
Module 2 : anytime (duration: 0.3 day), however, the course title "Function of QEIC" shall be conducted in advance.	
Module 3: anytime (duration: 0.2day)	
Module 4: anytime (duration: 0.3day)	

Technical Document 1 Training plan and materials

I-1 Function of QEIC

Module 5: anytime (duration: 0.2 day)

Module 6: anytime (duration: 0.3 day)

8. Equipment prepared or brought by participants (if any)

Outline of Training Course

1. Course Title:
Introduction on mangrove ecosystem
2. Objectives of the Course
To obtain a basic understanding on mangrove ecosystems
3. Expected Output (skills to be acquired by participants)
By the end of the course, participants should understand; <ul style="list-style-type: none">● Mangrove diversity and distribution● How mangroves are adapted to saline and anoxic conditions● About <i>Avicennia marina</i>● Reproduction strategies of mangroves● Common fauna in mangrove ecosystem including their habitat, diet● Food chain of mangrove ecosystem● The importance of mangrove ecosystem● Threats to mangrove ecosystem
4. Expected Participants (minimum required level for entry if any)
All target groups
5. Trainers
QEIC staff
6. Syllabus
Module 1 Lecture : Introduction on mangrove ecosystem (0.5 day)
Module 2 Field visit : Observation of mangrove ecosystem (0.5 day)
7. Schedule
Duration: 1 day, Frequency: 1-2/year (preferably during bird migratory season)
8. Equipment prepared or brought by participants (if any)
Clothes for suitable for field observation

Outline of Training Course

1. Course Title:
Introduction on Mangrove Ecosystem Monitoring Program
2. Objectives of the Course
To understand the monitoring methods of mangrove ecosystems
3. Expected Output (skills to be acquired by participants)
By the end of the course, participants should understand; <ul style="list-style-type: none">● The objective of monitoring● How to monitor and assess the health of mangrove tree● How to collect and identify fauna and monitor indicator species● How to monitor environmental conditions (water quality, soil quality, topography, water level)● To understand common natural and human threats to mangrove ecosystem● How to manage monitoring data
4. Expected Participants (minimum required level for entry if any)
QEIC/MECA staff, students, NGO, local community
5. Trainers
QEIC staff
6. Syllabus
Module 1 Lecture : Introduction on mangrove ecosystem monitoring program (0.5 day)
Module 2 Practice: Monitoring of mangrove (0.5 day)
Module 3 Practice: Monitoring of fauna (1.5 day)
Module 4 Practice: Monitoring of environmental condition (1.5 day)
7. Schedule
Duration: 4 days, Frequency: 1/year (preferably during winter)
8. Equipment prepared or brought by participants (if any)
Clothes suitable for field work

Outline of Training Course

1. Course Title:
Introduction on mangrove health assessment using remote sensing
2. Objectives of the Course
To learn how to monitor and assess mangrove forest health with remote sensing technology.
3. Expected Output (skills to be acquired by participants)
By the end of the course, participants should understand; <ul style="list-style-type: none">● How to delineate and estimate surface area of mangrove forest● How to calculate NDVI values of mangrove forest● How to calculate changes in NDVI values of mangrove forest● How to interpret the results through field verification
4. Expected Participants (minimum required level for entry if any)
QEIC/MECA staff, students (have basic skills in using image processing software such as ENVI)
5. Trainers
QEIC staff, Remote sensing expert
6. Syllabus
Module 1 Lecture : Introduction on mangrove health assessment using remote sensing (0.5 day)
Module 2 Practice: Mangrove health assessment using image processing software (2 days)
Module 3 Practice: Field verification (0.5 day)
7. Schedule
Duration: 3 days, Frequency: 1/year
8. Equipment prepared or brought by participants (if any)
Clothes suitable for field work

Outline of Training Course

1. Course Title:
Introduction on “Transplanted-seedling Monitoring Program”
2. Objectives of the Course
To understand monitoring methods of transplanted seedling
3. Expected Output (skills to be acquired by participants)
By the end of the course, participants should understand;
<ul style="list-style-type: none">● The objective of monitoring● How to measure seedling growth● How to monitor seedling health● Potential factors that could affect seedling growth and health
4. Expected Participants (minimum required level for entry if any)
MECA staff, students, NGO, local community
5. Trainers
QEIC staff
6. Syllabus
Module 1 Lecture : Introduction on “Transplanted-seedling Monitoring Program” (0.5 day)
Module 2 Practice: Monitoring of seedling growth and health (0.5 day)
7. Schedule
1 day, preferably during transplantation season
8. Equipment prepared or brought by participants (if any)
Clothes suitable for field work

Outline of Training Course

1. Course Title:	
Method of Mangrove Tree Plantation	
2. Objectives of the Course	
This training course is prepared for the practical mangrove plantation procedures in the field level including seed collection and treatment, seedling production and transplanting in the selected locations.	
3. Expected Output (skills to be acquired by participants)	
By the end of this training course, participants should;	
<ul style="list-style-type: none"> ● understand the significance and present situation of mangrove plantation and the suitable criteria for the selection of general plantation site and specific planting area, ● understand the general characteristics of mangrove seeds and the method of seed collection along with the treatment and storage method of collected seeds, ● understand the preparation of pot and sowing method along with the nursery design and irrigation system for proper seedling production, and ● understand the procedure for transplanting of produced seedlings and the maintenance of planted trees. 	
4. Expected Participants (minimum required level for entry if any)	
QEIC/MECA Staff and selected NGO members	
5. Trainers	
QEIC Staff	
6. Syllabus	
Module 1	Lecture : Significance of mangrove plantation and selection of suitable site (1 day)
Module 2	Lecture and Practice : Seed collection methods and treatment of collected seeds (0.5 day)
Module 3	Lecture and Practice : Operation of nursery for proper seedling production (0.5 day)
Module 4	Lecture and Practice : Transplanting procedure and maintenance of planted trees (1 day)
7. Schedule	
Duration: 3 days in total, Frequency: 1/year	
Module 1: 1 day before seed production period (June/July)	
Module 2+3 : 1 day during seed production period (August/September)	
Module 4 : 1 day during transplanting period (January/February)	
8. Equipment prepared or brought by participants (if any)	
Mangrove Plantation Guideline	

Technical Document 1 Training plan and materials

IV-1 Introduction on mangrove ecosystem protection

Outline of Training Course

1. Course Title:
Introduction on mangrove ecosystem protection
2. Objectives of the Course
To learn practical and regulatory measures to protect mangrove ecosystem
3. Expected Output (skills to be acquired by participants)
By the end of the course, participants should understand;
<ul style="list-style-type: none">● Legal framework for mangrove protection● The various natural and human threats to mangrove ecosystem● Possible protective measures against the threats
4. Expected Participants (minimum required level for entry if any)
QEIC/MECA staff, NGOs, local community, private sector
5. Trainers
QEIC staff
6. Syllabus
Module 1 Lecture : Introduction on mangrove ecosystem protection (0.5 day)
7. Schedule
Duration: 0.5 day
8. Equipment prepared or brought by participants (if any)

Outline of Training Course

1. Course Title:
Introduction of QEIC database
2. Objectives of the Course
This training course aims to introduce the available database in the QEIC and the structure of each database.
3. Expected Output (skills to be acquired by participants)
By the end of this training course, participants should; <ul style="list-style-type: none">● understand the kind of database available in the QEIC,● understand the database structure of monitoring data,● understand the database structure of mangrove site,● understand the database structure of mangrove fauna
4. Expected Participants (minimum required level for entry if any)
QEIC/MECA Staff and Research Organizations
5. Trainers
QEIC Staff
6. Syllabus
Module 1 Lecture : Introduction of database available in the QEIC (0.5day)
7. Schedule
Module 1 : anytime (duration: 0.5 day)
8. Equipment prepared or brought by participants (if any)

Outline of Training Course

1. Course Title:	
Producing education materials	
2. Objectives of the Course	
This training course is prepared to learn how to prepare education materials to achieve respective learning goals and objectives and to learn how to design education programs regarding mangroves and mangrove ecosystem.	
3. Expected Output (skills to be acquired by participants)	
By the end of this training course, participants should;	
<ul style="list-style-type: none"> ● understand type of education materials for environment education of mangroves and mangrove ecosystem, ● understand necessary contents of education materials for environment education of mangroves and mangrove ecosystem, ● prepare education materials based on the above-mentioned contents; such as quiz, puzzle, bingo card, and etc. ● understand factors to be considered in designing education programs, ● understand goals of education programs and suitable education materials to be used, ● understand how to prepare activity sheet of the education program, and ● understand how to evaluate the education program. 	
4. Expected Participants (minimum required level for entry if any)	
QEIC/MECA Staff and selected NGO members	
5. Trainers	
QEIC Staff	
6. Syllabus	
Module 1	Lecture : Different type of education materials
Module 2	Lecture and Discussion : Necessary contents of education materials for environment education of mangroves and mangrove ecosystem
Module 3	Lecture and Practice: Preparation of education materials
Module 4	Lecture : Factors to be considered in designing education programs
Module 5	Lecture : Goals of education programs and suitable education materials to be used
Module 6	Lecture and Practice : Preparing activity sheet of the education program
Module 7	Lecture and Practice : Evaluation of the education program
7. Schedule	
Duration: 2 days	
Module 1: 0.2 day	
Module 2: 0.4 day	

Technical Document 1 Training plan and materials

VI-1 Producing education materials

Module 3: 0.4 day

Module 4: 0.2 day

Module 5: 0.2 day

Module 6: 0.4 day

Module 7: 0.2 day

8. Equipment prepared or brought by participants (if any)

Outline of Training Course

1. Course Title:
Implementing education programs
2. Objectives of the Course
This training course is prepared to learn how to implement education programs regarding mangroves and mangrove ecosystem.
3. Expected Output (skills to be acquired by participants)
By the end of this training course, participants should;
<ul style="list-style-type: none">● understand how to use education materials to implement education programs effectively, and● understand how to implement education programs based on activity sheet of the program.
4. Expected Participants (minimum required level for entry if any)
QEIC/MECA Staff and selected NGO members
5. Trainers
QEIC Staff
6. Syllabus
Module 1 Lecture and Practice : how to use education materials to implement education programs
Module 2 Lecture and Practice : how to implement education programs based on the activity sheet
7. Schedule
Duration: 1 day (Module 1: 0.3 day, Module 2: 0.7 day)
8. Equipment prepared or brought by participants (if any)

Outline of Training Course

1. Course Title:
Introduction of the exhibition
2. Objectives of the Course
This training course is prepared to learn basic idea on exhibition plan for QEIC regarding mangroves and mangrove ecosystem.
3. Expected Output (skills to be acquired by participants)
By the end of this training course, participants should; <ul style="list-style-type: none"> ● understand the contents of exhibition plan for QEIC, ● understand how to prepare worksheet on exhibition articles in order to enhance visitors' understanding on the articles, and ● understand lessons learnt from other organizations
4. Expected Participants (minimum required level for entry if any)
QEIC/MECA Staff and selected NGO members
5. Trainers
QEIC Staff
6. Syllabus
Module 1 Lecture : Contents of exhibition plan for QEIC
Module 2 Lecture and practice: Preparing worksheet on exhibition articles
Module 3 Lecture and discussion: Lessons learnt from other organizations
7. Schedule
Duration: 0.5 day (Module 1: 0.2 day, Module 2: 0.2 day, Module 3: 0.1 day)
8. Equipment prepared or brought by participants (if any)

5 Trainers' manual

To conduct the training program effectively, procedure, method, necessary materials, point to be cared as a trainer is specified for each training module.

Technical Document 1 Training plan and materials

Trainer's manual

Course title: Function of QEIC

Module 1

Title: Introduction of QEIC functions and activities

Venue: QEIC lecture room

Method: Power point presentation

Duration: 1 hour lecture

Procedure:

- Explain major functions of the QEIC (Slide No. 1 - 2)
- Explain major activities of the QEIC (Slide No. 3 - 22)
- Explain major publications, web site and exhibition (Slide No. 23 - 25)
- Explain annual schedule of the activities of the QEIC (Slide No. 26)
- Explain organizational structure of the QEIC(Slide No. 27)

Module 2

Title: Introduction of case studies of similar institutions in the world

Venue: QEIC lecture room

Method: Power point presentation

Duration: 1.5 hours

Contents:

- Explain outline of similar case study in the world (slide No.1 - 2)
- Explain case studies in the world (slide No. 3 - 16)
- Explain difference of activities between QEIC (slide No. 17)

Module 3

Title: Introduction of facilities of the QEIC

Venue: QEIC lecture room

Method: Power point presentation

Duration: 1 hour

Contents:

- Explain facilities in the QEIC (slide No. 1 - 9)
- Explain QNR and facilities such as board walk, observation hut (slide No. 10 - 12)

Technical Document 1 Training plan and materials

Trainer's manual

Course title: Function of QEIC

Module 4

Title: Visual tour of facilities, mangrove nursery and Qurm Nature Reserve

Venue: QEIC, QNR

Method: Tour

Duration: 1.5 hours

Procedure:

Step	Activity	Necessary material/equipment	Venue	Reference
1	Explain facilities in QEIC	Training material I-1-3-2	QEIC	Manual for trainer I-3-1
2	Show QNR from the top of the QEIC	Training material I-1-3-2 Satellite image of QNR	QEIC	
3	Show the nursery, board walk and mangrove transplanted site	Training material I-1-3-2	QNR	

Module 5

Title: Laboratory tour

Venue: QEIC lecture room, QEIC lab

Method: Lecture and tour

Duration: 1 hour

Procedure:

Step	Activity	Necessary material/equipment	Venue	Reference
1	Explain the laboratory and available parameters	Training material I-1-3-3	QEIC	Manual for trainer I-3-1
2	Show the laboratory and equipment	Training material I-1-3-3	QEIC	
3	Explain necessary maintenance for the equipment	Training material I-1-3-3	QEIC	

Technical Document 1 Training plan and materials

Trainer's manual

Course title: Function of QEIC

Module 6

Title: Introduction of field equipment

Venue: QEIC lecture room, QEIC equipment storage

Method: Lecture and tour

Duration: 1.5 hours

Procedure:

Step	Activity	Necessary material/equipment	Venue	Reference
1	Explain the field equipment laboratory and available parameters	Training material I-1-3-4	QEIC	Manual for trainer I-3-1
2	Show the equipment storage and equipment	Training material I-1-3-4	QEIC	
3	Explain necessary maintenance for the equipment	Training material I-1-3-4	QEIC	

Technical Document 1 Training plan and materials

Trainer's manual

Course title: Introduction on mangrove ecosystem

Module 1

Title: Introduction on mangrove ecosystem

Venue: QEIC lecture room

Lecturer: QEIC staff

Method: Power point presentation

Duration: 0.5 day

Contents:

Explain the following:

- Mangrove diversity and distribution
- How mangroves are adapted to saline and anoxic conditions
- About *Avicennia marina*
- Reproduction strategies of mangroves
- Common fauna in mangrove ecosystem including their habitat, diet
- Food chain of mangrove ecosystem
- The importance of mangrove ecosystem
- Threats to mangrove ecosystem

Module 2

Title: Observation of mangrove ecosystem

Venue: QNR

Lecturer: QEIC staff

Method: Field observation of mangrove and fauna

Duration: 0.5 day

Procedure:

Step	Activity	Necessary equipment	Venue
1	Observe the aerial roots, leaf, flower, seed of mangrove	-	QNR boardwalk
2	Observe different types of crabs and shells found along the boardwalk and mudflat	-	QNR boardwalk, mudflat area
3	Observe fish by collecting with fish cage	Fish cage	QNR boardwalk
4	Observe birds along the mudflats	Binoculars and scope	Mudflat area

Trainer’s manual

Course title: Introduction on mangrove ecosystem monitoring program

Module 1

Title: Introduction on mangrove ecosystem monitoring program

Venue: QEIC lecture room

Lecturer: QEIC staff

Method: Power point presentation

Duration: 0.5 day

Contents:

- Explain objective, concept and procedure of mangrove ecosystem monitoring program

Module 2

Title: Monitoring of mangrove tree

Venue: QNR, QEIC

Lecturer: QEIC staff

Method: Field practice

Duration: 0.5 day

Procedure:

Step	Activity	Necessary equipment	Venue	Reference
1	Explain the basic monitoring procedure		QNR	Mangrove Monitoring Guideline 2.1.1
2	Show how to select monitoring site and tree	Stake, tape measure (100 m), marker tape, GPS, clipboard/field sheet	QNR	Mangrove Monitoring Guideline Section 2.1.2
3	Show how to measure tree height and trunk circumference	Measuring rod, tape measure (2 m), tree tag, clipboard/field sheet	QNR	Mangrove Monitoring Guideline Section 2.1.3
4	Show how to assess tree health	Clipboard/field sheet, camera	QNR	Mangrove Monitoring Guideline Section 2.1.4
5	Show how to manage collected data	Computer, database format	QEIC	Mangrove Monitoring Guideline Section 2.1.7

Technical Document 1 Training plan and materials

Trainer's manual

Course title: Introduction on mangrove ecosystem monitoring program

Module 3

Title: Monitoring of fauna

Venue: QNR, QEIC

Lecturer: QEIC staff, Bird expert, Staff from MSFC

Method: Field practice

Duration: 1.5 days

Procedure:

Day 1 (1 day)

Step	Activity	Necessary equipment	Venue	Reference
1	Explain the basic monitoring procedure		QNR	Mangrove Monitoring Guideline Section 3.1
2	Show fauna collection methods with net and cage	Seine net, fish cage, small hand net, bucket, glass jars	QNR	Mangrove Monitoring Guideline Section 3.2.1
3	Show fauna collection methods by digging	Shovel, scoop, sieve, glass jars	QNR	Mangrove Monitoring Guideline Section 3.2.1
4	Show how to take live photos and preserve the collected fauna	Camera, aquarium, small hand net, labels, waterproof markers, jars, ethanol/formalin solution, water, cooler box	QNR	Mangrove Monitoring Guideline Section 3.2.1
5	Show how to identify and make basic size measurements of the collected fauna Lecturer: Staff of MSFC	Ruler, camera, board, pin, identification guidebooks, clipboard/field sheet	QEIC	Mangrove Monitoring Guideline Section 3.2.2
6	Show how to manage collected data	Computer, database format	QEIC	Mangrove Monitoring Guideline Section 3.2.1

Day 2 (0.5 day)

Step	Activity	Necessary equipment	Venue	Reference
1	Show how to survey and identify birds Lecturer: Bird expert	Telescope, binoculars, camera, GPS	QNR	Mangrove Monitoring Guideline Section 3.3
2	Show example of how to monitor indicator species	Stake, tape measure (100 m), quadrat, clipboard/field sheet	QNR	Mangrove Monitoring Guideline Section 3.5

Trainer’s manual

Course title: Introduction on mangrove ecosystem monitoring program

Module 4

Title: Monitoring of environmental condition

Venue: QNR, QEIC lab, QEIC computer room

Method: Field practice

Duration: 1.5 days

Procedure:

Step	Activity	Necessary material/equipment	Venue	Reference
1	Show how to collect water samples and measure water quality	Water quality meter (pH, salinity, DO), water sampler/bucket, sampling bottle, clipboard/field sheet, thermometer, cooler box/ice, GPS, portable depth sounder, labels and waterproof markers	QNR	Mangrove Monitoring Guideline Section 4.2
2	Show how to collect soil samples and measure soil quality	Soil sampler, ORP meter, soil-color chart, water quality meter (pH, salinity, DO), distilled water, measuring cylinder, spoon, sampling bottle, clipboard/field sheet, thermometer, cooler box/ice, GPS, labels and waterproof markers	QNR	Mangrove Monitoring Guideline Section 4.3
3	Show how to conduct topography and water level monitoring	Stake, measure, camera, GPS	QNR	Mangrove Monitoring Guideline Section 4.4 & 4.5
4	Show how to analyze COD and nutrients	Analysis equipment (colorimeter, reagents, distilled water etc.)	QEIC	Mangrove Monitoring Guideline Section Appendix 3
5	Show how to manage collected data	Computer, database format	QEIC	

Technical Document 1 Training plan and materials

Trainer's manual

Course title: Introduction on mangrove health assessment using remote sensing

Module 1

Title: Introduction on mangrove health assessment using remote sensing

Venue: QEIC lecture room

Lecturer: QEIC staff, remote sensing expert

Method: Power point presentation

Duration: 0.5 day

Contents:

- Explain objective, concept and procedure of mangrove health assessment using remote sensing

Module 2

Title: Mangrove health assessment using image processing software

Venue: QEIC computer room

Lecturer: QEIC staff, remote sensing expert

Method: Practice

Duration: 2 days

Procedure:

Step	Activity	Necessary equipment	Venue	Reference
1	Show how to georeference satellite image	Computer, satellite image, image processing software	QEIC	Remote sensing guideline Section 4.2
2	Show how to delineate and estimate surface area of mangrove forest	Computer, satellite image, image processing software	QEIC	Remote sensing guideline Section 4.3
3	Show how to calculate NDVI values of mangrove forest	Computer, satellite image, image processing software	QEIC	Remote sensing guideline Section 4.4
4	Show how to calculate changes in NDVI values of mangrove forest	Computer, satellite image, image processing software	QEIC	Mangrove Monitoring Guideline Section 4.5

Technical Document 1 Training plan and materials

Trainer's manual

Course title: Introduction on mangrove health assessment using remote sensing

Module 3

Title: Field verification

Venue: QNR

Lecturer: QEIC staff, remote sensing expert

Method: Practice

Duration: 0.5 day

Procedure:

Step	Activity	Necessary equipment	Venue	Reference
1	Verify the results of NDVI through field reconnaissance	Leaf spectrophotometer	QNR	

Technical Document 1 Training plan and materials

Trainer's manual

Course title: Introduction on Transplanted-seedling Monitoring Program

Module 1

Title: Introduction on Transplanted-seedling Monitoring Program

Venue: QEIC

Method: Power point presentation

Duration: 0.5 day

Contents:

- Explain objective, concept and procedure of Transplanted-seedling Monitoring Program

Module 2

Title: Monitoring of seedling growth and health

Venue: QNR, QEIC

Method: Field practice

Duration: 0.5 day

Procedure:

Step	Activity	Necessary equipment	Venue	Reference
2	Show how to select monitoring seedling	Stake, tape measure (100 m), marker tape, GPS, clipboard/field sheet, tree tag	QNR	Mangrove Monitoring Guideline Chapter 3, Section 2.1
3	Show how to measure seedling growth	Tape measure, caliper, clipboard/field sheet	QNR	Mangrove Monitoring Guideline Chapter 3, Section 2.2
4	Show how to estimate ratio of unhealthy seedling	Clipboard/field sheet, camera	QNR	Mangrove Monitoring Guideline Chapter 3, Section 2.3
5	Show how to manage collected data	Computer, database format	QEIC	Mangrove Monitoring Guideline Chapter 3, Section 2.5

Trainer’s manual

Course title: Method of Mangrove Tree Plantation

Module 1

Title: Significance of mangrove plantation and selection of suitable site

Venue: QEIC lecture room and QNR

Method: Power point presentation and field training

Duration: 2 hours lecture and 3 hours field training

Procedure:

- Explain significance of mangrove plantation and selection of suitable site by using PPT in lecture room
- Shift to QNR for field training

Step	Activity	Necessary material/equipment	Venue	Reference
1	Visit to one candidate location for mangrove plantation		QNR	
2	Explain the contents of checklist	Checklist for site selection	QNR	Checklist for site selection
3	Evaluate the conditions according to the checklist	Refractometer, Binocular, Clinometer, Scoop	QNR	Checklist for site selection
4	Visit to another location for mangrove plantation and repeat the evaluation	Refractometer, Binocular, Clinometer, Scoop	QNR	Checklist for site selection
5	Show how to enter and analyze collected data	Computer, Data sheet	QEIC	

Trainer’s manual

Course title: Method of Mangrove Tree Plantation

Module 2+3

Title: Seed collection methods and treatment of collected seeds/Operation of nursery for proper seedling production

Venue: QEIC lecture room and QNR nursery

Method: Power point presentation and field training

Duration: 2 hours lecture and 2 hours field training (1st day) and 4 hours field training (2nd day)

Procedure:

- Explain seed collection methods and treatment of collected seeds by using PPT in lecture room (1 hour)
- Explain operation of nursery for proper seedling production by using PPT in lecture room (1 hour)
- Shift to QNR Nursery for field training

Step	Activity	Necessary material/equipment	Venue	Reference
1	Explain general structure of the nursery with the principle of tidal irrigation		QNR Nursery	Mangrove Plantation Guideline Section 3.1
2	Explain general flow of seed collection, treatment and plantation		QNR Nursery	Mangrove Plantation Guideline Section 3.1
3	Show how to collect matured seeds from mangrove trees	Small bucket or plastic bag	QNR	
4	Show how to soak collected seeds in large container and keep the container overnight	Large container of about 100 liter and seawater	QNR Nursery	

- Visit to QNR Nursery in the next day to continue the field training

Step	Activity	Necessary material/equipment	Venue	Reference
5	Show how to remove bug infested seeds and pericarp to obtain healthy naked seeds	Small bucket, Large container and Seawater	QNR Nursery	
6	Show how to prepare a pot by filling sand for sowing	Plastic pots, Sand, Scoop	QNR Nursery	
7	Show how to arrange the pots in the nursery bed		QNR Nursery	
8	Show how to sow seeds in the pots arranged		QNR Nursery	

Technical Document 1 Training plan and materials

Trainer's manual

Course title: Method of Mangrove Tree Plantation

Module 4

Title: Transplanting procedure and maintenance of planted trees

Venue: QEIC lecture room and QNR

Method: Power point presentation and field training

Duration: 2 hours lecture and 3 hours field training

Procedure:

- Explain transplanting procedure and maintenance of planted trees using PPT in lecture room
- Shift to QNR for field training

Step	Activity	Necessary material/equipment	Venue	Reference
1	Explain general flow of transplanting method		QNR Nursery	Mangrove Plantation Guideline Section 3.3
2	Explain how to select suitable location for transplanting		QNR selected site	Mangrove Plantation Guideline Section 3.3
3	Show how to prepare the planting holes and distribute the seedlings	Measuring tapes, Shovels, Wheel barrows	QNR selected site	
4	Show how to transplant seedlings at the holes prepared	Cutter for plastic bag, Scoop	QNR selected site	Trasplanting brochure
5	Show how to measure the planted area by GPS	GPS	QNR selected site	
6	Show how to obtain data from GPS, plot on satellite image and measure the area	Computer, Satellite image	QEIC	

Technical Document 1 Training plan and materials

Trainer's manual

Course title: Introduction on mangrove ecosystem protection

Module 1

Title: Introduction on mangrove ecosystem protection

Venue: QEIC lecture room

Lecturer: QEIC staff

Method: Power point presentation

Duration: 0.5 day

Contents:

Explain the following:

- Legal framework for mangrove protection
- The various natural and human threats to mangrove ecosystem
- Possible protective measures against the threats

Trainer’s manual

Course title: Producing Education Materials

Module 1

Title: Different type of education materials

Venue: QEIC lecture room

Method: Power point presentation + Samples of Education Materials

Duration: 1 hour lecture

Procedure:

- Explain different type of education materials by using PPT in lecture room
- Show samples of education materials

Step	Activity	Necessary material/equipment	Venue	Reference
1	Explain different type of education materials		QEIC	Guideline for environmental education program
2	Show samples of education materials	Samples of education materials	QEIC	

Module 2

Title: Contents of education materials for environmental education of mangroves

Venue: QEIC lecture room

Method: Power point presentation and group discussion

Duration: 15 minutes lecture and 1 hour group discussion/presentation

Procedure:

- Suggest possible contents of education materials by using PPT in lecture room
- Discuss necessary contents of education materials by group discussion
- Present results of the group discussion

Step	Activity	Necessary material/equipment	Venue	Reference
1	Suggest possible contents of education materials		QEIC	Guideline for environmental education program
2	Discuss necessary contents of education materials	Pen and stick-back card	QEIC	
3	Present results of the group discussion		QEIC	

Trainer’s manual

Course title: Producing Education Materials

Module 3

Title: Preparing education materials

Venue: QEIC lecture room

Method: Practice by participants

Duration: 2 hours practice

Procedure:

Step	Activity	Necessary material/equipment	Venue	Reference
1	Remind possible contents of education materials for mangrove		QEIC	Guideline for environmental education program
2	Practice 1: producing card puzzle	Photo of birds, cutter, and ruler	QEIC	
3	Practice 2: producing mangrove quiz	A4 paper and pen	QEIC	
4	Practice 3: producing field bingo card	A4 paper and pen		
5	Presentation of the results by participants			

Trainer’s manual

Course title: Producing Education Materials

Module 4+5

Title: Factors to be considered in designing education programs + Designing environmental education programs

Venue: QEIC lecture room

Method: Power point presentation

Duration: 2 hours lecture

Procedure:

- Explain factors to be considered in designing education programs by using PPT in lecture room
- Explain goals of education programs and suitable education materials to be used
- Explain how to design environmental education programs using activity sheet

Step	Activity	Necessary material/equipment	Venue	Reference
1	Explain factors to be considered in designing education programs		QEIC	Guideline for environmental education program
2	Explain goals of education programs and suitable education materials to be used		QEIC	
3	Explain how to design environmental education programs	Activity sheet of environmental education program	QEIC	

Technical Document 1 Training plan and materials

Trainer's manual

Course title: Producing Education Materials

Module 6

Title: Preparing activity sheet of environmental education program

Venue: QEIC lecture room

Method: Practice by participants

Duration: 10 minutes lecture and 2 hours practice/presentation

Procedure:

- Remind the method of education program designing by preparing activity sheet
- Practice to design education program (determine target people and goal of program, and design a program)
- Present prepared education program by participants

Step	Activity	Necessary material/equipment	Venue	Reference
1	Remind the method of education program designing		QEIC	
2	Practice to design education program	Activity sheet	QEIC	
3	Present prepared education program by participants		QEIC	

Module 7

Title: Evaluation of environmental education program

Venue: QEIC lecture room

Method: Power point presentation + Samples of evaluation

Duration: 30 minutes lecture

Procedure:

- Explain purpose and method of program evaluation in lecture room
- Show examples of program evaluation

Step	Activity	Necessary material/equipment	Venue	Reference
1	Explain purpose and method of program evaluation		QEIC	
2	Show examples of program evaluation	Evaluation sheet, case study of program evaluation	QEIC	

Technical Document 1 Training plan and materials

Trainer's manual

Course title: Implementing Education Programs

Module 1

Title: Implementing environmental education program (lecture)

Venue: QEIC lecture room

Method: Power point presentation

Duration: 20 minutes lecture

Procedure:

Step	Activity	Necessary material/equipment	Venue	Reference
1	Explain timetable and contents of the trial education program		QEIC	Guideline for environmental education program
2	Explain education materials to be used	Education materials such as poster, brochure, photo list, and feedback sheet	QEIC	

Module 2

Title: Implementing environmental education program (practice)

Venue: QNR

Method: Field training

Duration: 3 hours

Procedure:

Step	Activity	Necessary material/equipment	Venue	Reference
1	Explain mangroves and mangrove forests in Oman	Poster: Mangrove forests in Oman	QNR	
2	Explain food chain in mangrove ecosystem	Poster: Food chain, Brochure: Mangrove ecosystem	QNR	
3	Visit the mangrove nursery		QNR	
4	Observe mangrove forest through the board walk	Photo list of animals in mangrove forests	QNR	
5	Bird watching	Photo list and telescope	QNR	
6	Feedback	Feedback sheet	QNR	

Trainer’s manual

Course title: Introduction of QEIC exhibition

Module 1

Title: Contents of exhibition plan for QEIC

Venue: QEIC lecture room

Method: Power point presentation

Duration: 1 hour lecture

Procedure:

- Explain contents of exhibition plan for QEIC by using PPT in lecture room

Step	Activity	Necessary material/equipment	Venue	Reference
1	Explain the contents of exhibition plan		QEIC	Exhibition plan for QEIC
2	Explain permanent exhibition and special exhibition		QEIC	Exhibition plan for QEIC
3	Explain floor plan of the exhibition		QEIC	Exhibition plan for QEIC

Module 2

Title: Utilization of worksheet and learning book

Venue: QEIC lecture room

Method: Power point presentation

Duration: 1 hour lecture and practice

Procedure:

- Explain worksheet and learning book by using PPT in lecture room (20 minutes)
- Practice to produce worksheet by the participants in lecture room (40 minutes)

Step	Activity	Necessary material/equipment	Venue	Reference
1	Explain what is worksheet and learning book		QEIC	Example of worksheet and learning book
2	Practice to produce worksheet by the participants		QEIC	
3	Presentation of results of the practice		QEIC	

Technical Document 1 Training plan and materials

Trainer's manual

Course title: Introduction of QEIC exhibition

Module 3

Title: Lessons learnt from other nature centers

Venue: QEIC lecture room

Method: Power point presentation

Duration: 30 minutes lecture

Procedure:

- Explain lessons learnt from other nature centers using PPT in lecture room

Step	Activity	Necessary material/equipment	Venue	Reference
1	Explain lessons learnt from other nature centers		QEIC	Exhibition plan for QEIC
2	Explain lessons learnt from EXPO 2012 in Korea		QEIC	Exhibition plan for QEIC

6 List of materials

Materials to be used on the training, such as powerpoint presentation, document and guideline, are listed in Table 3. Soft copy of the materials are stored in the attached CD (refer to the "Material" column for the file name).

Table 3 List of training materials

Category	Course title	Module			Material format	Material		
		No	Mode	Contents				
I	General	1. Function of QEIC	1	Lecture	Introduction of QEIC functions and activities	PPT	I-1-1 Function of QEIC.pptx	
			2	Lecture	Introduction of case studies of similar institutions in the world	PPT	I-1-2 Case study.pptx	
			3	Lecture	Introduction of facilities of QEIC	PPT	I-1-3 Introduction of facility.pptx	
			4	Quick tour:	Visual tour of facilities, mangrove nursery and Qurm Nature Reserve	DM	I-1-4 Quick Tour.docx	
			5	Tour	Laboratory tour	PPT	I-1-5 Laboratory.pptx	
			6	Lecture:	Detailed introduction of the laboratory, equipment and available parameters, necessary maintenance			
	2. Introduction on mangrove ecosystem	1	Lecture	Introduction of field equipment	PPT	I-1-5 Laboratory.pptx		
		2	Lecture:	Detailed introduction of the field equipment, necessary maintenance				
	II	Monitoring	1. Introduction on Mangrove Ecosystem Monitoring Program	1	Lecture	Introduction on mangrove ecosystem monitoring program	PPT	II-1 Introduction on Mangrove Ecosystem Monitoring Program.pptx
				2	Practice	Monitoring of mangrove	GL	-
3				Practice	Monitoring of fauna	GL		
4				Practice	Monitoring of environmental condition	GL		
2. Introduction on mangrove health assessment using remote sensing		1	Lecture	Introduction on mangrove health assessment using remote sensing	PPT	II-2 Introduction on mangrove health assessment using remote sensing.ppt		
		2	Practice	Mangrove health assessment using image processing software	GL	-		
		3	Practice	Field verification	GL			
3. Introduction on "Transplanted-seedling Monitoring Program"		1	Lecture	Introduction on "Transplanted-seedling Monitoring Program"	PPT	II-3 Introduction on Transplanted-seedling Monitoring Program.pptx		
		2	Prctice	Monitoring of seedling growth and health	GL	-		
III		Plantation	1. Method of mangrove tree plantation	1	Lecture	Significance of mangrove plantation and selection of suitable site	PPT, GL	III-1-1 Significance Plantation.pptx
				2	Lecture & practice	Seed collection methods and treatment of collected seeds	DM, PPT, GL	III-1-2 Seed collection.pptx
				3	Lecture & practice	Operation of nursery for proper seedling production	DM, PPT, GL	III-1-3 Operation of nursery.pptx
	4			Lecture & practice	Transplanting procedure and maintenance of planted trees	DM, PPT, GL	III-1-4 Transplanting procedure.pptx	
IV	Protection	1. Introduction on mangrove ecosystem protection	1	Lecture	Introduction on mangrove ecosystem protection	PPT, GL	Materials\IV-1 Introduction on mangrove ecosystem protection.pptx	
V	Database	1. Introduction of QEIC database	1	Lecture	Introduction of database available in the QEIC	PPT	The prepentasion material is not yet prepared, since the database is not developed at moment.	
			1	Lecture	Different type of education materials	PPT	VI-1-1 Materials.ppt	
			2	Lecture & discussion	Necessary contents of education materials for environment education of mangroves and mangrove ecosystem	PPT, discussion	VI-1-2 EE Contents.ppt	

Technical Document 1 Training plan and materials

Category		Course title	Module			Material format	Material
			No	Mode	Contents		
VI	Education	1. Producing education materials	3	Lecture & practice	Preparation of education materials	practics	-
			4	Lecture	Factors to be considered in designing education programs	PPT	VI-1-4,5 EE Program.ppt
			5	Lecture	Goals of education programs and suitable education materials to be used	PPT	VI-1-4,5 EE Program.ppt
			6	Lecture & practice	Preparing activity sheet of the education program	practice	-
			7	Lecture & practice	Evaluation of the education program	PPT, practice	VI-1-7 Evaluation.ppt
		2. Implementing education programs	1	Lecture & practice	How to use education materials to implement education programs	PPT, practice	VI-2-1 Implementing.ppt
			2	Lecture & practice	How to implement education programs based on the activity sheet	practice	-
VII	Exhibition plan	1. Introduction of QEIC exhibition	1	Lecture	Importance of story line in designing exhibition plan	PPT	VII-1-1 Exhibition Plan.pptx
			2	Lecture & practice	Preparing work sheet on exhibition articles	PPT, practice	VII-1-2 Work Sheet.pptx
			3	Lecture & discussion	Lessons learnt from other organization	PPT, discussion	VII-1-3 Other Organizations.ppt

Note: PPT: Microsoft Power Point material, DM: Document material, GL: Guideline

The Qurm Environmental Information Center Project

Technical Document 2 Mangrove Monitoring Guideline



March 2014

JICA Expert Team

Table of contents

Chapter 1 Introduction

1. Background.....	1
2. Characteristics of mangrove ecosystems in Oman	1
3. Basic outfits and gears for field survey	2

Chapter 2 Mangrove Ecosystem Monitoring Program

1. Introduction	3
2. Monitoring of mangrove forest	4
2.1 Monitoring method of mangrove forest.....	5
2.1.1 Basic concept and method	5
2.1.2 Selection of monitoring sites and trees	5
2.1.3 Monitoring of mangrove tree growth	8
2.1.4 Monitoring of mangrove tree health	9
2.1.5 Investigation of possible causes of tree health degradation.....	13
2.1.6 Necessary field survey equipment	16
2.1.7 Management of monitoring data.....	16
3. Monitoring method of fauna	17
3.1 Basic concept and procedure	17
3.2 Development of fauna inventory.....	17
3.2.1 Collection of fauna	18
3.2.2 Species identification of collected fauna.....	22
3.2.3 Development of species inventory.....	23
3.3 Development of bird inventory.....	23
3.4 Selection of indicator species	24
3.5 Monitoring of indicator species.....	25
3.6 Investigation of possible causes of population change	27
4. Monitoring method of environmental conditions.....	28
4.1 Introduction	28
4.2 Water quality	28
4.2.1 Water quality parameters	28
4.2.2 Water quality monitoring sites.....	28
4.2.3 Field survey procedure.....	28
4.2.4 Necessary field survey equipment	29
4.2.5 Assessment and management of monitoring data	30

4.3 Soil quality	30
4.3.1 Soil quality parameters	30
4.3.2 Soil quality monitoring sites	31
4.3.3 Field survey procedure	31
4.3.4 Necessary field survey equipment	35
4.3.5 Assessment and management of monitoring data	35
4.4 Topography	35
4.4.1 Photo monitoring	36
4.4.2 Sedimentation monitoring	36
4.5 Water level.....	38
5. Inspection monitoring	38

Chapter 3 Transplanted-seedling Monitoring Program

1. Introduction	40
2. Monitoring method	40
2.1 Selection of monitoring seedling	40
2.2 Monitoring method of seedling growth	41
2.3 Monitoring method of seedling health.....	41
2.4 Monitoring method of environmental condition	43
2.5 Necessary field survey equipment.....	43
2.6 Management of monitoring data	44

Appendix

- Appendix 1 Guidelines for Mangrove Health Assessment using Remote Sensing
- Appendix 2 Calibration method of portable water quality meter
- Appendix 3 Analysis procedure of COD and inorganic nutrients using HACH DR890 portable colorimeter

Contents of attached CD

Folder 1 Sample field sheets

- 1. Sample field sheet for mangrove monitoring
- 2. Sample field sheet for fauna monitoring

3. Sample field sheet for environmental condition monitoring
4. Sample field sheet for inspection monitoring
5. Sample field sheet for transplanted-seedling monitoring

Folder 2 Sample database format

1. Sample database format for mangrove monitoring
2. Sample database format for fauna monitoring
3. Sample database format for environmental condition monitoring
4. Sample database format for inspection monitoring
5. Sample field sheet for transplanted-seedling monitoring

Chapter 1 Introduction

1. Background

The “Mangrove Monitoring Guideline (hereinafter referred as “Guideline”)” was prepared to explain the methodologies of the mangrove monitoring programs that were developed through the “Qurm Environmental Information Center (QEIC) Project”, a project implemented between Japan International Cooperation Agency (JICA) and Ministry of Environment and Climate Affairs (MECA). The monitoring programs consist of the following two programs:

- Mangrove Ecosystem Monitoring Program
- Transplanted-seedling Monitoring Program

The monitoring methodologies of “Mangrove Ecosystem Monitoring Program” and “Transplanted-seedling Monitoring Program” are described in detail in Chapters 2 and 3, respectively.

Although the Guideline is intended for application in Oman, it could be applied to other countries as well, with perhaps slight modifications.

The Guideline should also be revised in accordance to the experiences gained through the monitoring activities.

2. Characteristics of mangrove ecosystems in Oman

Natural mangrove forests in Oman are comprised of one species *Avicennia marina*. They are mainly distributed in lagoons and inner-bays dotted along the mainland coast. Mangrove forests are also occasionally found along the coasts of offshore islands such as Mahut Island. Mangrove forests in the Dhofar region are unique, as they are often isolated from the sea by sandy beach. Figure 1.2.1 shows the type of areas where mangrove forests are developed in Oman.



Figure 1.2.1 Type of areas where mangrove forests are developed in Oman

3. Basic outfits and gears for field survey

There are various dangers involved when conducting field surveys in mangrove forest, such as sunburn, dehydration, insect attacks and cuts by sharp objects (e.g. tree branch, shells). Hence, field surveyors should be equipped with appropriate protective outfits and gears. Following are recommended outfits and gears:

- Long-sleeve shirt and trouser
- Hat
- Diving boots
- Gloves
- Sunglass
- Sun screen
- Insect repellent
- Drinking water

Chapter 2 Mangrove Ecosystem Monitoring Program

1. Introduction

Mangroves in Oman grow under stressful natural conditions and threats to these mangroves and its ecosystem are mounting mainly due to recent population growth, economic development and coastal development. The “Mangrove Ecosystem Monitoring Program” was developed so to monitor the status of mangrove ecosystems that are under threat from natural and human impacts, and to implement conservation and management measures in accordance to the monitoring results. The status of mangrove ecosystems is assessed in an integrated manner by monitoring the various components that constitute and sustain mangrove ecosystems. It consists of monitoring of mangrove forest, fauna and environmental conditions. In addition, regular inspection monitoring is included so to detect of any presence of human or natural threats. Figure 2.1.1 shows the basic framework of the “Mangrove Ecosystem Monitoring Program”. Table 2.1.1 outlines the monitoring methods of each monitoring items and the relevant sections in the Guideline.

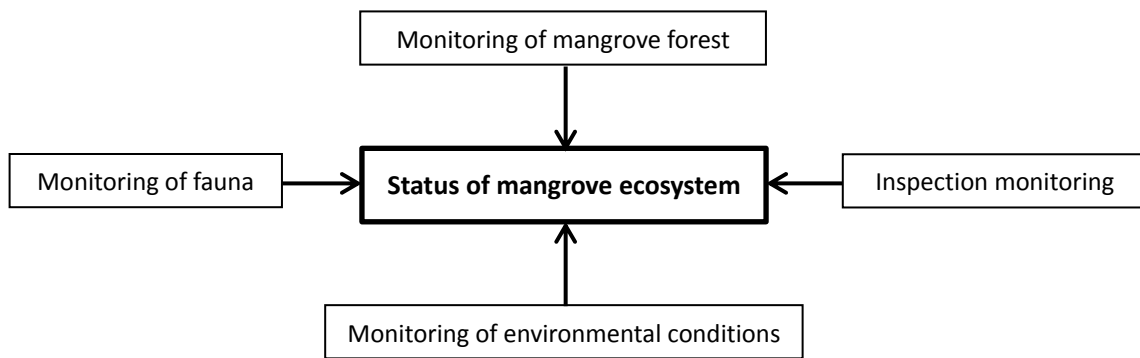


Figure 2.1.1 Basic framework of “Mangrove Ecosystem Monitoring Program”

Table 2.1.1 Outline of monitoring methods of “Mangrove Ecosystem Monitoring Program” and relevant sections in the Guideline

Monitoring item		Method/parameter	Frequency	Relevant section in the Guideline
Mangrove forest	Tree growth	Measurement of tree height and trunk circumference	1/year (2/year in initial year)	Section 2.1
	Tree health	Visual assessment of mangrove health	1/year (2/year in initial year)	Section 2.1
		Remote sensing assessment of mangrove health	1/year	Appendix 1
Fauna		Monitoring of indicator species population	2/year	Section 3.1-3.4
Environmental condition	Water quality	Measurement of temp., salinity, pH, DO, COD, nitrate, nitrite, ammonium, phosphate	2/year	Section 4.2
	Soil quality	Measurement of temp., salinity, EC, pH, ORP, nitrate, phosphate	2/year	Section 4.3
	Topography	Photo monitoring of lagoon mouth	6/year	Section 4.4.1
		Sedimentation monitoring of lagoon mouth	6/year	Section 4.4.2
	Water level	Water level monitoring of waterway	6/year	Section 4.5
Inspection		Identification of threats through visual inspection	6/year	Section 5

Note that the monitoring items and frequency should be adjusted in accordance to the situation of the target monitoring site.

2. Monitoring of mangrove forest

A healthy mangrove forest is fundamental to the sustenance of mangrove ecosystem. Therefore, the monitoring program will focus on monitoring the health status of the mangrove forest. The Guideline provides the following two monitoring approaches:

- The first approach assesses the health of mangrove forest by monitoring representative mangrove trees within the forest through field survey. The health of each tree is assessed by measuring growth and visually observing selected health indicators. It is quick, simple and requires no special expertise or equipment, and can be implemented after some brief training. However, the effectiveness of this approach may be limited for large forests as there may be difficulty in monitoring sufficient amount of representative trees. In such case, the second approach using remote sensing (see below) may be used in combination.
- The second approach involves the use of remote sensing (satellite image) technology for assessing forest health. The advantage of remote sensing is that it can cover large areas and areas where access is hard. However, satellite images are costly, and certain level of expertise will be required in using image processing software. Ground-truth work will also be required to verify the results. Remote sensing should be applied mainly for large mangrove forests,

where field survey is insufficient. The procedure of remote sensing assessment is described in the guideline attached as Appendix 1 (Guideline for Mangrove Health Assessment using Remote Sensing).

2.1 Monitoring method of mangrove forest

2.1.1 Basic concept and procedure

The health of mangrove forest is assessed by monitoring the growth and health of representative mangrove trees within the forest, and then comparing the results between successive surveys. The health status of each tree is determined by observing selected health indicators. If the monitored trees show any signs of health degradation (or no health improvement of unhealthy tree) between the successive surveys, it may be a sign that the health of the surrounding mangrove forest is under a degraded or stressed state. In such case, the cause of such health degradation should be investigated and appropriate actions taken accordingly. In principal, monitoring should be conducted 1/year (2/year in initial year), preferably during the same months. Figure 2.2.1 shows the basic monitoring procedure (refer to the ensuing Sections for more details):

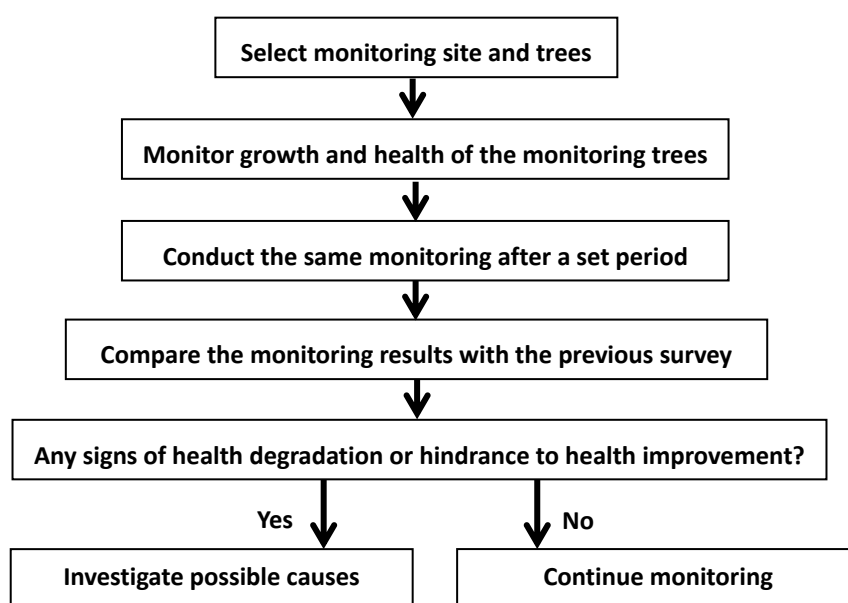


Figure 2.2.1 Basic procedure of mangrove health monitoring by field survey

2.1.2 Selection of monitoring site and trees

The number and location of the monitoring sites should be determined in accordance to the characteristics of each site, taking into account factors such as forest size, accessibility, availability of time and manpower. Following is one approach that could be employed for selection of monitoring site and trees, based on transect survey method.

Step 1: Zoning of mangrove forest

First divide the mangrove forest into several zones by using satellite images or maps as shown in

Figure 2.2.2.



Figure 2.2.2 Zoning of mangrove forest

Step 2: Setting of monitoring transect

For each zone, set up sufficient quantity of monitoring transect as shown in Figure 2.2.3. The transects should be set vertical to the forest edge and long enough so that it covers the entire width of the forest



Figure 2.2.3 Example of monitoring transect set up

However, note that in some forests, it would be difficult to apply vertical transects as *Avicennia* forest are often very dense and access to the inner area almost impossible unless the branches are cut. In such case, as a compromise, the monitoring transects may be set along the forest edge as shown in Figure 2.2.4.



Figure 2.2.4 Example of monitoring transect set up (alternative option)

Alternatively, if it is difficult to cover the entire forest for reasons such as accessibility, lack of manpower or time, monitoring may be focused on areas that are considered to have comparatively high risks of degradation such as:

- Mangrove areas near construction site
- Mangrove areas that are susceptible to grazing
- Mangrove areas that are susceptible to pollution

Step 3: Selection of monitoring trees

Once the monitoring site and transects are selected, the next step is to select the monitoring trees within the transect. Following are the basic procedures:

- Establish a transect at the monitoring site by laying a rope or tape measure. Then mark the start and end of the transect with a stake as shown in Figure 2.2.5. Record the location of the stakes with GPS. The stakes should be durable and installed deep enough so that it remains fixed until the next survey.

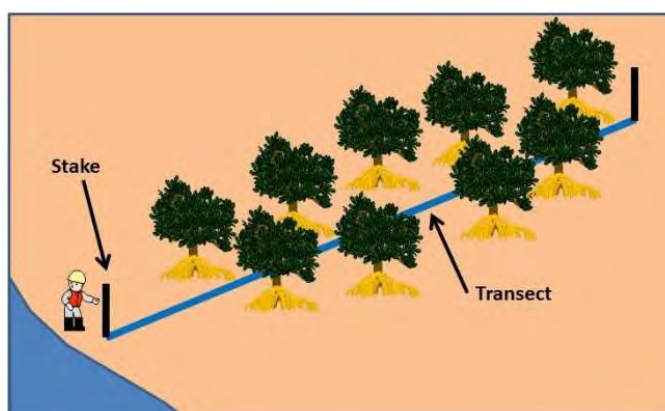


Figure 2.2.5 Image of transect

- Once the transect is set, select trees that are touching or within 1-2 m of the transect. The

number of monitoring trees should be at least be more than 10% of the number of trees along the transect (e.g. more than 10 trees if the number of trees along the transect is 100 trees). The selected trees should also be evenly distributed and not concentrated in one location. Figure 2.2.6 shows examples of monitoring tree selection.

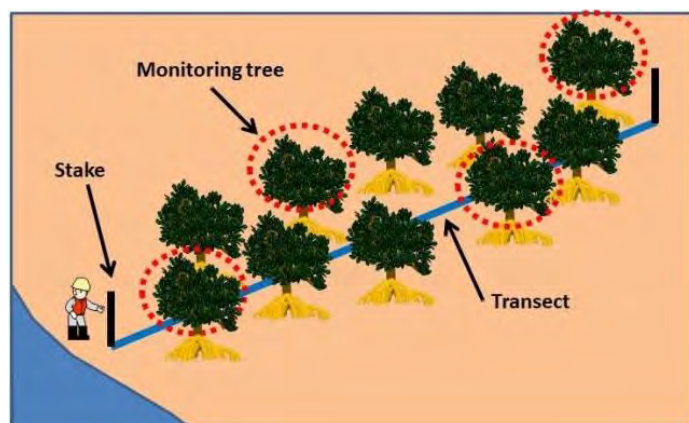


Figure 2.2.6 Examples of monitoring tree selection

- Attach a numbered tag onto the selected trees so that they can be identified in the ensuing surveys. Use tags that have high tolerance to sunlight and salt, so that they remain extant until the next survey. Figure 2.2.7 shows an example of a tree tag.

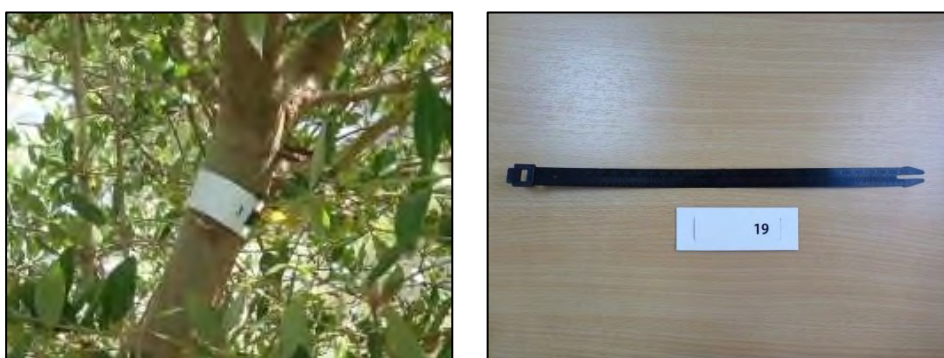


Figure 2.2.7 Example of tree tag

2.1.3 Monitoring of mangrove tree growth

Tree height and trunk circumference are measured to monitor tree growth. Tree height is measured from the ground level to the tree top by using a measuring rod (see Figure 2.2.8).

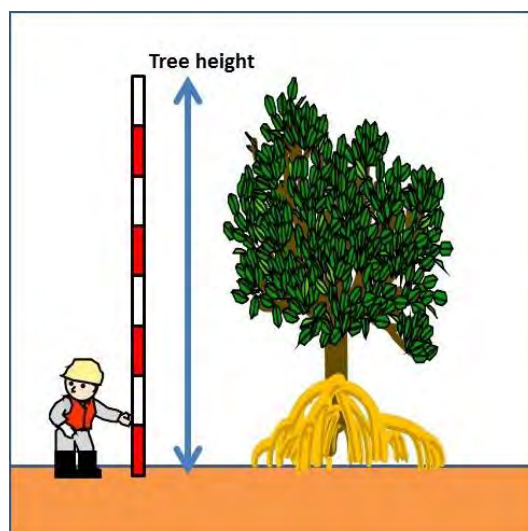


Figure 2.2.8 Measurement of tree height with measuring rod

Trunk circumference is measured at a fixed height above ground level (e.g. 130 cm) as shown in Figure 2.2.9. Often *Avicennia marina* has numerous numbers of trunks protruding from the ground, so choose one trunk for monitoring and continue to measure the same trunk (off course you can monitor more than one trunk if you are willing!). Mark the trunk that you are measuring so you can identify it later (the tree tag mentioned above can be used). Note the above results into a field sheet (sample field sheet is included in the attached CD).

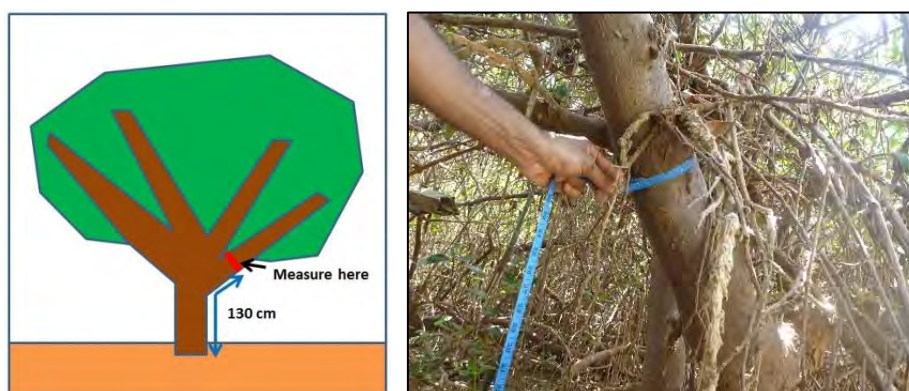


Figure 2.2.9 Measurement method of trunk circumference

2.1.4 Monitoring of mangrove tree health

The health of a mangrove tree is assessed by first visually observing the following health indicators.

- Leaf/branch density
- Leaf health
- Tree-top dieback
- Flowering

The status of each health indicator is rated by the surveyor as either “Good”, “Fair” or “Poor” by

referring to the assessment criteria shown in Table 2.2.1. Then based on the rating of each health indicator, the overall health status of the mangrove tree is rated as either “Good”, “Fair” or “Poor” by referring to the assessment criteria shown in Table 2.2.2. Note the results into a field sheet (sample field sheet is included in the attached CD).

Table 2.2.1 Tree health indicators and assessment criteria

Health indicator		Assessment criteria		
		Good	Fair	Poor
1	Leaf/branch density	High	Moderate	Low
2	Leaf health	Most leaves are healthy (e.g. > 80%)	Mixture of unhealthy leaves	Most leaves are unhealthy (e.g. > 80%)
3	Tree-top dieback	No dieback	Some dieback	Significant or complete dieback
4	Flowering*	Abundant	Less abundant than usual	Very few or none

*: Applicable only in flowering season

Table 2.2.2 Assessment criteria of overall health of mangrove tree

Good	Fair	Poor
All health indicators rated as “Good”	One or more health indicators rated as “Fair” or no “Poor”	One or more health indicators rated as “Poor”

When conducting the assessment, make sure to observe the whole tree rather than focusing only on one part of the tree. Since judgment will be reliant on the surveyor’s impression, two or more surveyors should participate in the survey, so to reaffirm the validity of each other’s judgment. Try to conduct the assessment briefly based on “first impression” as you might get confused if you observe for long time. In addition, take photos of the tree for later reference. Following are detailed description of each health indicator.

(1) Leaf/branch density

In general, a healthy tree will have high density of branches and leaves, and vice versa for unhealthy trees. Note that healthy trees may naturally have low branch/leaf density in the lower section, due to for example old age, insufficient sunlight penetration caused by dense branch/leaves above and so on. Hence judgment should be made by taking into account such factors. Figure 2.2.10 shows varying degrees of branch/leaf density and respective health conditions.

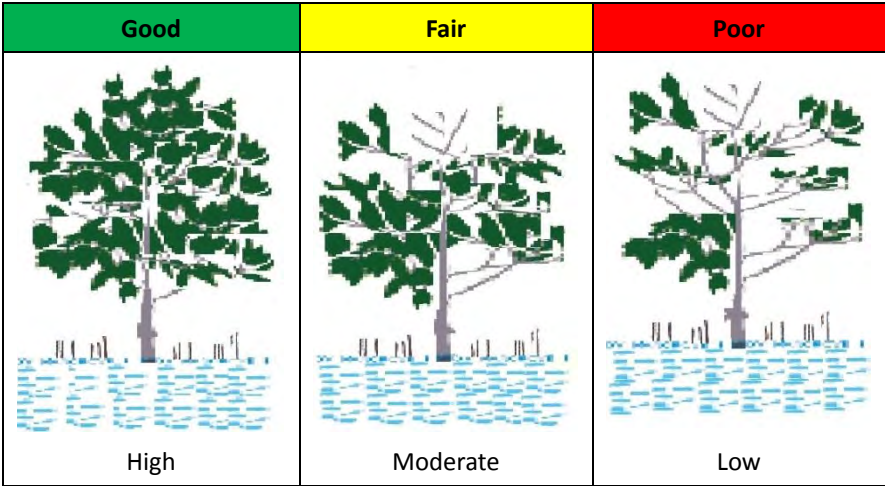


Figure 2.2.10 Varying degrees of branch/leaf density and respective health conditions

(2) Leaf health

In general, leaves of an unhealthy tree will be small, curled and yellowish in color. However, note that leaves naturally turn yellowish prior to shedding so it must not be confused as sign of unhealthiness. Figure 2.2.11 shows some examples of healthy and unhealthy leaves.

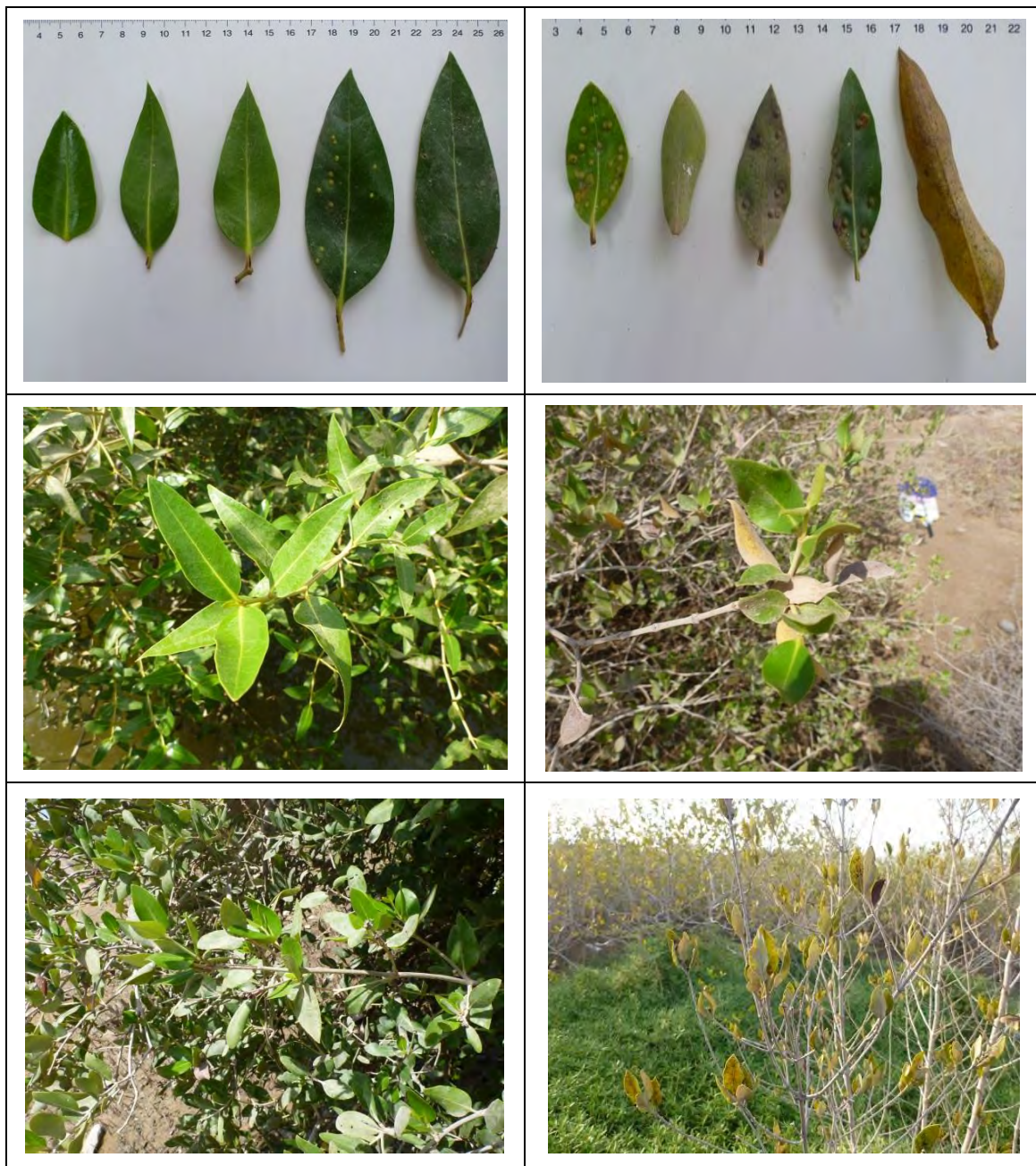


Figure 2.2.11 Examples of healthy (left) and unhealthy (right) leaves

(3) Tree-top dieback

When trees are under stress or unhealthy, they often shed their leaves from the top portion of the tree. This is because more effort is required to transport water and nutrients to the top portion of the tree. Figure 2.2.12 shows an example of tree-top dieback.



Figure 2.2.12 Example of tree-top dieback

(4) Flowering

This indicator is applicable only for reproductive trees and during flowering season. A healthy reproductive tree will generally have abundant flowers and vice versa for unhealthy trees. The flowers range from white to a golden yellow color, are less than a centimeter across, and occur in clusters of three to five. In Oman, the main flowering season of *Avicennia marina* differs with the region. Table 2.2.3 shows the main flowering season by region. Figure 2.2.13 shows flower of *Avicennia marina*.

Table 2.2.3 Main flowering season of *Avicennia marina* by region

Region	Main flowering season
Muscat	May-June
Dhofar	November-December



Figure 2.2.13 Flower of *Avicennia marina*

2.1.5 Investigation of possible causes of tree health degradation

If degradation of tree health is identified between successive surveys, investigate possible causes

by observing factors that could affect tree health. Also refer to the monitoring results of the other monitoring components (e.g. monitoring results of environmental condition). Following are possible factors that may affect tree health.

(1) Lack of water supply

Mangrove trees need regular supply of seawater to grow. If there is no sign of seawater inundation even during high tide, the tree is likely to be under stressful condition.

(2) Water stagnation

Water stagnation occurs when water exchange is insufficient, which consequently could degrade the quality of the water and soil that the mangroves depend on. Hence, observe whether the waters around the mangrove trees are exchanged through tidal movement.

(3) High salinity

High water or soil salinity will affect growth of mangrove. Check the salinity of the adjacent water and underlying soil (see Section 4.3.3 for method of soil salinity measurement).

(4) Soil erosion/sedimentation

Soil erosion or sedimentation may be stressful to mangrove trees. Erosion may unstable the tree by exposing the roots. Sedimentation may bury the aerial roots and hinder respiration. Soil erosion or sedimentation may be identified by observation or by measuring the sedimentation rate with a permanent stake (see Section 4.4 for the measurement method of sedimentation).

(5) Garbage and algae entanglement

Garbage (esp. plastic bags) and algae are sometimes found entangled on mangrove trees, including around the aerial roots. This may be stressful to mangrove trees for example by hindering respiration through the aerial root. Figure 2.2.14 shows garbage and algae entangled on mangrove tree.



Figure 2.2.14 Garbage (left) and algae (right) entangled on mangrove tree

(6) Intrusion of other plant species

Non-mangrove plant species (e.g. halophyte plants) can sometimes intrude into mangrove areas, and affect the health of mangrove or in extreme case cause death. Figure 2.2.15 shows halophyte plants intruding into mangrove areas.



Figure 2.2.15 Mangroves affected by intrusion of halophyte plants

(7) Animal grazing

Animal grazing can affect the health of a tree by removing fresh branches and leaves. In Oman, grazing by camels, goats and donkeys are common. Figure 2.2.16 shows mangrove trees affected by animal grazing.

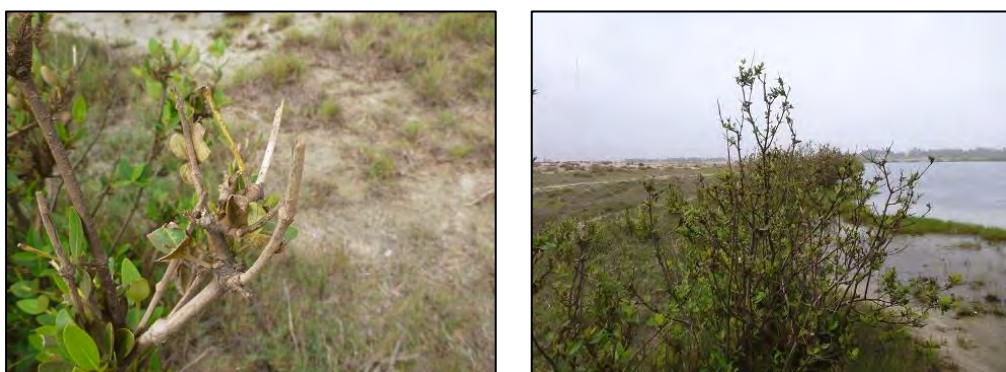


Figure 2.2.16 Mangrove trees affected by animal grazing

(8) Insect pest and fungi

In general, when leaves are unhealthy or stressed, they are more likely to be infested by insect pests and fungi. Typical pest may include scale insects, leafhopper, sandfly and so on. Figure 2.2.17 shows examples of pest and infested leaves.

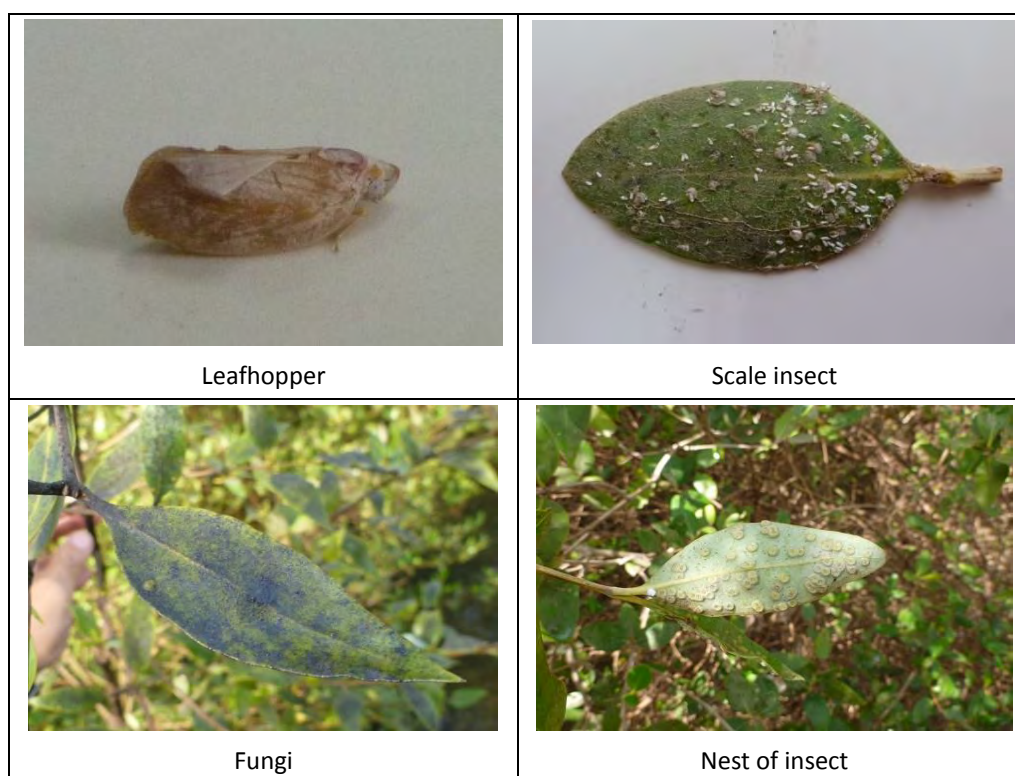


Figure 2.2.17 Examples of insect pests and leaves stressed by insect and fungi

2.1.6 Necessary field survey equipment

- Tape measure (e.g. 2 m, 100 m)
- Stakes (e.g. 1.5 m)
- Tree tags
- GPS
- Field sheet/clip board
- Waterproof marker
- Camera
- Measuring rod (e.g. 12 m)
- Thermometer
- Refractometer

2.1.7 Management of monitoring data

The monitoring data should be stored into a database, which should include the following information (sample database format is included in the attached CD):

- Survey conditions (date, time, weather, tide level etc.)
- Results of tree height and trunk circumference measurement
- Results of tree health survey and possible stress factors
- Photographs of the surveyed trees

3. Monitoring method of fauna

3.1 Basic concept and procedure

Mangrove ecosystems are sustained through the interaction of various types and sizes of fauna, and monitoring of these fauna may provide us indications on the status of the mangrove ecosystem. For example, if a significant reduction in bird population is identified through monitoring, we may infer that the abundance of their usual food source (e.g. crabs) is declining, and from it we can also infer that the mangrove ecosystem is under a degraded state for some reason.

However, since it is impractical to monitor all fauna species, monitoring could instead be conducted by selecting “indicator species”, which are types of species that provide indications on the status of the mangrove ecosystem. Among the many fauna types, the Guideline will focus on selecting indicator species from the fish, crab, gastropod and bird families, as they are one of the most conspicuous fauna in the mangrove ecosystem and therefore are relatively easy to identify and monitor.

In order to select indicator species, it is first necessary to understand the type of species that are present at the monitoring site. The initial year will hence focus on developing a species inventory for fishes, crabs, gastropods and birds through field survey. Once the inventory is completed, an appropriate indicator species will be selected, and from then on monitoring will focus on the selected indicator species. Monitoring should be conducted 2 times/year, preferably during the same seasons. Figure 2.3.1 shows the basic procedure of the fauna monitoring program.

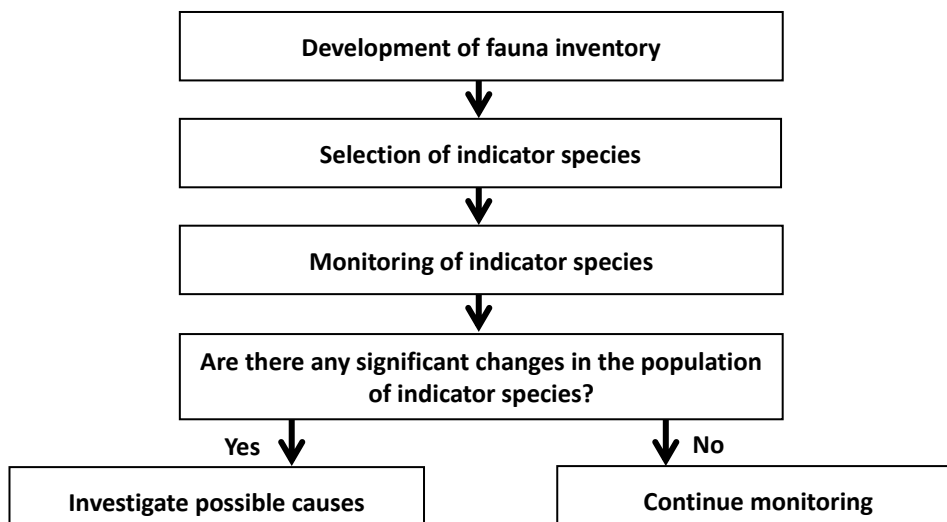


Figure 2.3.1 Basic procedure of fauna monitoring

3.2 Development of fauna inventory

Fauna inventory is developed through the following processes:

- Collection of fauna from the field
- Species identification of the collected fauna
- Development of inventory database

The ensuing Sections provide basic methods of the above processes for fish, crabs and gastropods.

Bird inventory involves a slightly different approach as it is impractical to collect them (see Section 3.3).

3.2.1 Collection of fauna

(1) Collection by nets

Various types of nets can be used to collect faunas living in the waterway, such as fishes and crabs. Figure 2.3.2 shows examples of different types of nets and their characteristics.

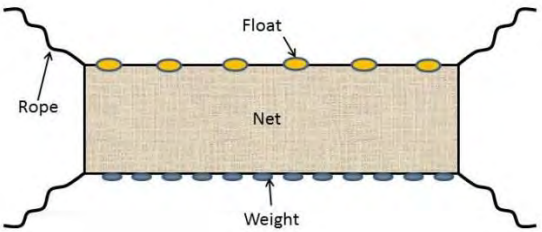

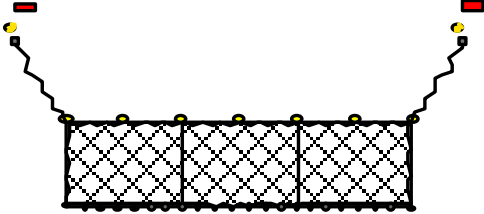

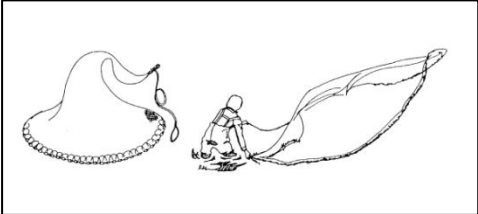
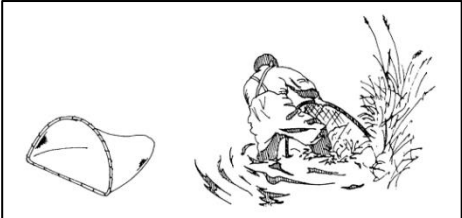

Net type	Characteristics
Seine net	<p>Most suitable for catching animals in relatively shallow waters.</p>  
Gill net	<p>Catches indiscriminately all types of animals larger than the mesh size.</p>  
Cast net	<p>Effective in catching animals in relatively shallow waters. Requires certain skills.</p> 
Hand net	<p>Effective in catching animals in tide pools or along the edges of waterway.</p>  

Figure 2.3.2 Examples of different types of nets and their characteristics

(2) Collection by cage

Various types of cages can be used to collect faunas living in the waterway, such as fishes and crabs. The type of fauna caught will depend on the bait and mesh size. Figure 2.3.3 shows examples of different types of cages.



Figure 2.3.3 Examples of different types of cages

(3) Collection by digging

Burrowing organisms (e.g. crabs and gastropods) can be caught by digging around their burrow with a shovel or scoop. Figure 2.3.4 shows the basic procedures using crabs as an example:






<p>Step 1: First look for burrowing crabs, which is easiest during low tide.</p>	
<p>Step 2: Once the crab hides into its burrow, quickly dig around the burrow with a shovel or scoop (e.g. up to around 20-30 cm depth).</p>	
<p>Step 3: Transfer the soil into a sieve and remove the soil by washing it with water.</p>	
<p>Step 4: Collect the crabs remaining inside the sieve</p>	
<p>Step 5: Transfer the crab into a container for later identification</p>	

Figure 2.3.4 Collection procedure by digging (example with crabs)

(4) Collection by hand

Some crab species (e.g. sersamid crabs) climb on the trunk/branch of mangrove tree. These crabs can be collected directly by hand but wear gloves to prevent injury. Gastropods can also be collected by hand especially during low tide where they come out to feed on the mud surface.

(5) Photographs of collected fauna

If the collected fishes are still alive, take live photos by using a portable aquarium (see Figure 2.3.5), as it will be useful for later identification (they lose their natural coloration once they are dead). Make sure the photos are properly focused on the fish. Take multiple photos so the best photo can be chosen later.

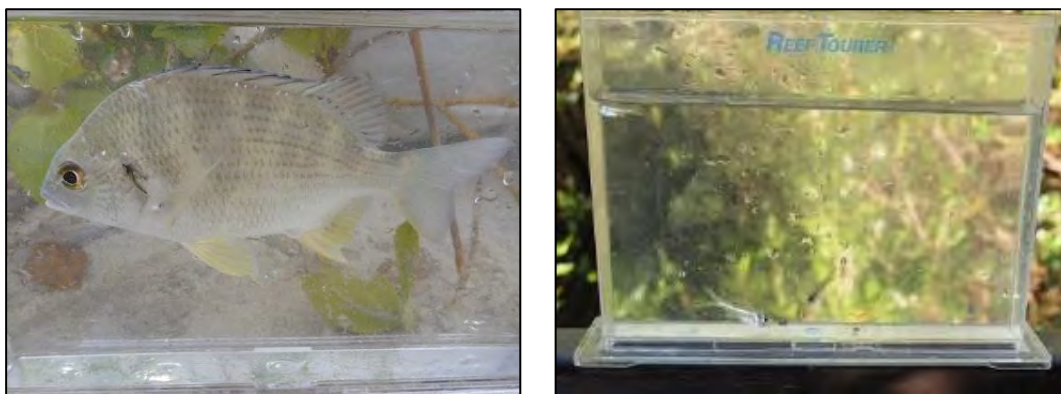


Figure 2.3.5 Photo of live fish taken with a portable aquarium

(6) Recording of field survey information

Record necessary information such as below into a field sheet (sample field sheet is included in the attached CD):

- Location and characteristics of the collected area
- Collection method
- Characteristics of the collected fauna (e.g. life stage, abundance)

(7) Preservation of collected fauna

To minimize decay of the collected fauna during transportation, preserve them in a cooler box with ice. Alternatively, the samples may be preserved in a glass jar filled with formalin (e.g. 10%) or ethanol (e.g. 80%) solution. Also note the following information on a waterproof label and put it inside the jar with the samples.

- Name of mangrove site
- Collected date and time
- GPS coordinates of the collected site
- Collection method
- Jar no.

(8) Necessary field survey equipment

- Collection tools (nets, cages, scoop/shovel, sieve)
- Equipment for sample preservation (alcohol/formalin solution, glass jars, waterproof label)
- Portable aquarium

- Identification guidebook
- Field sheet and clip board
- Small hand net for transferring collected samples
- Bucket
- GPS
- Digital camera
- Waterproof pen
- Cooler box with ice
- Gloves

3.2.2 Species identification of collected fauna

In principal, the collected fauna should be identified at the lab by referring to relevant identification guidebooks or websites. Table 2.3.1 shows some useful guidebooks or websites. Consult relevant university or research institutes if uncertain.

Table 2.3.1 Guidebooks and websites for species identification

	Title	Author/publisher/website
Fishes	Coastal fishes of Oman	John E. Randall / University of Hawaii Press
	FishBase	http://www.fishbase.org/search.php
Crabs	Crustacea Guide of the World	Helmut Debelius / Ikan
Gastropods	Seashells of Eastern Arabia	DT Bosch et al. / Motivate Publishing
	Seashells of Oman	Donald Bosch / Longman
	Handbook on Mangrove Associate Molluscs of Sundarbans	Zoological Survey of India

In the process, also take photos and basic body size measurements of the collected samples. Figure 2.3.6 shows where to measure body size for fish, crab and gastropod.

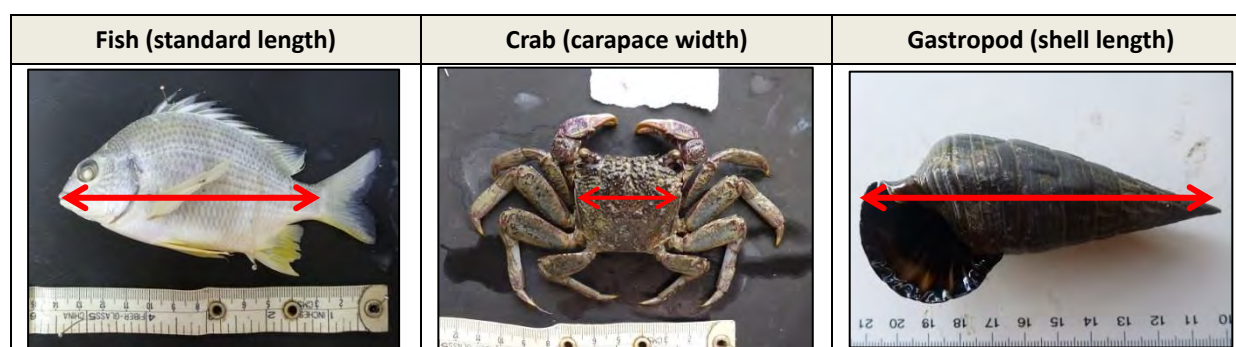


Figure 2.3.6 Method of size measurement for fish, crab and gastropod

Once the above identification processes are completed, store the fauna in a shelf by preserving them inside a jar with formalin or ethanol solution.

3.2.3 Development of species inventory

Once the collected faunas are identified, record the species name and the following information into an inventory database (sample database format is included in the attached CD).

- ✓ Collected date and time
- ✓ GPS coordinates of the collected site
- ✓ Collection method
- ✓ Scientific name, common name, family name
- ✓ Body size
- ✓ Life stage (juvenile or adult)
- ✓ Abundance (common or rare)

3.3 Development of bird inventory

Since it is impractical to collect birds from the field, birds will need to be identified in the field or later by taking photographs. Hence, the surveyor will require skills in rapid bird identification and good photograph skills. Following are the basic survey procedure:

- Prior to conducting the survey, identify the main bird habitats (e.g. feeding and roosting areas) through field reconnaissance. Also consider migratory seasons when deciding the survey period.
- Once the main bird habitats are identified, plan the time, location and method of the survey. Survey can be conducted by observing birds from a fixed point, by walking around the forest, from the waterway by using a kayak or a combination of these. Make sure to record the surveyed site or route with GPS.
- If possible, conduct the survey at varying tide levels (e.g. low and high tides). Consider light conditions as birds will be hard to identify when the sun is behind them.
- Observe and identify the birds by using telescope or binocular (see Figure 2.3.7), and make sure to keep a certain distance from the birds so to avoid scaring the birds away. Also count the number of individuals for each species. Try to take photos of the birds with high-magnification camera for later reference. Avoid wearing brightly-colored clothes as you may be more easily spotted by birds. Table 2.3.2 shows useful guidebooks for bird survey and identification.



Figure 2.3.7 Bird observation with telescope and binocular

Table 2.3.2 Guidebooks for bird survey and identification

Title	Publisher
Guidance on waterbird monitoring methodology: Field Protocol for waterbird counting	Wetlands International
Birdwatching guide to Oman	Al Roya Publishing
Oman Bird List	Sultan Qaboos Univeristy
Birds of the Middle East	Porter Aspinall
Common birds in Oman	Al Roya Press & Publishing House

- Record the following information into a field sheet (sample field sheet is included in the attached CD).
 - ✓ GPS coordinates of survey site
 - ✓ Weather conditions
 - ✓ Tide level
 - ✓ Identified species and their abundance
- After the field survey, record the information into an inventory database (sample database format is included in the attached CD).

Necessary field survey equipment

- Binocular
- Telescope, tripod, digital camera
- Telephoto camera, tripod
- Kayak
- Counter
- GPS
- Field sheet/clip board
- Identification guidebook

3.4 Selection of indicator species

One of the most critical aspects of the fauna monitoring program is the selection of appropriate indicator species. While indicator species may comprise from individual species or group of species (e.g. species that belong to the same family or have similar characteristics), there should be a good reason for the selection. Hence, experts should be consulted in the selection process. Following are some potential indicator species:

- Species that belong to the top of the food chain, such as herons and swimming crabs (see Figure 2.3.8)



Figure 2.3.8 Photo of heron (left) and swimming crab (right)

- Species that play a key role in the mangrove ecosystem food chain such as leaf eating sesamid crabs and mudwhelks (see Figure 2.3.9).



Figure 2.3.9 Photo of sesamid crab (left) and mudwhelk (right)

- Species that are very common in the mangrove ecosystem such as fiddler crabs and gobies (see Figure 2.3.10).



Figure 2.3.10 Photo of fiddler crab (left) and goby (right)

In addition, the following factors should be considered in the selection process:

- The indicator species should be selected from various habitat types within the mangrove ecosystem (e.g. waterway, mudflat and forest areas)
- Monitoring of the selected species is cost effective and relatively easy (even possible by non-experts)
- The ecology of the selected species is well known (e.g. food, behavior, habitat)

3.5 Monitoring of indicator species

In principal, indicator species are monitored by estimating their abundance through field survey and then comparing the results between successive surveys. The field survey method should be determined in accordance to the type of indicator species selected, but should be relatively easy so

that non-experts (e.g. local citizens) can also participate. Following is an example monitoring method in case fiddler crabs are selected:

Step 1: Look for an area where fiddler crabs are predominant. Select an appropriate survey area (e.g. 10 m x 10 m) and mark the boundaries with a stake (see Figure 2.3.11).

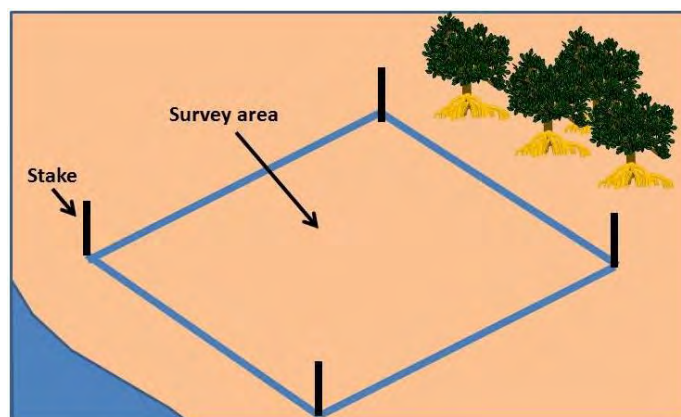


Figure 2.3.11 Selection of survey area

Step 2: Randomly place several 1 m x 1m quadrats (e.g. 10 quadrats) inside the survey area (see Figure 2.3.12).

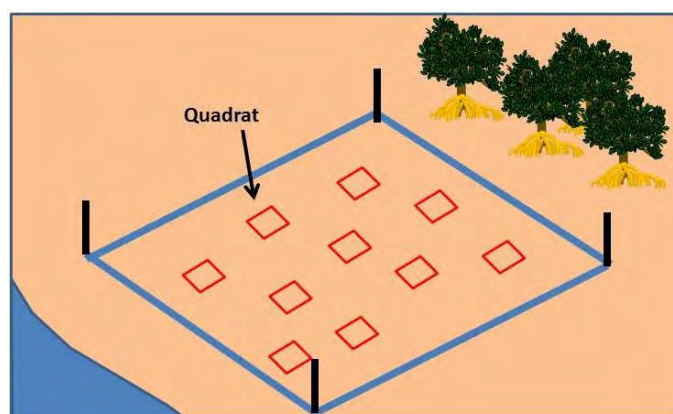


Figure 2.3.12 Placement of quadrat

Step 3: Count the number of crab burrows inside each quadrat and recorded it onto a field sheet (see Figure 2.3.13).

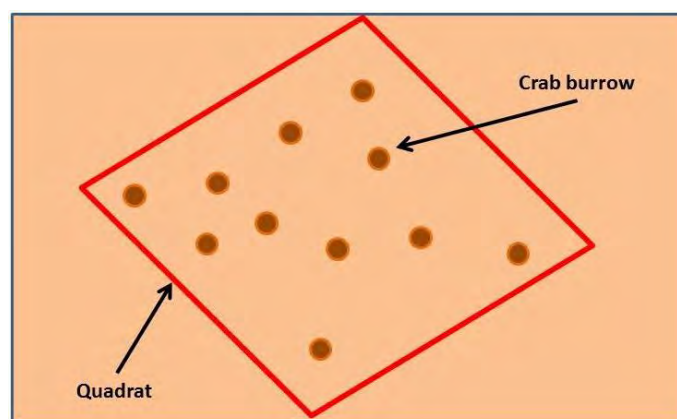


Figure 2.3.13 Counting of crab burrows

Step 4: Estimate the number of crab burrows per square meter (m^2) of the survey area through the following formula:

$$\text{No. of crab burrows}/m^2 = \text{total no. of crab burrows} / \text{number of quadrats}$$

Step 5: Conduct the same survey after a set period at the same survey area and compare the values. Any significant decrease in the values may indicate that the crab population is decreasing, and its cause should be investigated.

3.6 Investigation of possible causes of population change

If significant changes of indicator species population are identified between successive surveys, investigate possible causes that may have affected the abundance of indicator species. Also refer to the monitoring results of the other monitoring components (e.g. monitoring results of environmental condition and socioeconomic activities). Following are possible factors that may affect abundance of indicator species.

- Degradation of water quality (e.g. eutrophication)
- Change in hydrology of the waterway (e.g. closure of lagoon mouth)
- Reduction of mangrove leaf litter
- Intrusion of invasive species
- Illegal fishing
- Excessive expansion of mangrove

4. Monitoring method of environmental conditions

4.1 Introduction

Monitoring of environmental condition is important, as mangroves and fauna are influenced by the conditions of the ambient environment. Of particular importance are:

- Water quality
- Soil quality
- Topography
- Water level

The monitoring methods of the above components are described in the ensuing sections.

4.2 Water quality

Degradation of water quality could have adverse impacts on aquatic fauna and mangrove trees. Therefore, water quality monitoring consists of parameters that are relevant to both aquatic fauna and mangrove trees. Monitoring should be conducted at least 2/year, but should be conducted more frequently at sites where the risk of water quality degradation is high.

4.2.1 Water quality parameters

In general, the following water quality parameters should be monitored:

- Water temperature
- Salinity
- pH
- Dissolved oxygen (DO)
- Chemical Oxygen Demand (COD)
- Inorganic nutrients (nitrate (NO₃-N), nitrite (NO₂-N), ammonium (NH₄-N), phosphate (PO₄-P))

Pollutants such as heavy metals, oil and pesticides should also be monitored if there are such pollution risks (note that these pollutants are not covered in this Guideline).

4.2.2 Water quality monitoring sites

In principal, water quality should be monitored at representative areas of the mangrove forest (e.g. upstream, midstream and downstream of the waterway). In order to select a representative site, the biological (e.g. fish habitat) and physical (e.g. topography, hydrology) characteristics of the mangrove site should be considered. Water quality should also be monitored at areas where there are high risks of water pollution (e.g. areas receiving wastewater inflow).

If water is shallow (e.g. less than 1 m), monitoring of the surface layer should be sufficient. If water is deep (e.g. more than 1 m), try to monitor the bottom layer as well.

4.2.3 Field survey procedure

Following are basic field survey procedures (sample field sheet is included in the attached CD):

- In principal, monitoring should be conducted twice, once each during flood and ebb tides (see

Figure 2.4.1). So plan the timing of survey carefully by checking the local tide chart. Field survey should preferably be conducted by at least 2-3 surveyors.

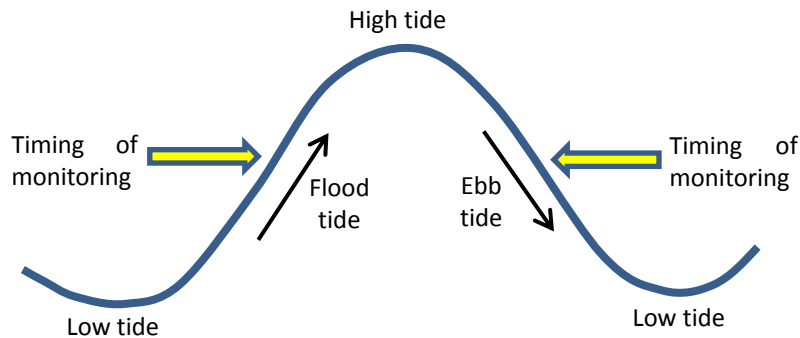


Figure 2.4.1 Timing of water quality monitoring

- Record basic information about the survey sites such as: location (GPS coordinate), weather and water depth. Water depth may be measured with a measuring pole or portable depth sounder.
- Water temperature, salinity, pH and DO should be measured at the site using portable water quality meters. You can either dip the sensor directly into the water or by first collecting water samples with a bucket or water sampler (see Figure 2.4.2). Make sure to rinse the bucket or water sampler prior to sampling to prevent contamination. Also calibrate the instruments prior to use (see Appendix 2 for calibration method).



Figure 2.4.2 Measurement of water quality with portable water quality meters

- COD and inorganic nutrients are analyzed at the laboratory by bringing back water samples. Collect around 500 ml of water sample as each parameter requires approximately 100 ml for analysis. The water samples should be stored in a cooler box (with ice) when transporting to minimize biological breakdown. Appendix 3 shows the analysis procedure of COD and inorganic nutrients.

4.2.4 Necessary field survey equipment

- GPS
- Field sheet/clipboard
- Tissue

- Distilled water
- Wash bottle
- Measuring pole/portable depth sounder
- Cooler box/ice
- Bucket/water sampler
- Kayak (if water is deep)
- Sampling bottles
- Labels and waterproof markers
- Thermometer
- Salinity meter
- pH meter
- DO meter

4.2.5 Assessment and management of monitoring data

Once the field survey and laboratory analysis is completed, the data should be recorded into a database (sample database format is included in the attached CD). The data may be compared with results of previous surveys and other sites or appropriate water quality standards. If any abnormal values are recorded, the cause of such abnormality should be investigated. Table 2.4.1 shows examples of water quality standards established by other countries for protection of aquatic organisms (there are no national water quality standards in Oman).

**Table 2.4.1 Examples of water quality standards established by other countries
(for protection of aquatic organisms)**

Parameter	Japan ^{*1}	Australia ^{*2}	Canada ^{*3}
pH	7.8-8.4	8-8.4	7.0-8.7
DO	>6 mg/l	>90 (% saturation)	>8 mg/l
COD	2 mg/l	-	-
NOx (NO ₃ ⁻ + NO ₂ ⁻)	-	8 µgN/l	-
Ammonium (NH ₄ ⁺)	-	10 µgN/l	-
Phosphate (PO ₄ ³⁻)	-	5 µgP/l	-

*1: Fisheries Water Quality Standard

*2: Australian and New Zealand Guidelines for Fresh and Marine Water Quality (Tropical Australia)

*3: Canadian Water Quality Guidelines for the Protection of Aquatic Life

4.3 Soil quality

Soil quality is important for the health of mangrove trees, as they absorb water and nutrients from the soil. Therefore, soil quality monitoring should consist of parameters that may affect the health of mangrove tree. Soil quality should be measured at two depths: around 10 cm and 40 cm below the surface.

4.3.1 Soil quality parameters

In general, the following soil quality parameters should be monitored:

- Soil texture
- Soil color
- Soil temperature
- Oxidation-Reduction Potential (ORP)
- Electrical conductivity (EC)
- Salinity (NaCl)
- pH
- Nitrate (NO₃-N)
- Phosphate (PO₄-P)

4.3.2 Soil quality monitoring sites

In principal, soil quality should be monitored at areas adjacent to the mangrove tree monitoring sites.

4.3.3 Field survey procedure

Following are basic field survey procedures (sample field sheet is included in the attached CD):

(1) Collection of soil sample

Soil samples are collected by using a core sampler, up to a depth of around 50 cm. Samples should be collected preferably during low tide. Collect at least 3 samples for each site.



Figure 2.4.3 Collection of soil sample with core sampler

(2) Classification of soil texture

Classify the soil texture into either sandy or muddy by observing and rubbing the soil sample between your fingers. Table 2.4.2 shows the general characteristics of sandy and muddy soil.

Table 2.4.2 Characteristics of sandy and muddy soil

Sandy soil	Muddy soil
<ul style="list-style-type: none"> • Predominantly comprised of sand particles (0.125 – 2 mm) • Individual soil particles will be visible with naked eye • Soil will have a gritty feel 	<ul style="list-style-type: none"> • Predominantly comprised of silt and clay particles (0.0625 – 0.0039 mm) • Individual soil particles will not be visible with naked eye • Soil will have a sticky feel

(3) Classification of soil color

Soil color may give clues to the conditions that the soil is subjected to. Soil can exhibit a wide range of color: gray, black, white, red, brown, yellow and so on. Classify soil color by visual observation or by using soil-color chart (see Figure 2.4.4), if available.

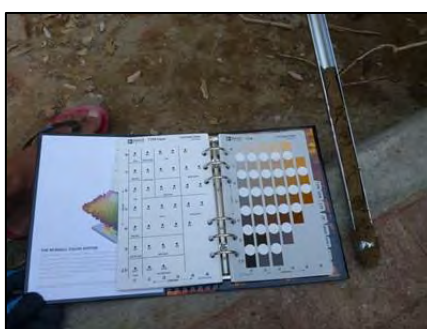


Figure 2.4.4 Classification of soil color with soil-color chart

(4) Measurement of soil temperature

Soil temperature is measured by inserting soil thermometer into the soil sample (see Figure 2.4.5).



Figure 2.4.5 Measurement of soil temperature with soil thermometer

(5) Measurement of Oxidation-Reduction Potential (ORP)

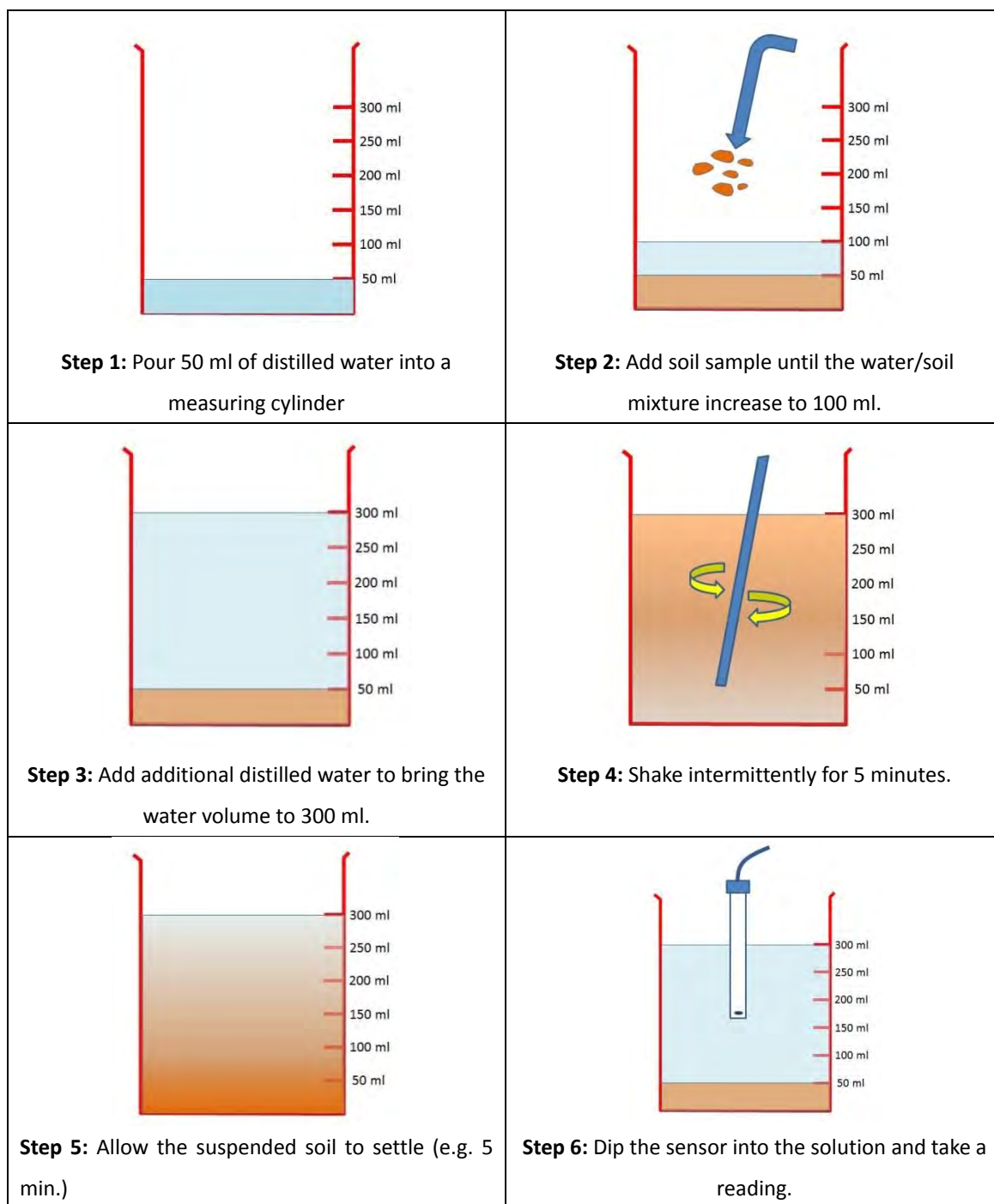
Oxidation-Reduction Potential (ORP) is measured by directly inserting an ORP sensor into the soil sample (see Figure 2.4.6). Insert the probe deep into the sample. Measurement should be conducted as soon as possible after collecting the sample, as values will change quickly once exposed to air.



Figure 2.4.6 Measurement of ORP with ORP meter

(6) Measurement of EC, salinity, pH

EC, salinity and pH can be measured in the field by first preparing a 1:5 ratio soil/water suspension. Figure 2.4.7 shows the procedure of measuring EC, salinity and pH with 1:5 ratio soil/water suspension.



Note: The described volume is an example.

Figure 2.4.7 Procedure of measuring EC, salinity and pH with 1:5 ratio soil/water suspension

(7) Measurement of nitrate (NO₃⁻) and phosphate (PO₄³⁻)

Plants require an adequate supply of nutrients, particularly nitrate and phosphate. Nitrate and phosphate are analyzed at the laboratory by collecting water from the 1:5 ratio soil/water suspension. The water samples should be stored in a cooler box (with ice) when transporting to minimize biological breakdown. Approximately 100 ml of water sample is required for each parameter. The

analysis procedure is same as the water quality (see Appendix 3).

4.3.4 Necessary field survey equipment

- GPS
- Field sheet/clipboard
- Labels and waterproof markers
- Cooler box/ice
- Soil sampler
- Water sampling bottle
- Soil color chart
- Distilled water
- Measuring cylinder (around 500 ml)
- Soil thermometer
- ORP meter
- EC meter
- pH meter

4.3.5 Assessment and management of monitoring data

Once the field survey and laboratory analysis is completed, the data should be recorded into a database (sample database format is included in the attached CD). The obtained data may be compared with results of previous surveys and other sites or appropriate soil quality standards. If any abnormal values are recorded, the cause of such abnormality should be investigated. Table 2.4.3 shows the tolerance level of plants against varying salinity levels.

Table 2.4.3 Tolerance level of plants against varying salinity levels

Salinity rating	EC _{se} * (dS/m)	Effect
Slightly saline	1.5-2	Salinity effects usually minimal
Moderately saline	2-6	Yield of salt sensitive plants restricted
Highly saline	6-15	Only salt tolerant plants yield satisfactorily
Extremely saline	>15	Few salt tolerant plants yield satisfactorily

*: Electrical conductivity (EC) value of saturated extract. The above values are applicable if EC levels are measured on a saturated extract.

Source: Queensland Government

Totally anoxic sediments have redox potentials below -200 mV, while typical oxygenated soils have potentials of above +300 mV.

4.4 Topography

Topographic alterations may have significant impacts on mangrove ecosystem. One of the major concerns is the decrease in the depth or closure of the lagoon mouth, which may occur through natural or human induced coastal accretion or erosion process. Such alterations will significantly

change the lagoon hydrology and as a consequence degrade the mangrove forest and ecosystem through reduced water exchange, water stagnation or ultimately drying-up of the waterway. The Guideline provides two approaches for monitoring the topography of the lagoon mouth.

4.4.1 Photo monitoring

The topography of the lagoon mouth may be monitored by taking photographs of the mouth from a fixed location and height at regular intervals (e.g. 2/month). Following are the basic procedures:

- Try to choose a location where you can have a good overall view of the mouth (see Figure 2.4.8). Record the location with GPS.



Figure 2.4.8 Example of photo monitoring

- If possible, install at the monitoring location a permanent stake with a platform for placing camera (see Figure 2.4.9).

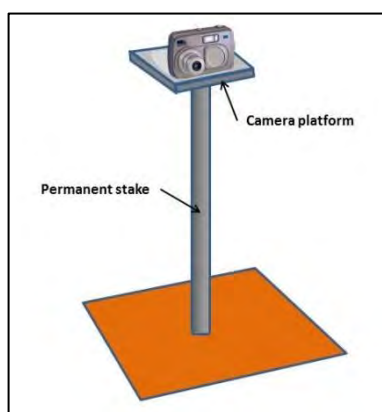


Figure 2.4.9 Example of platform for photo monitoring

- Take photographs of the mouth and upload the photograph into a database (sample database format is included in the attached CD). Try to take photographs during similar tide levels.

4.4.2 Sedimentation monitoring

The topography of the lagoon mouth may also be monitored by measuring the rate of

sedimentation. Sedimentation rate is monitored by installing permanent stakes at the lagoon mouth, and then measuring the distance between the top of the stake and soil surface at regular intervals (e.g. 2/month). A decrease in the distance between successive surveys will indicate that the area is under sedimentation. Following are the basic monitoring procedures:

- Install permanent stakes (e.g. PVC pipe with 1.5 m length) along the cross-section of the inlet mouth (see Figure 2.4.10). Make sure the stakes are installed vertically and deep enough (e.g. > 50 cm) so that it will not move downward or upward.

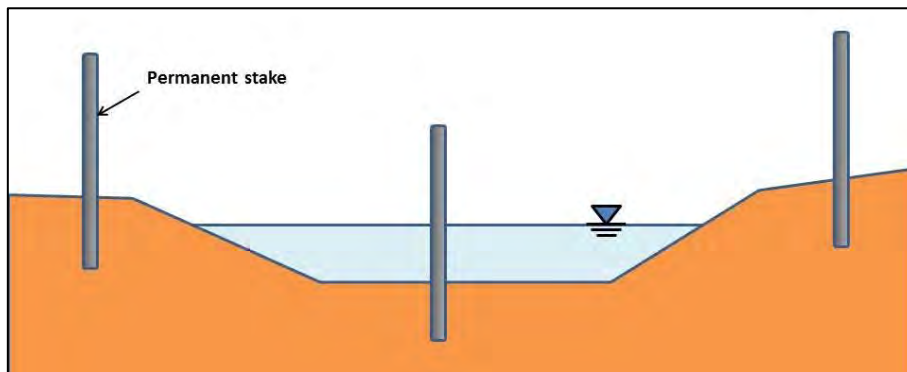


Figure 2.4.10 Image of permanent stake installation

- Measure the distance between the top of the stake and soil surface (see Figure 2.4.11) and record the values into a field sheet and later into the database (sample field sheet and database format is included in the attached CD).

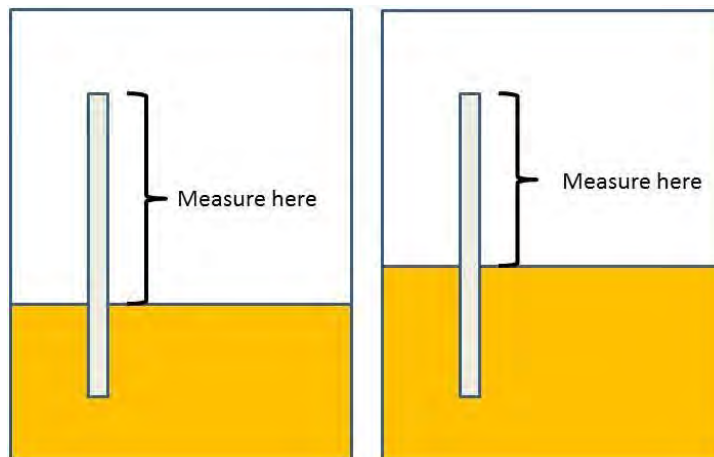


Figure 2.4.11 Measurement method of sedimentation

- Conduct the same measurement after a set period (e.g. 2 month) and compare the values. Make sure to measure the same side of the stake as the previous survey. If the values are less than the previous survey, the area can be considered to be under sedimentation.

Alternatively, sedimentation may also be monitored by measuring the cross-section profile of the

lagoon mouth with auto level. However, this method will require a fixed reference point and certain level of expertise in conducting the measurements and will not be covered in this Guideline.

4.5 Water level

Long-term elevation of the lagoon water level may have adverse impacts on mangroves, by for example, constantly inundating the aerial roots and hindering their respiration. Water level is monitored by fixing a permanent stake inside the waterway, and then measuring the distance between the top of the stake and water surface (see Figure 2.4.12) at regular intervals (e.g. 2/month). A decrease in the distance between successive surveys will indicate that the water level is increasing. Note that this method is applicable only for mangrove sites where there is no tidal fluctuation, such as at the closed khawrs of Salalah (sample field sheet and database format is included in the attached CD).

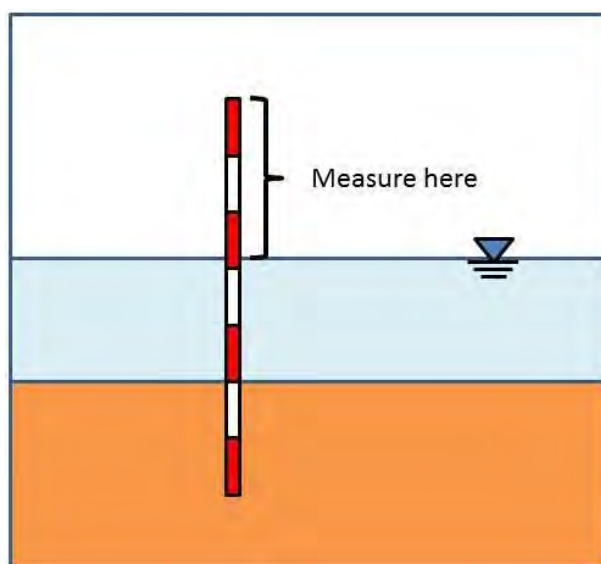


Figure 2.4.12 Measurement of water level with a permanent stake

5. Inspection monitoring

To supplement the monitoring surveys described in the preceding sections, regular visual inspection surveys should be conducted around the mangrove forest to identify of any presence of human or natural threats to the mangrove ecosystem. The frequency of inspection should be at least every 2 months. Following are among others some of the threats that should be checked through visual inspection:

- Grazing of mangrove tree by domestic animals (e.g. camels, goats, donkeys)
- Entanglement of waste on mangrove tree
- Wastewater discharge
- Illegal fishing
- Intrusion of invasive plant species
- Overgrowth and entanglement of algae on mangrove tree
- Water stagnation

The inspector should walk around the forest recording its route using GPS tracking function. If any threats are identified, the inspector should record the type of threat and GPS location into a field sheet (sample field sheet is included in the attached CD). Photographs should also be taken at the site. Once the inspection is completed, the identified threats, photographs and inspection route should be recorded into database (sample database format is included in the attached CD).

Chapter 3 Transplanted-seedling Monitoring Program

1. Introduction

The main objective of the “Transplanted-seedling Monitoring Program” is to monitor the growth and health status of the transplanted seedlings, and if unhealthy seedlings are identified, to implement protective measures by investigating possible causes. In addition, the data and findings obtained through the monitoring activities should be referred to increase the success rate of future transplantation activities. The monitoring program consists of the following components:

- Monitoring of seedling growth
- Monitoring of seedling health
- Monitoring of environmental condition

Monitoring should be conducted as frequently as possible (e.g. 1/month) and continued until the seedlings are considered to have stabilized in the new environment (e.g. confirmation of aerial roots). The ensuing Sections provide detailed methodologies on the monitoring program (sample field sheet is included in the attached CD).

2. Monitoring method

2.1 Selection of monitoring seedling

Since it is impractical to monitor all the transplanted seedlings, monitoring activities should focus on representative areas of the transplantation site. Once the area is selected, establish a quadrat around the target seedlings as shown in Figure 3.2.1. The size and shape of the quadrat should be determined in accordance to the configuration of the transplantation. The boundary of the quadrat should be marked for example by installing permanent stakes at the corners of the quadrat and then connecting them with a rope. Record the GPS coordinates of the quadrat so that the location can be identified in the ensuing survey.

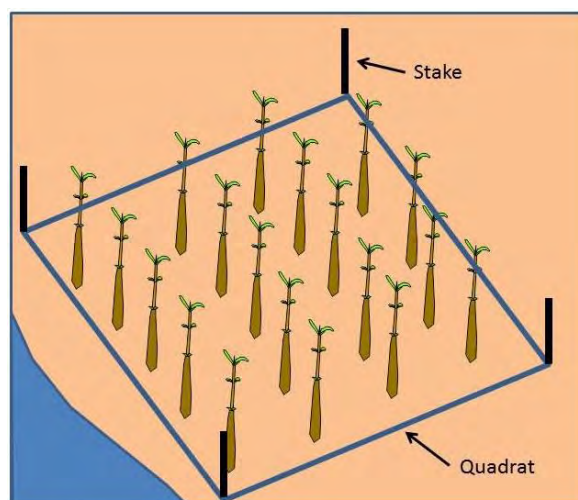


Figure 3.2.1 Establishment of monitoring quadrat

2.2 Monitoring method of seedling growth

The growth of the seedlings is monitored by measuring stem height, stem diameter and number of leaves. Following are the basic monitoring procedures:

- Select the seedlings to be monitored within the quadrat. The selected seedlings should be sufficient in quantity (e.g. more than 10% of the total) and evenly distributed (see Figure 3.2.2). Tag the selected seedlings by using a numbered tag and cable tie. Do not tie the tags too tight as it will stress the stem.

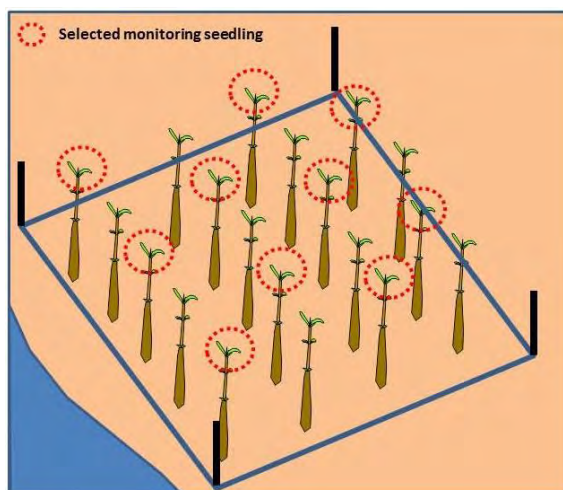


Figure 3.2.2 Example of monitoring seedling selection

- Measure the stem height and diameter of the selected seedlings as shown in Figure 3.2.3.

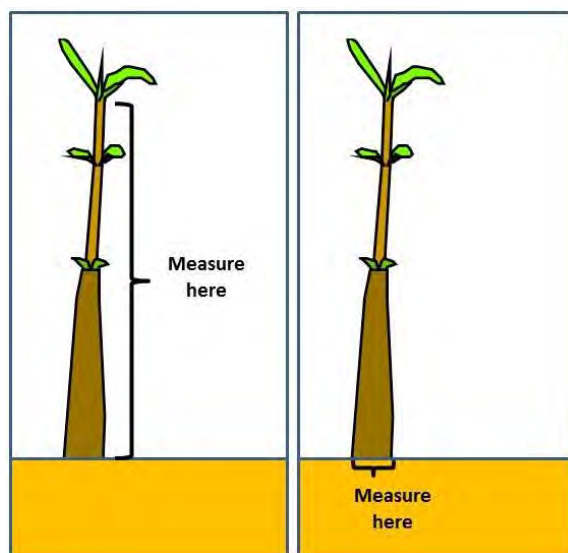


Figure 3.2.3 Measurement of stem height (left) and diameter (right)

2.3 Monitoring method of seedling health

Seedling health is monitored by visually estimating the ratio of unhealthy seedling (including dead seedlings) within the monitoring quadrat. Record the spatial trend of unhealthy seedlings into a field

sheet as shown in Figure 3.2.4. Take photographs of the quadrat for later reference. In general, an unhealthy seedling will have among others the following characteristics:

- Low leaf density
- Small and curled leaf shape
- Yellowish leaf color
- Stunted growth

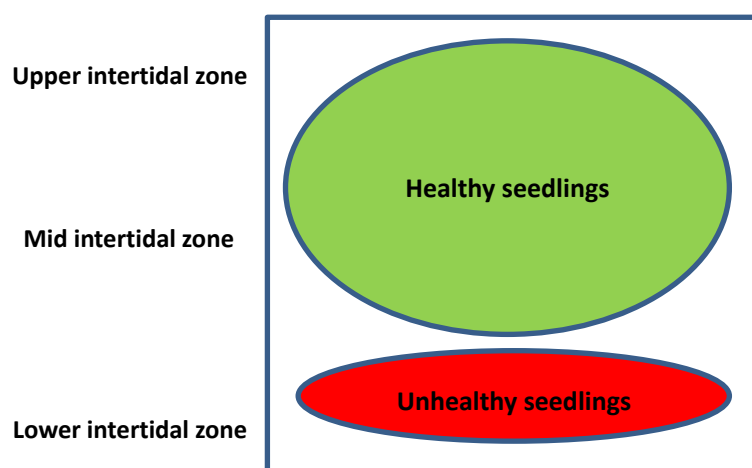


Figure 3.2.4 Example of spatial trend of unhealthy seedling

If unhealthy seedlings are found, the causes of unhealthiness should be investigated by considering its spatial trend (e.g. high rate of unhealthy seedling in the lower intertidal zone) and possible factors that can affect seedling health. Table 3.2.1 shows possible factors that can affect seedling health and investigation methods.

Table 3.2.1 Possible factors that can affect seedling health and investigation method

Stress factor		Investigation method
Lack of water supply	Lack of water supply may result in drying-up of soil and hence lack of water for the seedlings.	Observe whether the monitoring area becomes inundated by seawater during high tide. Also check whether the inlet mouth is not closed.
Lack of water exchange	Lack of water exchange may deteriorate water and soil conditions.	Observe whether the waters around the monitoring area recede at low tide. Also check whether the inlet mouth is not closed. If there is water stagnation, measures the DO concentration.
Soil erosion	Soil erosion may destabilize the seedlings.	Observe whether the roots of the seedlings are not exposed.
Infestation by insect pests and fungi	Insect pests can hinder growth for example by eating the leaves or sucking the sap.	Observe of any presence of insect pests on leaves and stem.
Entanglement of algae and garbage	Algae and garbage can stress the seedling by getting entangled around the stem.	Observe if algae and garbage is not entangled around the stem.
Intrusion of other plant species	Intrusion of other plant species (e.g. halophytes) can stress the seedling.	Observe of any presence of halophytes.
Animal grazing	Animal grazing can stress the seedling by eating the leaves and branch.	Observe of any presence of grazing on leaves and branch as well as feces.
High salinity conditions	High water and soil salinity will hinder seedling growth.	Measure salinity of adjacent water and underlying soil (refer to Chapter 2 for measurement methods)
Low oxygen soil conditions	Hypoxic or anoxic soil conditions will hinder seedling growth.	Measure oxidation-reduction potential of the underlying soil (refer to Chapter 2 for measurement methods)

2.4 Monitoring method of environmental condition

In general, water and soil quality should be monitored. If possible, measure all the monitoring parameters covered in the “Mangrove Ecosystem Monitoring Program”. However, if that is difficult, try at least to monitor parameters that can be measured *in situ* with portable meters. Topography and water level should also be monitored if considered necessary.

2.5 Necessary field survey equipment

- GPS
- Camera
- Field sheet/clipboard
- Stake/rope/hammer
- Tag and cable tie
- Tape measure and caliper
- DO meter
- Soil sampler
- Distilled water

- Measuring cylinder
- ORP meter
- Salinity meter or refractometer

2.6 Management of monitoring data

The monitoring data should be stored into a database, which should include the following information (sample database format is included in the attached CD):

- Site information (location and characteristics of the monitoring sites)
- Survey conditions (date, time, weather, tide level etc.)
- Results of stem height and diameter measurement
- Results of seedling health survey and possible stress factors
- Photographs of the surveyed quadrat

Appendix 1

Guidelines for Mangrove Health Assessment using Remote Sensing

Appendix 1 Guidelines for Mangrove Health Assessment using Remote Sensing

Appendix 1 Guidelines for Mangrove Health Assessment using Remote Sensing

Table of Contents

1.	Introduction.....	1
2.	Available satellite imagery.....	1
2.1	Landsat satellites	1
2.2	High-resolution satellites.....	2
3.	Basic functions of ENVI.....	2
3.1	Loading a grayscale or color images.....	3
3.2	Displaying the cursor location and value	4
3.3	Displaying image profiles.....	5
3.4	Performing quick contrast stretching.....	5
3.5	Displaying interactive scatter plots	5
3.6	Linking two displays.....	6
3.7	Dynamic overlays.....	6
3.8	Annotating the image	6
3.9	Adding Grid Lines.....	9
3.10	Saving and outputting an image.....	9
4.	Procedures for mangrove health assessment	10
4.1	Color composite images	10
4.2	Georeferencing of images	12
4.3	Setting of boundary of study area and calculation of surface area.....	15
4.4	Calculation of Normalized Difference Vegetation Index	19
4.4	Comparison of NDVI values	21
5.	Conclusion	27
6.	References.....	28

Appendix 1 Guidelines for Mangrove Health Assessment using Remote Sensing

Appendix 1 Guidelines for Mangrove Health Assessment using Remote Sensing

1. Introduction

Remote sensing and geographical information system (GIS) have emerged as invaluable technologies for ecosystem analysis, evaluation, and monitoring. They have been used worldwide in several projects dealing with prioritizing and analyzing resource management alternatives including the monitoring of mangrove.

As part of the Qurm Environmental Information Center (QEIC) project by the Ministry of Environment and Climate Affairs (MECA) and Japan International Cooperation Agency (JICA), remote sensing technology (satellite image) was considered as an effective method for monitoring and assessment of the health status of mangrove forests in Oman.

While there are various approaches for monitoring mangrove forest, this Guideline focuses on the use of Normalized Difference Vegetation Index (NDVI), which is a common index of vegetation health. In general, high NDVI value will indicate healthy vegetation but there is no established threshold value to differentiate healthy and unhealthy mangrove. The health status will therefore be assessed by comparing the NDVI values between target and baseline years. In other words, a decrease in the NDVI value from the baseline year may imply that the mangrove forest is in a degraded state. Moreover, since mangroves have seasonal variation in health, it is preferable to compare images between the same seasons. Ground-truth works will also be important to verify the results.

The Guideline explains the basic assessment procedures by using the image processing software, ENVI and satellite images of Qurm Nature Reserve (October 2011 and September 2012). Therefore, the prerequisite for using this Guideline is fundamentals of remote sensing and familiarity with the use of ENVI software. The Guideline also provides brief explanations on available satellite images and basic functions of ENVI.

2. Available satellite imagery

2.1 Landsat satellites

Landsat MSS with a spatial resolution of 80 m per pixel and four spectral bands was launched by the United States Space and Administration Agency (NASA) in 1972. Landsat TM with an improved spatial and spectral resolution was launched in 1984. Landsat 1 to 3 were equipped with the MSS sensor whereas Landsat 4 and 5 had TM sensors. Landsat 7, which was launched on April 15, 1999, and still active, has the ETM+ sensor. Landsat 8 was launched on February 11, 2013. Landsat 8 carries a ETM+ sensor, a new band 9 for cirrus cloud detection and two thermal bands 10 and 11 with spatial resolution of 100 m. Landsat TM and ETM+ sensors are multispectral radiometers capable of providing medium-resolution images of the Earth's surface in spectrally filtered radiation at the visible, near-infrared, short-wave infrared, and thermal-infrared wavelengths. For Landsat TM, the nominal pixel resolution is 30 m in the six visible, near and short-wave infrared bands. However, the thermal-infrared band has a spatial

Appendix 1 Guidelines for Mangrove Health Assessment using Remote Sensing

resolution of 120 m in the TM, and 60 m in the ETM+ sensors, respectively. In addition, the ETM+ carries a 15 m panchromatic band. A typical TM and ETM+ scene is 185 by 185 km. Orthorectified Landsat MSS, TM and ETM+ images data are freely available and can be downloaded from the internet (<http://earthexplorer.usgs.gov>).

2.2 High-resolution satellites

Commercial satellite companies launched sub meter ground resolution satellites following the deregulation by the United States Government in the 1990s. The first commercial satellite, Ikonos, with one meter resolution in panchromatic and 4 m multispectral was launched by Space Imaging in 1999. Since then a range of high-resolution satellites have been launched notably QuickBird, GeoEye, WorldView and KOMPSAT. GeoEye, launched by Digitalglobe on September 6, 2008 is highest available commercial satellite with a ground resolution of 41 cm in panchromatic and 1.65 m in four multispectral bands in the visible and near-infrared wavelengths (Table 1).

Table 1 Characteristics of GeoEye spectral bands

Sensor	Spectral bands	Wavelength (μm)
GeoEye 1-2	Panchromatic	0.450-0.900
	Band 1 (Blue)	0.450-0.520
	Band 2 (Green)	0.529-0.600
	Band 3 (Red)	0.625-0.695
	Band 4 (Near-infrared)	0.760-0.800

3. Basic functions of ENVI

There are several available commercial and free software for digital image processing of remote sensing data. The analysis in this Guideline is based on ENVI, which is one the leading commercial image processing software.

ENVI software provides a WINDOWS-NT based environment with an intuitive point-and-click graphical user interface. Most functions in ENVI are assessed through icons, pull down and form menus, where text dialog boxes, buttons and scroll bars make it simple to set all parameters before a function is applied to a displayed image. Help documents, tour and field guides are available for further information. Some selected basic functions are described below. Refer to the ENVI tutorial ENVI_intro.pdf (ENVI, 2003) for more details. A file named Qurm-GeoEye-sept-18-2012.dat which is GeoEye satellite image of the Qurm National Park area recorded on September 18, 2012 is used in the illustrations below. The step-by-step instructions below are taken from ENVI tutorials (ENVI, 2003) and the online ENVI Help.

3.1 Loading a grayscale or color images

1) Grayscale Image

Opening an Image File:

- From the ENVI main menu bar, select File > Open Image File.
- Navigate to the Qurm-GeoEye-sept-18-2012.dat file and click Open



The list of available GeoEye bands is provided as shown in the above figure.

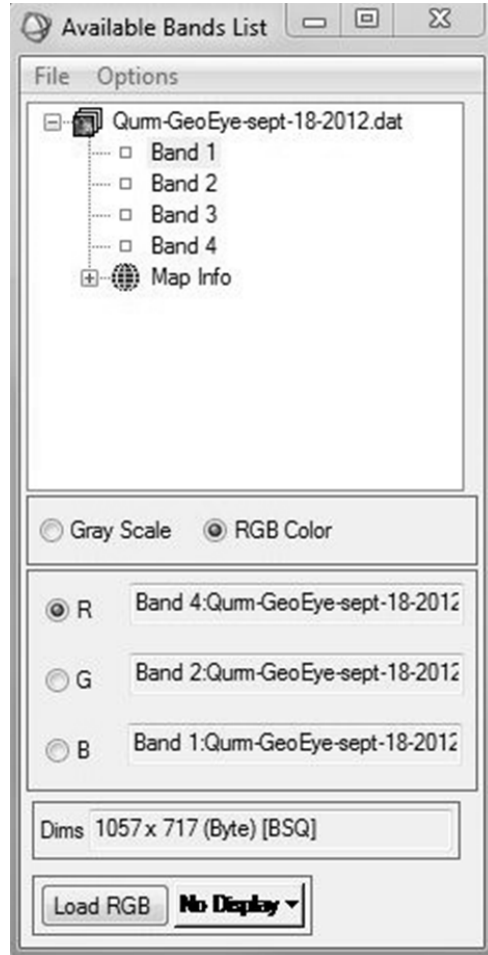
- Select Band 1. The band you have chosen is displayed in the field marked Selected Band.
- Click the Gray Scale radio button then click Load Band to load the image into a new display. Band 1 will be loaded as a grayscale image.

2) Color Image

- To display **GeoEye band 421 in RGB** from a Qurm-GeoEye-sept-18-2012.dat.
- Click the **RGB Color** radio button, then select **Band 4** Qurm-GeoEye-sept-18-2012.dat. The band you have chosen is displayed in the field marked R (see figure below)
- Select **Band 2**. The band you have chosen is displayed in the field marked G.
- Select **Band 1**. The band you have chosen is displayed in the field marked B.

Appendix 1 Guidelines for Mangrove Health Assessment using Remote Sensing

- Click **Display #1** and select **New Display**.
- Click **Load RGB** to load the image into a new display.



3.2 Displaying the cursor location and value

- To display the cursor location and value, select **Window >Cursor Location/Value** from either the ENVI main menu bar or the Display group menu bar. You can also right-click in the Image window and select **Cursor Location/Value**.
- Move the mouse cursor over the Image, Scroll, or Zoom windows to display location and value information in the Cursor Location/Value dialog.
- Double-click in the Image window to hide the Cursor Location/Value dialog. Double-click again to show the Cursor Location/Value dialog.
- From the Cursor Location/Value menu bar, select **File >Cancel** to close the dialog.

3.3 Displaying image profiles

- From the Display group menu bar, select **Tools > Profiles > X Profile** to display a window plotting data values versus sample number for a selected line in the image.
- From the Display group menu bar, select **Tools > Profiles > Y Profile** to display a plot of data value versus line number.
- From the Display group menu bar, select **Tools > Profiles > Z Profile** to display a spectral plot. You can also open a Z profile from the right-click menu in any **Image** window.
- From the Display group menu bar, select **Window > Mouse Button Descriptions** to view the descriptions of the mouse button actions in the Profile displays.
- A red crosshair extends to the top and bottom and to the sides of the Image window. The red lines indicate the line or sample locations for the vertical or horizontal profiles. Move the crosshair around the image (just as you move the Zoom box) to see the three image profile plots update to display data on the new location.
- Close the profile plots by selecting **File > Cancel** from the menu bar within each window.

3.4 Performing quick contrast stretching

You can perform quick contrast stretches using default parameters and data from either the Image window, the Zoom window, or the Scroll window.

- From the Display group menu bar, select **Enhance** and apply various contrast stretches (Linear, Linear 0-255, Linear 2%, Gaussian, Equalization, and Square Root).
- Compare the effects of the various stretches on the display group.

3.5 Displaying interactive scatter plots

You can plot the data values of two selected image bands versus each other in a scatter plot to graphically display the overlapping values.

- From the Display group menu bar, select **Tools > 2D Scatter Plots**. The Scatter Plot Band Choice dialog appears, allowing you to choose the two image bands to compare.
- Select one band for the x axis and another band for the y axis and click **OK**. It may take a few seconds for ENVI to extract and tabulate the data values.
- Once the scatter plot has appeared (see image right), position the mouse cursor anywhere in the Image window and drag with the left mouse button pressed. Pixel values contained in a ten-pixel by ten-pixel box surrounding the crosshair will be highlighted in red on the scatter plot.
- From the Display group menu bar, select **Window > Mouse Button Descriptions** to display the functions of the different mouse button actions when applied in the Scatter Plot display.
- Click and drag the cursor around in the Image window to observe the dancing pixels effect.

3.6 Linking two displays

Link the two displays together for comparison. When you link two displays, any action you perform on one display (scrolling, zooming, etc.) is echoed in the linked display. To link the two displays on your screen, do the following.

- From the Display group menu bar, select **Tools > Link > Link Displays**. You can also right-click in the Image window and select **Link Displays**.
- Click **OK** in the Link Displays dialog to establish the link.
- Scroll and zoom in one display group and observe as your changes are mirrored in the second display.

3.7 Dynamic overlays

ENVI's multiple dynamic overlay feature allows you to dynamically superimpose parts of one or more linked images onto another image. Dynamic overlays are turned on automatically when you link two displays, and may appear in either the Image window or the Zoom window.

- Click the left mouse button in one of the Image windows to see the image displays overlaid on one another.
- To create a smaller overlay area, position the mouse cursor anywhere in either Image window (or Zoom window) and hold down and drag with the **middle mouse button**. Upon button release, the smaller overlay area is set and a small portion of the linked image will be superimposed on the current Image window.
- Click the left mouse button in the Image window and drag the small overlay window around the image to see the overlay effects.
- Resize the overlay area at by clicking and dragging the middle mouse button until the overlay area is the desired size.

3.8 Annotating the image

ENVI's flexible annotation features allow you to add text, polygons, color bars, and other symbols to your plots and images. The Annotation Text dialog allows you to choose from a variety of annotation types. Different types are selected from the **Object** menu and include Text, Symbols, Rectangles, Ellipses, Polygons, Polylines, Arrows, Map Scale Bars and Declination Diagrams, Map Keys, Color Table Ramps, and Images. By default, the Annotation dialog starts up with Text selected. Other fields in the dialog let you control the size, color, placement, and angle of the annotation text. When you select different annotation types from the **Object** menu, the fields in the dialog change to display options appropriate to the new type.

- From the Display group menu bar, select **Overlay > Annotation**.
- Type some text in the text field of the Annotation Text dialog.

Appendix 1 Guidelines for Mangrove Health Assessment using Remote Sensing

- Select a font, font size, and color using the fields provided in the dialog, then position the mouse pointer in the Image window and click the left mouse button. Your text is displayed in the window at the point you clicked.
- Using the left mouse button, drag the handle (displayed in the image below as a diamond shape to the left, bottom of the text) to position the text in the window.
- You can continue to change the annotation's properties and position by changing the fields in the dialog box or dragging the text or symbol while holding down the left mouse button. When you are satisfied with the annotation, click the right mouse button to fix the annotation in position.



Appendix 1 Guidelines for Mangrove Health Assessment using Remote Sensing



- You can save your image annotation by selecting **File>Save Annotation** from the Annotation Text dialog menu bar. If you do not save your annotation in a file, it will be lost when you close the Annotation Text dialog (you will be prompted to save the annotation if you close without first saving). You can also restore saved annotation files by selecting **File> Restore Annotation** from the Annotation Text dialog menu bar.
- To edit an annotation element that has already been set in the image, select **Object>Selection/Edit** from the Annotation Text dialog menu bar.
- Draw a box around the annotation you wish to edit by clicking and dragging with the left mouse button. When the handle reappears, click and drag the handle and annotation to move and configure the item just as you would a new annotation.
- To suspend annotation operations and return to normal ENVI functionality temporarily, select the **Off** radio button at the top of the Annotation Text dialog. This allows you to use the scroll and zoom features in your display without losing your annotations. To return to the annotation function, select the radio button in the Annotation Text dialog for the window you are annotating.
- Leave your annotation on the Image window as you complete this tutorial

3.9 Adding Grid Lines

You can use grid lines to overlay one or more grids on an image. Grids can be pixel-based or map-coordinate and/or latitude/longitude based (for georeferenced images). Each image display can have its own set of grids, which are displayed in the Image, Scroll, and Zoom windows.

- From the Display group menu bar, select **Overlay > Grid Lines** to open the Grid Line Parameters dialog box. As soon as you choose this option, an image border is automatically added.
- You can adjust the grid line attributes by setting the line thickness and color and the grid spacing by selecting **Options > Edit Pixel Grid Attributes** from the Grid Lines Parameters dialog menu bar. This selection brings up the Edit Pixel Attributes dialog box.
- In the Edit Pixel Attributes dialog, you can change the color, thickness and grid spacing for the labels, lines, box and corners of the grid. When the attributes are set up to your satisfaction, click **OK** in the Edit Pixel Attributes dialog to apply the changes to the grid on the images.
- When you have added a satisfactory grid, click **Apply** in the Grid Line Parameters dialog.

3.10 Saving and outputting an image

ENVI gives you several options for saving and outputting your filtered, annotated, gridded images. You can save your work in ENVI's image file format, or in several popular graphics formats (including Postscript) for printing or importing into other software packages. You can also output directly to a printer.

- From the Display group menu bar, select **File > Save Image As > Image File** to save your work in ENVI's native format (as an RGB file). The Output Display to Image File dialog appears.
- Select **24-Bit color** or **8-Bit grayscale** output.
- Click the **Change Graphic Overlay Selections** to select graphics options (including annotation and gridlines)
- Set border options.
- Select output to **Memory** or **File** using the desired radio button. If output to **File** is selected, enter an output filename.
- If you select other graphics file formats from the **Output File Type** drop-down which, by default is set to ENVI, your choices will be slightly different.
- Click **OK** to save the image. This process saves the current display values for the image, not the actual data values.

4. Procedures for mangrove health assessment

4.1 Color composite images

Satellite image color composites using the visible and infrared bands can be used in field mapping as well as visual assessment of the health of mangrove forests. Color composites incorporating the near-infrared are most useful because of the high reflectance of healthy vegetation in that region compared to the visible. Figs. 1 and 2 show the GeoEye color composites generated from bands 3, 2, and 1 and from bands 4, 2, and 1 acquired on September 18, 2012. In Fig. 2 the near-infrared, band 4, was projected through a red filter and consequently vegetation shows up in shades of red. Figs 3 and, 4 show similar GeoEye image recorded on October 11, 2011.



Fig. 1. GeoEye band 3, 2, and 1 color composite image of Qurm mangrove and surrounding areas recorded on September 18, 2012.

Appendix 1 Guidelines for Mangrove Health Assessment using Remote Sensing



Fig. 2. GeoEye band 4, 2, and 1 color composite image of Qurm mangrove and surrounding areas recorded on September 18, 2012.



Fig. 3. GeoEye band 3, 2, and 1 color composite image of Qurm mangrove and surrounding areas recorded on October 11, 2011.



Fig. 4. GeoEye band 4, 2, and 1 color composite image of Qurm mangrove and surrounding areas recorded on October 11, 2011.

4.2 Georeferencing of images

An important component to change detection or multitemporal data analysis is radiometric calibration and geometric corrections. The images used in this study were georeferenced to the UTM zone 40 and WGS84, the projection used by the National Survey Authority of Oman, to facilitate their comparisons and to map changes between the two dates. In general a registration of error of less than half of a pixel is accepted. The step-by-step instructions below are taken from ENVI tutorial and online ENVI Help.

ENVI's image registration and geometric correction utilities allow the user to reference pixel-based images to geographic coordinates and/or correct them to match base image geometry. Ground control points (GCPs) are selected using the Image and Zoom windows for both image-to-image and image-to-map registration. Coordinates are displayed for both base and uncorrected image GCPs, along with error terms for specific warping algorithms. Next GCP point prediction allows simplified selection of GCPs.

Warping is performed using resampling, scaling and translation (RST), polynomial functions (of order 1 through n), or Delaunay triangulation. Resampling methods supported include nearest-neighbor, bilinear interpolation, and cubic convolution. Comparison of the base and warped images using ENVI's multiple dynamic overlay capabilities allows quick assessment of registration accuracy.

Appendix 1 Guidelines for Mangrove Health Assessment using Remote Sensing

Use **Select GCPs: Image-to-Map** to select GCPs for image-to-map registration. Use the Zoom window to select GCPs. (Image-to-map registration requires you to display at least one image.) When selecting GCPs, you can select subpixel coordinates. Choose to enter corresponding map coordinates manually, from a Vector window, from a base image, or from a GPS link. When you select enough points to define a warp polynomial, you can begin to predict GCP locations in the warp image. You can save and restore GCPs to and from files, and you can change the color labels and order of the GCP markers. See Warping and Resampling for descriptions of the warping methods.

- Open the image file and display the desired band.
- From the ENVI main menu bar, select **Map > Registration > Select GCPs: Image to Map**. The Image to Map Registration dialog appears.
- If you have more than one image open, select the display group to use from the **Input Display** drop-down list. If only one image is displayed, it is automatically selected.
- In the **Select Registration Projection** list, select the output projection or enter a custom projection type.
- Click **OK**. The Ground Control Points Selection dialog appears.

Collecting Ground Control Points (Image-to-Map)

The procedure for selecting GCPs is similar to that for image-to-image registration.

- In the Image window, position the Zoom box over the desired GCP area.
- In the Zoom window, left-click on a specific pixel to position the cursor over that pixel or portion of that pixel. The coordinates of the selected location appear in the Ground Control Points Selection dialog in the **Image X** and **Image Y** fields. Subpixel coordinates are supplied to provide higher accuracy in selecting GCPs.
- Select from the following options:
 - o Enter GCPs from a base image.
 - o Automatically enter map coordinates from vector data.
 - o Automatically enter map coordinates from GPS locations.
 - o To enter map coordinates from a paper map, enter the easting and northing (or latitude/longitude) of the selected GCPs into **E** and **N** fields, respectively.
 - o To enter the map GCP location from a paper map in latitude and longitude, click the toggle button next to the map projection name and enter the values into the **Lat** and **Long** fields.
Use negative (-) longitude for the western hemisphere and negative (-) latitude for the southern hemisphere.
 - o To change the latitude and longitude values to degrees, minutes, and seconds, click **DMS**. To use decimal degrees, click **DDEG**.
 - o To return to map projection coordinates, click the projection toggle button.
The corresponding map projection coordinates are calculated automatically.
- When you select a desired pixel in the image and enter the map coordinates, click **Add Point** in the Ground Control Points Selection dialog to add the point to the list of GCPs. To

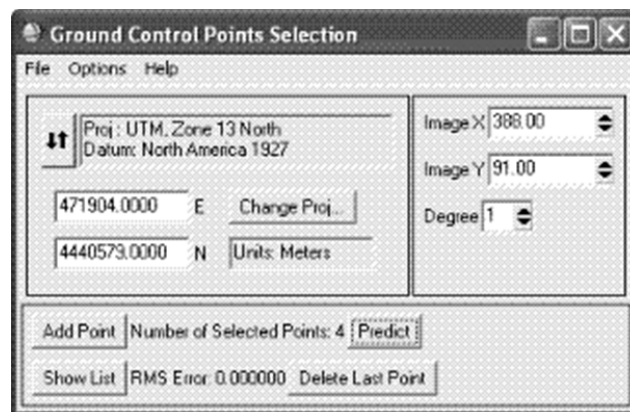
Appendix 1 Guidelines for Mangrove Health Assessment using Remote Sensing

view the Image to Map GCP List, click **Show List**. The Image to Map GCP List appears with the GCPs listed in a table.

When you add a GCP, a marker is placed in the image, which consists of an ID number next to an encircled crosshair. The marker indicates the selected pixel (or subpixel location). The center of the marker (located under the crosshair) indicates the actual GCP location.

When you select GCPs from a Vector window, ENVI also places a marker in the Vector window. The marker consists of an ID number of the GCP displayed with a +.

- Add additional GCPs using the same procedure. When you enter enough points, the Image to Map GCP List shows the predicted x,y coordinates for the selected warp, the x,y error, and the RMS error.



- The Ground Control Points Selection dialog shows the number of GCPs you selected. When you select a sufficient number of GCPs to conduct a first-degree polynomial warp, the total RMS error is also displayed.

Tip: For the best registration, try to minimize the RMS error by refining the positions of the pixels with the largest errors or by removing them. You can reduce errors by adding more points. If you only have a few points, place them near the image corners or widely scatter them throughout the image. For details about editing, predicting, and positioning GCPs, see GCP Options. For details about managing GCPs, see Managing GCPs.

Entering GCPs from a Base Image

If you have two files containing the same scene and one of the files contains map coordinate data, you can use that file as a base image and add GCPs to the image that is not georeferenced.

- Open and display a georeferenced image. This is the base image.
- Open and display a like image that is not georeferenced.
- From the ENVI main menu bar, select **Map > Registration > Select GCPs: Image to Map**. The Image to Map Registration dialog appears.

Appendix 1 Guidelines for Mangrove Health Assessment using Remote Sensing

- Select the non-georeferenced image as the **Input Display** and enter projection information. Click **OK**. The Ground Control Points Selection dialog appears.
- In the Image window of the georeferenced image, right-click and select **Pixel Locator** to open the Pixel Locator dialog.
- In the Zoom window of the georeferenced image, left-click on a specific pixel to position the cursor over that pixel or portion of that pixel. The coordinates of the selected location display in the Pixel Locator dialog, in sample and line order.
- In the Zoom window of the non-georeferenced image, select the same pixel.
- When you select the desired pixel in both images, click **Export** in the Pixel Locator dialog. The pixel information is exported to the Ground Control Points Selection dialog.
- In the Ground Control Points Selection dialog, click **Add Point**. The GCP is added to the non-georeferenced image.
- Add additional GCPs by following the same procedure.

Entering Map GCPs from Vector Windows

If you have a vector file for the area to map-register, you can extract the map coordinates directly from the vector data and load them into the Ground Control Points Selection dialog.

- Select GCPs from the displayed image.
- Load the vectors into a Vector window and use the vector cursor positioning capabilities (left-click) to locate a feature corresponding to the feature selected on the image.
- At the bottom of the Vector Parameters dialog, click **Export** to enter the map coordinates of the vector cursor directly into the Ground Control Points Selection dialog, or select **Export Map Location** from the Vector window right-click menu.
- In the Ground Control Points Selection dialog, click **Add Point** to enter the selected point into the registration.

Saving GCPs as Vector Files

To save the GCP points and all the associated information and attributes as an ENVI vector file, in the Available Vectors List, select the new registration's GCP vector layer, and select **File > Save Memory Layers to File** from the Ground Control Points selection dialog menu bar.

Warping Options

To use the GCPs to perform registration, select either **Options > Warp Displayed Band** or **Options > Warp File** from the Ground Control Points selection dialog menu bar. The Registration Parameters dialog appears.

4.3 Setting of boundary of study area and calculation of surface area

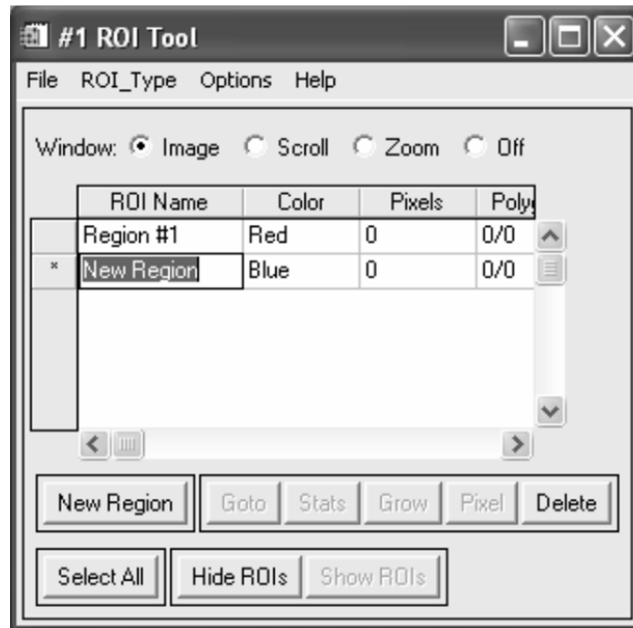
It is essential to know the general boundary and surface area of the mangrove forest and the other surfaces and how they change over time. Two techniques used by ENVI for surface area calculation as well as the boundary of the forest area is described below.

Use of Regions of Interest (ROIs)

ENVI lets you define regions of interest (ROIs) in your images. ROIs are typically used to extract statistics for classification, masking, and other operations.

- From the Display group menu bar, select **Overlay > Region of Interest**, or right-click in the Image window and select **ROI Tool**.
- Draw a polygon that represents the region of interest by clicking the left mouse button in the Image window to establish the first point of the ROI polygon then selecting further border points in sequence by clicking the left button again. Close the polygon by clicking the right mouse button, then accept the polygon by clicking the right mouse button again. The middle mouse button deletes the most recent point, or (if you have closed the polygon) the entire polygon.
- ROIs can also be defined in the Zoom and Scroll windows by selecting the appropriate window radio button in the ROI Tool dialog.
- When you have finished defining an ROI, it is shown in the dialog table, with the name, region color, number of pixels enclosed, and other ROI properties.
- ROIs can also be defined as polylines or as a collection of individual pixels by selecting the desired ROI type from the ROI_Type pull-down menu in the ROI Tool.
- Click the **New Region** button.
- Select an ROI by clicking in a cell of the far left column of the ROI Tool table. An ROI is selected when its entire row is highlighted. An asterisk next to the row also signifies the currently active ROI. Multiple ROIs can be selected by using **Shift**-click or **Ctrl**-click. All the ROIs can be selected by clicking the **Select All** button. Click and type to edit the values in the cells of the ROI Tool table. Change the name for the region and select a new color.
- Hide ROIs by selecting them in the table and clicking the **Hide ROIs** button. Use the **Show ROIs** button to re-display these hidden ROIs.
- Go to an ROI in the ENVI display by selecting it and clicking the **Goto** button.
- View the statistics for one or more ROIs by selecting them in the table and clicking the **Stats** button.
- Grow an ROI to its neighboring pixels within a specified threshold by selecting it and clicking the **Grow** button.
- Pixelate polygon and polyline ROIs by selecting them in the table and clicking the **Pixel** button. Pixelated objects become a collection of editable points.
- Delete ROIs by selecting them in the table and clicking the **Delete** button.
- The ROI Tool table also allows you to view and edit various ROI properties, such as name, color, and fill pattern. Menu options available at the top of the ROI Tool dialog let you perform other various tasks, such as calculate ROI means, save your ROI definitions, and load saved definitions. ROI definitions are retained in memory after the ROI Tool dialog is closed, unless you explicitly delete them. ROIs are available to other ENVI functions even if they are not displayed.
- Close the ROI Tool using the menu at the top of the table, select **File > Cancel**.

Appendix 1 Guidelines for Mangrove Health Assessment using Remote Sensing



Measurement Tool

Measurement Tool can be used to get a report on the distance between points in a polygon or polyline, and to get perimeter and area measurements for polygons, rectangles, and ellipses.

- Select one of the following options:
 - o From the ENVI main menu bar, select **Basic Tools > Measurement Tool**.
 - o From the Display group menu bar, select **Tools > Measurement Tool**.
- The Display Measurement Tool dialog appears.
- In the **Display** field, enter the number of the display that you want to take measurements from.
- Select the radio button for the display group window (**Image, Scroll, Zoom**) in which you want to measure. To disable the measurement function at any time, select the **Off** radio button.
- From the Display Measurement Tool menu bar, select **Type > area_shape** you want to measure.
- From the Display Measurement Tool dialog menu bar, select **Units > unit_type**. If the pixel size of the image is not stored in the header, and you select any unit except **Pixels**, complete the following steps when the Input Display Pixel Size dialog appears:
 - o In the **X Pixel Size** and **Y Pixel Size** fields, type the size of the pixels in your image.
 - o From the **Units** drop-down list, select the unit type.
 - o Click **OK**.
- From the Display Measurement Tool dialog menu bar, select **Area > report_type** to specify measuring the area in **Units²** (for example, meters²), **Acres**, or **Hectares**. If you select **Acres** or **Hectares**, The Input Display Pixels dialog appears. Enter the **X/Y Pixel Size**, select the **Units** from the drop-down list, and click **OK**.

Appendix 1 Guidelines for Mangrove Health Assessment using Remote Sensing

- From the Display Measurement Tool dialog menu bar, select **Options >** unit_type to specify whether the measurement information is reported as line segments (the default) or as point coordinates. The options are:
 - o **Report as Points:** To produce a listing of the vertices coordinates. The coordinates are reported as a pixel location (**Pixel (x,y)**).
 - o **Report as Segments:** To produce a listing of the line segment distances.
 - o **Georef Map (x,y)** or **Georef (Lat/Lon):** For georeferenced images, you can produce a listing of the coordinates as either map coordinates or as latitude and longitude coordinates.
- In the display group window, left-click and draw the shape.
 - o For **Rectangle** or **Ellipse** type, left-click and hold the button and drag the shape to the size. To draw a square or circle, middle-click and hold the button and drag.
 - o Right-click to close the polygon or complete the line.
 - o For **Polygon** type, the distance between the vertices are listed and the perimeter and total area are reported when the polygon is closed.
 - o For **Polyline** type, the distance between the vertices are listed and the total distance is given when the polyline is completed.
 - o For **Rectangle** type, the lengths of the side segments, the perimeter, and the total area are reported.
 - o For **Ellipse** type, the circumference and total area are reported.
 - o To erase the shape, right-click again.

Vector overlays showing the general outline of the mangrove forest, wadi and water, and open flat or bare soil are depicted in Fig. 5. From the September 18, 2012 GeoEye image, the general mangrove area is 100.2 hectares, water and wadi within the mangrove is 21.89 hectares and open land or bare soil is 12.96 hectares. The total area of the actual mangrove forest is 65.37 hectares.



Fig. 5. GeoEye band 4, 2, and 1 color composite image of Qurm mangrove and surrounding areas recorded on September 18, 2012 with overlays showing the general area of the mangrove forest (white) wadi and water (green) and open flat or bare soil (brown).

4.4 Calculation of Normalized Difference Vegetation Index

NDVI (Normalized Difference Vegetation Index) values indicate the amount of green vegetation present in the pixel. It is one of the most frequently used index for vegetation analysis. Higher NDVI values indicate more green vegetation. ENVI's NDVI uses the standard algorithm:

$$NDVI = \frac{NIR - Red}{NIR + Red}$$

In areas with less than 20% vegetation cover, NDVI must be used with caution as the ratio may not show any sensitivity to vegetation abundance (Choudhury and Tucker 1987). NDVI can saturate in dense vegetation conditions when the leaf area index becomes high. The value of the index ranges from -1 to 1. The common range for green vegetation is 0.2 to 0.8.

- From the ENVI main menu bar, select **Transform > NDVI**. The Input File dialog appears.
- Select an input file and perform optional spatial subsetting, then click **OK**. The NDVI Calculation Parameters dialog appears.

Appendix 1 Guidelines for Mangrove Health Assessment using Remote Sensing

- Specify the **Input File Type** (TM, MSS, AVHRR, and so on) from the drop-down list. ENVI automatically enters the bands it uses to calculate the NDVI in the **Red** and **Near IR** fields. To calculate the NDVI for a sensor type not listed in the drop-down list, enter the band numbers in the **Red** and **Near IR** fields.
- Select output to **File** or **Memory**.
- Select one of the following output types from the **Output Data Type** drop-down list.
 - o **Byte**: Enter the **Min** and **Max** NDVI value in the fields supplied.
 - o **Floating Point**
- Click **OK**. ENVI adds the resulting output to the Available Bands List.

NDVI image of the September 18, 2012 and that of October 11, 2011 are portrayed in Figs.6 and 7.



Fig. 6. GeoEye NDVI image of Qurm mangrove and surrounding areas recorded on September 18, 2012.



Fig. 7. GeoEye NDVI image of Qurm mangroves and surrounding areas recorded on October 11, 2011.

4.4 Comparison of NDVI values

Several change detection techniques applied to satellite digital images have been used successfully. Some of these include image difference, ratioing, principal component analysis (PCA), and selective principal component analysis (Jensen and Toll, 1982; Singh, 1989, Chavez and Kwarteng 1989, Chavez and MacKinnon 1994, Kwarteng and Chavez, 1998). In this study, selective principal component was used to map changes between the two dates. The technique uses either two bands from the same image or one band from each of the two images as input to principal component analysis—a statistical technique that rotates the axes of a multidimensional image space in the direction of maximum variance. Two bands recorded on different dates were used as input to the PCA. The first component (PC1) maps information that is common to both images (topography and surface reflectance) whereas the second component (PC2) maps the temporal contrast between the input images (Chavez and Kwarteng, 1989; Kwarteng and Chavez, 1998). NDVI change image was generated from the second principal components (PC2) of GeoEye NDVI images recorded in 2011 and 2012.

Principal Components is used to produce uncorrelated output bands, to segregate noise components, and to reduce the dimensionality of data sets. Because multispectral data bands are often highly correlated, the principal components (PC) transformation is used to produce

Appendix 1 Guidelines for Mangrove Health Assessment using Remote Sensing

uncorrelated output bands. This is done by finding a new set of orthogonal axes that have their origin at the data mean and that are rotated so the data variance is maximized.

Principal component bands are linear combinations of the original spectral bands and are uncorrelated. You can calculate the same number of output PC bands as input spectral bands. The first PC band contains the largest percentage of data variance and the second PC band contains the second largest data variance, and so on. The last PC bands appear noisy because they contain very little variance, much of which is due to noise in the original spectral data. principal components bands produce more colorful color composite images than spectral color composite images because the data is uncorrelated. ENVI can complete forward and inverse PC rotations.

Calculating Forward PC Rotations using ENVI

The forward PC rotation uses a linear transform to maximize the variance of the data. When you use forward PC rotation, ENVI allows you to calculate new statistics or to rotate from existing statistics. You can save the output of either as byte, floating-point, integer, long integer, or double precision values. You also have the option to subset the output of the PC rotation based on eigenvalues, and to generate output of only the PC bands that you need.

Computing New Statistics and Rotating

Use **Compute New Statistics and Rotate** to calculate the eigenvalue and covariance or correlation statistics for your data and to calculate the forward PC rotation transform.

- From the ENVI main menu bar, select **Transform > Principal Components > Forward PC Rotation > Compute New Statistics and Rotate**. The Input File dialog appears.
- Select the input file and perform optional spatial and spectral subsetting, and/or masking, then click **OK**. The Forward PC Parameters dialog appears.
-

Note: If you have any bad bands in your dataset, you should use spectral subsetting to exclude them from PC analysis. When bad bands are set to the same values as adjacent bands, when they are interpolated from nearby bands, when they are set to a constant value, or when they contain zero variance or large outliers, a “singularity” problem is encountered where the band becomes a near-perfect linear combination of other bands. This may cause the “Too Many Iterations in TQLI” error message to appear when you calculate the forward PC rotation.

Click **Stats Subset** to calculate the statistics based on a spatial subset or the area under an ROI. The calculated statistics are applied to the entire file or to a spatial subset of the file. See Statistics Subsetting for details.

- Enter the **Stats X/Y Resize Factors** less than 1 in the appropriate fields to sub-sample the data when calculating the statistics. This increases the speed of the statistics calculations. For example, using a resize factor of 0.1 will use every 10th pixel in the statistics calculations.
- In the **Output Stats Filename [.sta]** field, enter a filename for the noise statistics.

Appendix 1 Guidelines for Mangrove Health Assessment using Remote Sensing

- Select whether to calculate the PCs based on the **Covariance Matrix** or **Correlation Matrix** using the toggle button. Typically:
 - o Use **Covariance Matrix** when calculating the principal components.
 - o Use **Correlation Matrix** when the data range differs greatly between bands and normalization is needed.
- If you applied a mask, enter a value for the output results in the **Output Mask Value** field. ENVI applies the mask for the statistics calculation and the masked areas of the output dataset are set to the entered mask value.
- Select output to **File** or **Memory**.
- From the **Output Data Type** drop-down list, select the data type of the output file.
- To use a subset from eigenvalues, use the **Select Subset from Eigenvalues** toggle button to select **Yes** or **No**.
- If you chose **No** to selecting a subset from eigenvalues, select the **Number of Output PC Bands**. The default number of output bands is equal to the number of input bands.
- Click **OK**.

If you chose **No** to selecting a subset from eigenvalues, ENVI performs the transform and adds the output to the Available Bands List. The PC Eigenvalues plot window also appears. For information on editing and other options in the Eigenvalue plot window, see Using Interactive Plot Functions.

If you chose **Yes** to selecting a subset from eigenvalues, the Select Number of Output Bands dialog appears. Each band is listed with its corresponding eigenvalue and the cumulative percentage of data variance contained in each IC band. Do the following:

- o Select the **Number of Output IC Bands**. IC Bands with large eigenvalues contain the largest amounts of data variance, while bands with lower eigenvalues contain less data information and more noise. Sometimes, it is best to output only those bands with large eigenvalues to save disk space.
- o Click **OK**. ENVI performs the transform and adds the output to the Available Bands List. The output IC rotation contains only the number of bands that you selected. For example, if you chose 4 as the number of output bands, only the first four IC bands appear in your output file.

Rotating from Existing Statistics

If you have already calculated covariance and eigenvalue statistics for your data, you can use them as input into the PC rotation. You can use any statistics file in the PC rotation that contains covariance and eigen statistics for the same number of bands as your input data. (You may have already calculated these statistics using the **Basic Tools > Statistics** option or during a previous PC rotation session.)

- From the ENVI main menu bar, select **Transform > Principal Components > Forward PC Rotation > PC Rotation from Existing Stats**. The Input File dialog appears.

Appendix 1 Guidelines for Mangrove Health Assessment using Remote Sensing

- Select an input file and perform optional spatial subsetting, and/or masking, then click **OK**. The Enter Statistics Filename dialog appears with all of the existing statistics files in the current input data directory listed, using the default file extension .sta.
- Select the statistics file. The Forward PC Parameters dialog appears.
- Select whether to calculate the PCs based on the **Covariance Matrix** or **Correlation Matrix** using the toggle button. Typically:
 - o Use **Covariance Matrix** when calculating the principal components.
 - o Use **Correlation Matrix** when the data range differs greatly between bands and normalization is needed.
- Select output to **File** or **Memory**.
- From the **Output Data Type** drop-down list, select the data type of the output file.
- Select the number of output PC bands by using one of the following options:
 - o To select the number of output bands without examining the eigenvalues, select **No** from the **Select Subset from Eigenvalues** toggle button, then set the **Number of Output PC Bands**.
 - o To select the number of output MNF bands by examining the eigenvalues, use the following steps:
 - A. Select **Yes** from the **Select Subset from Eigenvalues** toggle button.
 - B. Click **OK**. ENVI calculates the statistics and the Select Output PC Bands dialog appears, with each band listed with its corresponding eigenvalue. Also listed is the cumulative percentage of data variance contained in each PC band for all bands.
 - C. Set the **Number of Output PC Bands**. For the best results, and to save disk space, output only those bands with high eigenvalues. Images with eigenvalues close to 1 are mostly noise.
- Click **OK**. When ENVI finishes processing, the PC Eigenvalues plot window appears and the PC bands are added to the Available Bands List. For information on editing and other options in the Eigenvalue plot window, see Using Interactive Plot Functions.

Fig. 8 shows that the NDVI values of the mangrove acquired on September 18, 2012 is between 0.3-0.6. The NDVI image recorded on October 11, 2014 show slightly higher values from 0.3 to 0.7 (Fig. 9) than the September 20 2012 image. The NDVI change image portrays insignificant changes between 2011 and 2012 (Fig 10). In the forest area the changes are between -0.1 and 0.1

Appendix 1 Guidelines for Mangrove Health Assessment using Remote Sensing

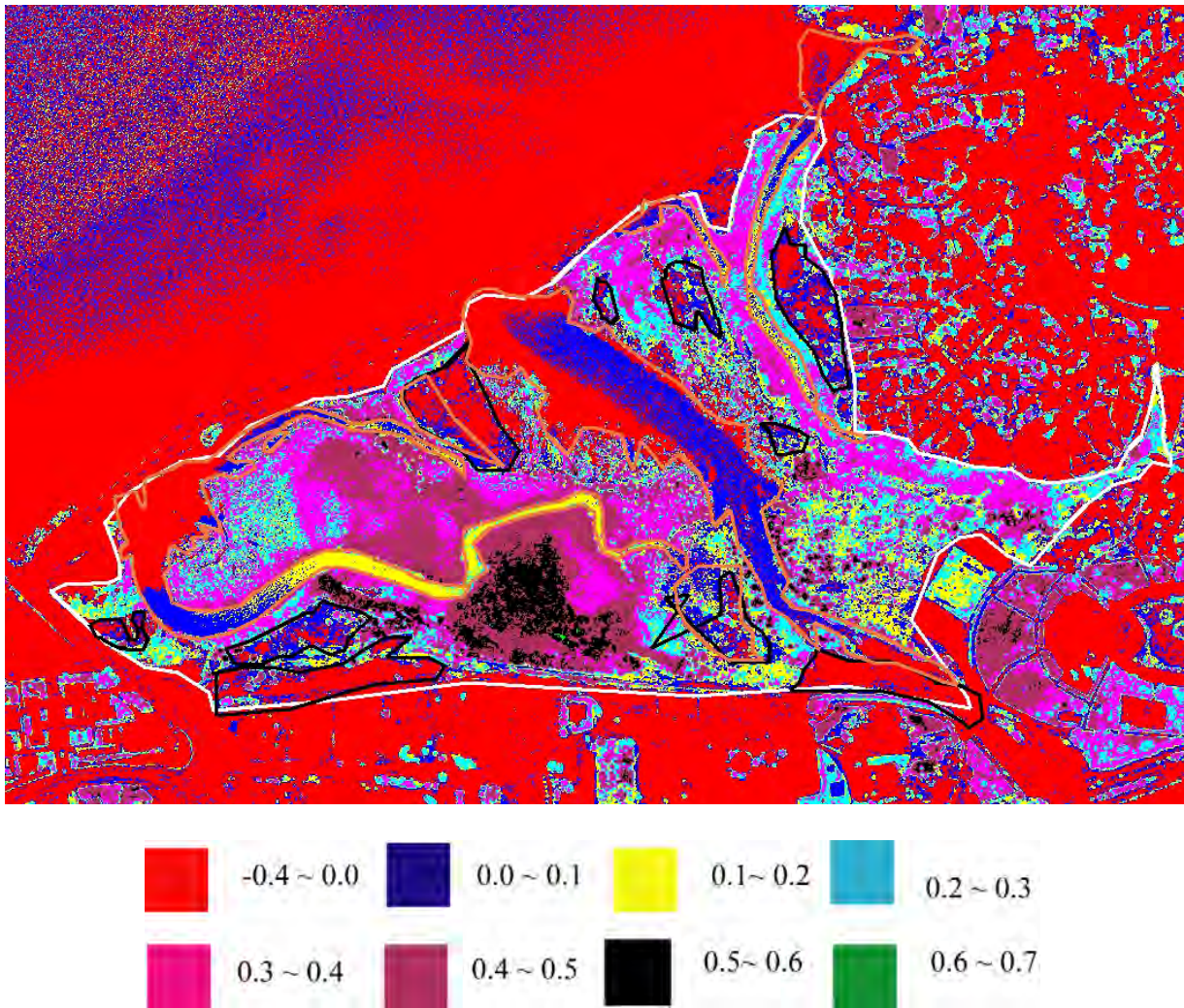


Fig. 8. GeoEye NDVI image of Qurm mangrove acquired on September 18, 2012 showing NDVI ranges. The overlays show the general area of the mangrove forest (white) wadi and water (brown) and open flat or bare soil (black).

Appendix 1 Guidelines for Mangrove Health Assessment using Remote Sensing

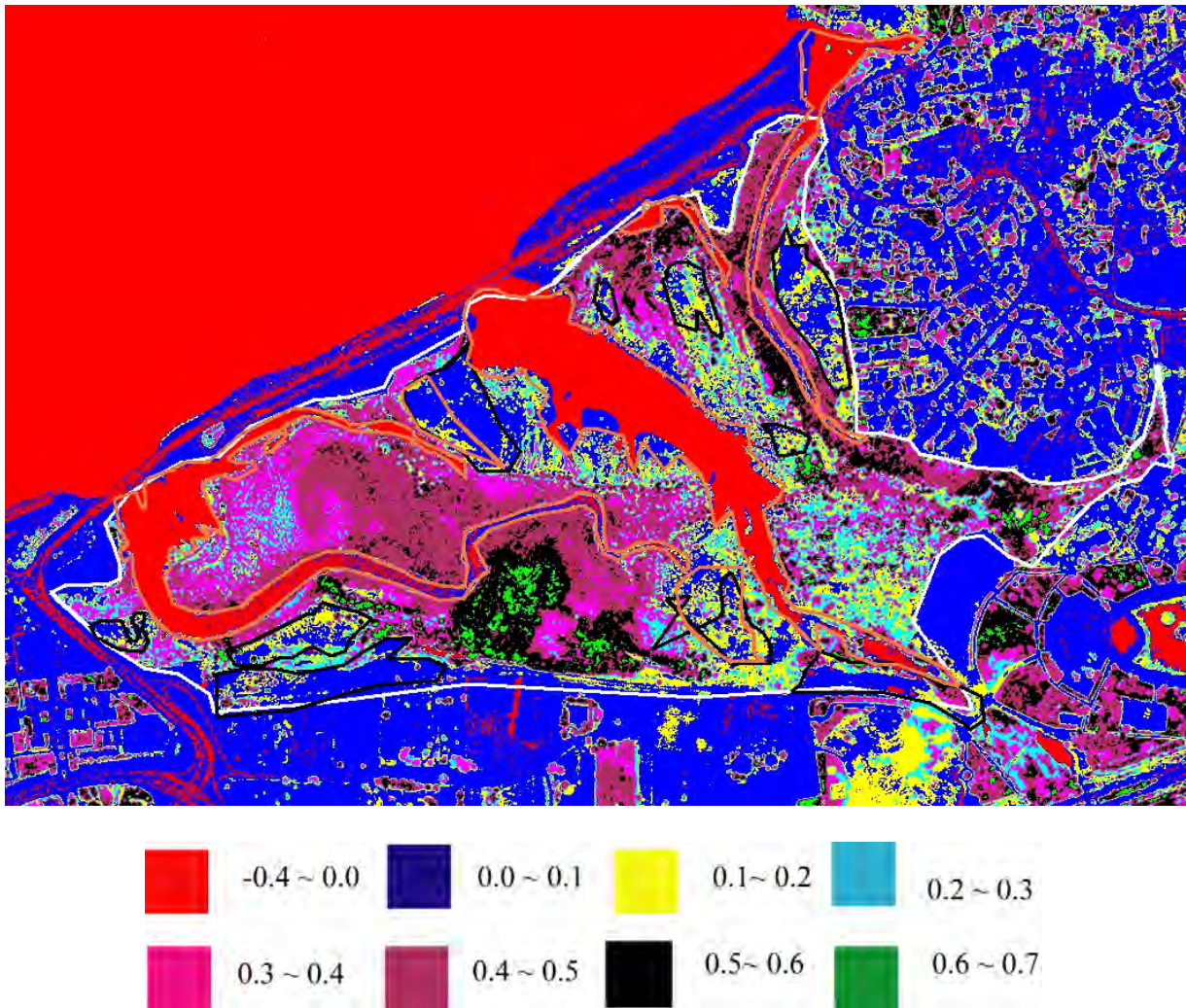


Fig. 9. GeoEye NDVI image of Qurm mangrove acquired on October 11, 2011 showing NDVI ranges. The overlays show the general area of the mangrove forest (white) wadi and water (brown) and open flat or bare soil (black)

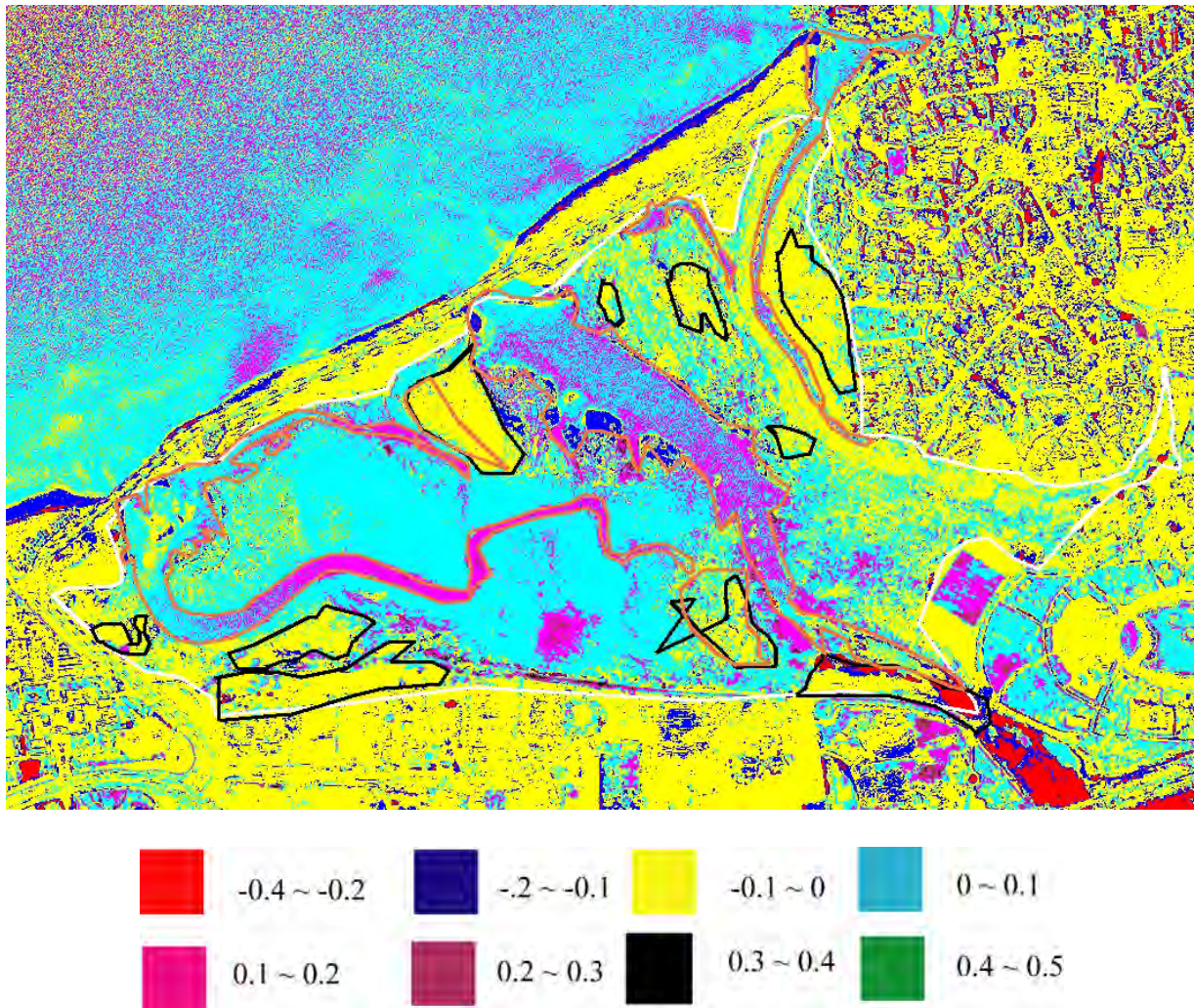


Fig. 10. Change between GeoEye NDVI images recorded on October 11, 2011 and September 18, 2012. The overlays show the general area of the mangrove forest (white) wadi and water (brown) and open flat or bare soil (black)

5. Conclusion

With improving spatial and spectral resolution data acquired in the visible, infrared and radar will continue to integral parts of several projects dealing with ecosystem evaluation and analysis including analysis of mangrove forests. This manual is intended to be an addition aid to mangrove analysis and evaluation in conjunction with fieldwork.

Remote sensing analysis and fieldwork indicate that the mangrove forest at Qurm National Park is stable. It is recommended that high-resolution satellite imagery should be used for health assessment and change detection studies at least every one or two years. From such studies and changes could be monitored.

6. References

- Chavez, Jr., P.S., and A.Y. Kwarteng. 1989. Extracting spectral contrast in Landsat Thematic Mapper image data using selective principal component analysis. *Photogrammetric Engineering and Remote Sensing*, 55: 339-348.
- Chavez, P.S. Jr. and D. Mackinnon. 1994. Automatic detection of vegetation changes in the southwestern United States using remotely sensed images. *Photogrammetric Engineering and Remote Sensing*, 60: 571-583.
- Choudhury, B.J., and C.J. Tucker, 1987. Satellite observed seasonal and inter-annual variation of vegetation over the Kalahari, the Great Victoria Desert, and the Great Sandy Desert: 1979-1984, *Remote Sensing of Environment*, 23: 233-241.
- ENVI, 2003. ENVI Tutorials. Research System Inc. Boulder Colorado, USA.
- Jensen, J.R., and D.L. Toll. 1982. Detecting residential land-use development at the urban fringe. *Photogrammetric Engineering and Remote Sensing*, 48: 629-643.
- Kwarteng, A.Y. 2010. Remote sensing imagery assessment of areas severely affected by cyclone Gonu, Muscat, Sultanate of Oman. In *Indian Ocean Tropical Cyclones and Climate Change*, Yassine Charabi (editor), Springer, Netherlands, p. 223-232.
- Kwarteng, A.Y. and P.S. Chavez, Jr. 1998. Change detection study of Kuwait City and environs using multitemporal Landsat Thematic Mapper data. *International Journal of Remote Sensing*, 19: 1651-1662.
- Singh, A. 1989. Review article: Digital change detection techniques using remotely-sensed data. *International Journal of Remote Sensing*, 10: 989-1003.
- Tucker, C.J., and P.J. Sellers, 1986. Satellite remote sensing of primary production, *International Journal of Remote Sensing*, 7:1395-1416.

Appendix 2

Calibration method of portable water quality meter

pH meter (SevenGo™ SG2)

1) Buffer groups

The pH meter allows you to perform 1-,2- and 3- point calibrations. If you select your calibration buffer group from one of the four predefined groups defined in the meter, the buffers are automatically recognized and displayed during calibration (auto buffer recognition). The four predefined buffer groups are:

B1	7.00	4.00	10.01	1.68		(at 25 °C)
B2	7.00	4.01	9.21	2.00	11.00	(at 25 °C)
B3	7.00	4.00	9.00	2.00	12.00	(at 20 °C)
B4	6.86	4.01	9.18	1.68		(at 25 °C)

Tables (B1...B4) for automatic temperature compensation are programmed in the meter.

2) Performing a 1-point calibration

Place the electrode in a calibration buffer and press **Cal**. The meter endpoints according to the preselected endpoint mode after the signal has stabilized or after pressing **Read** the meter display and freezes the relevant buffer value. The offset value and the slope are then shown on the display. To accept the calibration and return to sample measurement, press **Read**. To reject the calibration, press **Exit**.

3) Performing a 2-point calibration

- Step 1 Perform the first point calibration as described above in "Performing a 1-point calibration".
- Step 2 Rinse the electrode with deionized water.
- Step 3 Place the electrode in the next calibration buffer and press **Cal**.

The meter endpoints according to the preselected endpoint mode after the signal has stabilized after pressing **Read**. The meter displays and freezes the relevant buffer value, updates the electrode offset and shows the new slope calculated from the two calibration points.

To accept the calibration and return to sample measurement, press **Read**. To reject the calibration, press **Exit**.


4) Performing a 3-point calibration

Perform the same step as described above in "Performing a 2-point calibration", and then repeat step 2 and 3 for the third calibration point.

Conductivity meter (SevenGo™ SG3)

1) Selecting a standard

When using the conductivity meter, you have to select a standard for calibration.

Press and hold  until the current standard blinks.

Use the **^** or **v** key to select another standard. When the desired standard blinks, press **Read** to confirm your selection. The following three predefined are available:

- 84 µS/cm
- 1413 µS/cm
- 12.88 ms/cm

Tables for automatic temperature compensation are programmed in the meter for each standard.

2) Performing a calibration

Place the conductivity sensor in the defined calibration standard and press **Cal**.

With the default setting, the conductivity meter automatically endpoints when the signal is stable. To manually endpoint, press **Read**. The meter displays the value of the standard followed by the cell constant after a few seconds. To accept the calibration and return to sample measurement, press **Read**. To reject the calibration, press **Exit**.

Note

To ensure the most accurate conductivity readings, you should verify your cell constant with a standard solution regularly and recalibrate if necessary. Use always fresh standards.

DO meter (SevenGo™ SG6)

1) Preparing for Calibration

- Before performing a calibration, the sensor has to be connected to the instrument for at least 6 hours (Polarization Time)
- Before performing calibration, the membrane must be examined for damage or contamination. If the membrane is dirty, clean carefully with a soft moist cloth.

2) Performing a 1-Point calibration

- For calibration in vapour saturated air (100% O₂) place the electrode in a bottle 1cm above the water surface as shown in the graphic below.



- Press then **Cal**. The meter endpoints according to the pre-selected endpoint settings after the signal has stabilized or after pressing **Read**.
- Terminate calibration by pressing the **End** soft key. After the reading has end pointed, calibration results appear in the display.
- To use the calibration data for later measurements, press **Save**.
- To discard the calibration data, press **Cancel**.

Note

- To ensure the most accurate dissolved oxygen readings, it is advisable to calibrate regularly.
- For the 1Point-calibration, the sensor must be removed from the medium, gently cleaned and dried. Water droplets on the membrane must be removed because they prevent the sensor from being correctly calibrated.

Appendix 2 Calibration method of portable water quality meters

Appendix 3

Analysis procedure of COD and inorganic nutrients

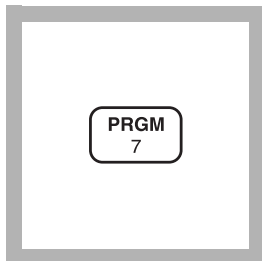
using HACH DR890 portable colorimeter

Nitrate nitrogen (NO₃-N): Method 8192

NITRATE, Low Range (0 to 0.50 mg/L NO₃⁻-N)

For water, wastewater and seawater*

Cadmium Reduction Method



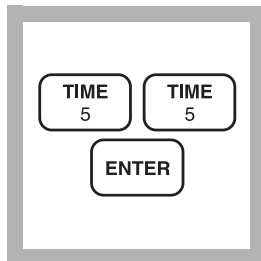
1. Enter the stored program number for low range nitrate nitrogen (NO₃⁻-N).

Press: **PRGM**

The display will show:

PRGM ?

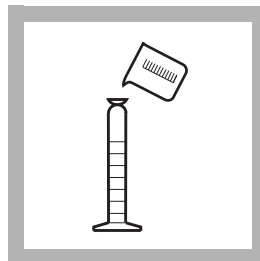
Note: For most accurate results, perform a Reagent Blank Correction using deionized water (see Section 1).



2. Press: **55 ENTER**

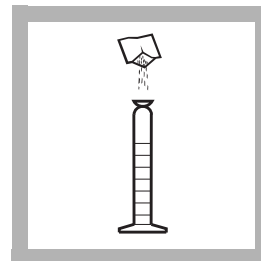
The display will show **mg/L, NO₃-N** and the **ZERO** icon.

*Note: For alternate forms (NO₃), press the **CONC** key.*



3. Fill a 25-mL graduated mixing cylinder to the 15-mL mark with sample.

Note: Adjust the pH of stored samples before analysis.

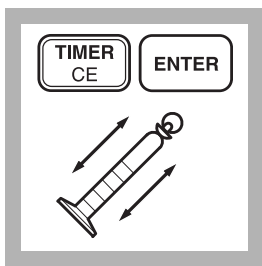


4. Add the contents of one NitraVer 6 Nitrate Reagent Powder Pillow to the cylinder. Stopper.

*Note: It is necessary to remove **all** the powder from the foil pillow. Tap the pillow until no more powder pours out. Be sure to remove powder from the corners of the pillow.*

* Seawater requires a manual calibration; see Interferences.

NITRATE, Low Range, continued

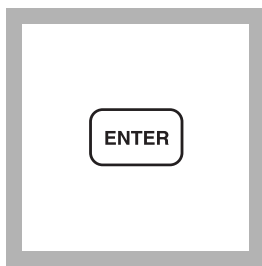


5. Press:

TIMER ENTER

A 3-minute reaction period will begin. Shake the cylinder vigorously throughout this three minute period.

Note: Shaking time and technique influence color development. For most accurate results, analyze a standard solution several times and adjust the shaking time to obtain the correct result.

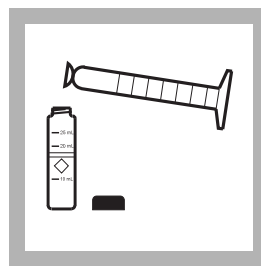


6. When the timer beeps, the display will show: **2:00 TIMER 2**

Press: **ENTER**

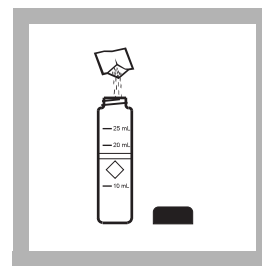
A 2-minute reaction period will begin.

Note: A deposit will remain after the powder dissolves and will not affect results.



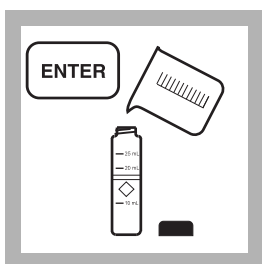
7. When the timer beeps, pour 10 mL of the sample into a sample cell.

Note: Do not transfer any cadmium particles.



8. Add the contents of one NitriVer 3 Nitrite Reagent Powder Pillow to the sample cell (the prepared sample). Cap the cell and shake gently for 30 seconds.

Note: A pink color will form if nitrate is present.

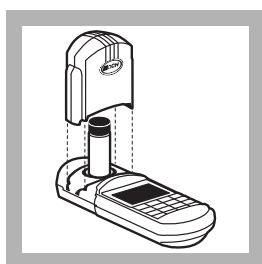


9. The display will show: **15:00 TIMER 3**

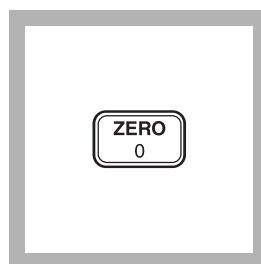
Press: **ENTER**

A 15-minute reaction period will begin.

Fill another sample cell (the blank) with 10 mL of sample.



10. When the timer beeps, place the blank into the cell holder. Tightly cover the sample cell with the instrument cap.

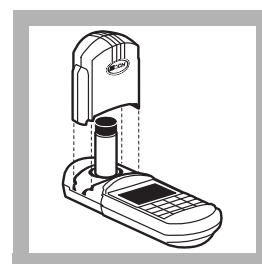


11. Press: **ZERO**

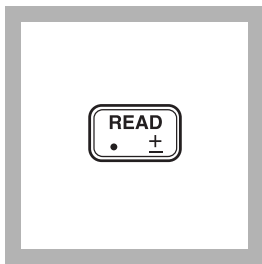
The cursor will move to the right, then the display will show:

0.00 mg/L NO₃-N

Note: If Reagent Blank Correction is on, the display may flash "limit". See Section 1.



12. Place the prepared sample into the cell holder. Tightly cover the sample cell with the instrument cap.



13. Press: READ

The cursor will move to the right, then the result in mg/L NO₃⁻-N (or alternate form) will be displayed.

Note: Standard Adjust may be performed using a prepared standard (see Section 1).

Note: Rinse the sample cell and cylinder immediately after use to remove all cadmium particles.

Note: See Pollution Prevention and Waste Management for proper disposal of cadmium.

Sampling and Storage

Collect samples in clean plastic or glass bottles. Store at 4 °C (39 °F) or lower if the sample is to be analyzed within 24 to 48 hours. Warm to room temperature before running the test. For longer storage periods, adjust sample pH to 2 or less with sulfuric acid, ACS (about 2 mL per liter). Sample refrigeration is still required.

Before testing the stored sample, warm to room temperature and neutralize with 5.0 N Sodium Hydroxide Standard Solution. Do not use mercury compounds as preservatives. Correct the test result for volume additions; see *Correction for Volume Additions (Section 1)* for more information.

NITRATE, Low Range, continued

Accuracy Check

Standard additions Method

- a) Fill three 25-mL graduated mixing cylinders with 15 mL of sample.
- b) Snap the neck off a Nitrate Nitrogen Ampule Standard Solution, 12.0 mg/L NO_3^- -N.
- c) Using the TenSette Pipet, add 0.1, 0.2, and 0.3 mL of the standard to the three samples. Stopper and mix well.
- d) Analyze each sample as described above. The nitrate nitrogen concentration should increase 0.08 mg/L for each 0.1 mL of standard added.
- e) If these increases do not occur, see *Standard Additions* (Section 1) for more information.

Standard Solution Method

Prepare a 0.20 mg/L nitrate nitrogen standard by diluting 2.00 mL of a 10.0 mg/L Nitrate Nitrogen Standard Solution to 100.0 mL with deionized water. Use this standard in place of sample in Step 3.

Standard Adjust

To adjust the calibration curve using the reading obtained with the 0.20-mg/L standard solution, press the **SETUP** key and scroll (using the arrow keys) to the STD setup option. Press **ENTER** to activate the standard adjust option. Then enter **0.20** to edit the standard concentration to match that of the standard used. Press **ENTER** to complete the curve adjustment. If you are using a reagent blank correction, the blank correction should be entered before the Standard Adjust feature is entered. See *Section 1, Standard Curve Adjustment* for more information.

Method Performance

Precision

In a single laboratory using a standard solution of 0.25 mg/L nitrate nitrogen (NO_3^- -N) and two representative lots of reagent with the instrument, a single operator obtained a standard deviation of ± 0.03 mg/L nitrate nitrogen.

NITRATE, Low Range, continued

Estimated Detection Limit

The estimated detection limit for program 55 is 0.01 mg/L NO₃⁻-N. For more information on the estimated detection limit, see *Section 1*.

Interferences

Interfering Substance	Interference Levels and Treatments
Calcium	100 mg/L
Chloride	Chloride concentrations above 100 mg/L will cause low results. The test may be used at high chloride concentrations (seawater) but a calibration must be done using standards spiked to the same chloride concentration.
Ferric iron	All levels
Nitrite	All levels: This method measures both the nitrate and nitrite in the sample. If nitrite is present, the nitrite nitrogen test Program 60 should be done on the sample. Pretreat the nitrate nitrogen sample with the following pretreatment. Then subtract the amount of nitrite found from the results of the LR nitrate nitrogen test using the pretreated sample. <ol style="list-style-type: none">1. Add 30-g/L Bromine Water dropwise to the sample in Step 3 until a yellow color remains. Mix after each drop.2. Add one drop of 30-g/L Phenol Solution to destroy the yellow color.3. Proceed with the LR Nitrate procedure.
pH	Highly buffered samples or extreme sample pH may exceed the buffering capacity of the reagents and require sample pretreatment.
Strong oxidizing and reducing substances	Interfere at all levels

Summary of Method

Cadmium metal reduces nitrates present in the sample to nitrite. The nitrite ion reacts in an acidic medium with sulfanilic acid to form an intermediate diazonium salt which couples to chromotropic acid to form a pink-colored product.

Pollution Prevention and Waste Management

NitaVer 6 contains cadmium metal. Both samples and reagent blanks will contain cadmium (D006) at a concentration regulated as hazardous wastes by the Federal RCRA. Do not pour these solutions down the drain. See *Section 3* for more information on proper disposal of these materials.

NITRATE, Low Range, continued

REQUIRED REAGENTS

Low Range Nitrate Reagent Set (100 tests)..... 24298-00
Includes: (1) 21071-69, (1) 21072-49

Description	Quantity Required		Unit	Cat. No.
	Per Test			
NitriVer 3 Nitrite Reagent Powder Pillows.....	1 pillow	.....	100/pkg	21071-69
NitriVer 6 Nitrate Reagent Powder Pillows	1 pillow	.....	100/pkg	21072-49

REQUIRED APPARATUS

Cylinder, graduated, mixing, 25 mL..... 1 each..... 1896-40
Sample Cell, 10-20-25 mL, w/ cap..... 2..... 6/pkg..... 24019-06

OPTIONAL REAGENTS

Description		Unit	Cat. No.
Bromine Water, 30 g/L.....	29 mL	*	2211-20
Nitrate Nitrogen Standard Solution, 10.0 mg/L as NO ₃ ⁻ -N.....	500 mL	.....	307-49
Nitrate Nitrogen Standard Solution, Voluette ampule, 12 mg/L as NO ₃ ⁻ -N, 10 mL	16/pkg	.....	14333-10
Phenol Solution, 30 g/L	29 mL	.....	2112-20
Pretreatment Kit, contains: (1) 2112-20, (1) 2211-20.....	each	.....	2268-00
Sodium Hydroxide Standard Solution, 5.0 N	50 mL*	SCDB	2450-26
Sulfuric Acid, ACS	500 mL*	.....	979-49
Water, deionized.....	4 L	.....	272-56

OPTIONAL APPARATUS

Ampule Breaker..... each..... 21968-00
Dropper, for 29-mL bottle..... each..... 2258-00
Flask, volumetric, Class A, 100 mL each | | 14574-42 | || pH Indicator Paper, 1 to 11 pH | 5-roll/pkg | | 391-33 | |
pH Meter, *sensio*TM1, portable, with electrode	each	51700-10	
Pipet, serological, 2 mL	each	532-36	
Pipet, TenSette, 0.1 to 1.0 mL.....	each	19700-01	
Pipet Tips, for 19700-01 TenSette Pipet	50/pkg	21856-96	
Pipet Tips, for 19700-01 TenSette Pipet	1000/pkg	21856-28	
Pipet, volumetric, Class A, 2.00 mL.....	each	14515-36	
Pipet Filler, safety bulb	each	14651-00	
Thermometer, -20 to 110 °C.....	each	26357-02	

Nitrate at these levels can also be determined directly using the Nitrate Ion Selective Electrode (Cat. No. 23488-00).

For Technical Assistance, Price and Ordering

In the U.S.A.—Call 800-227-4224

Outside the U.S.A.—Contact the Hach office or distributor serving you.

* Contact Hach for larger sizes

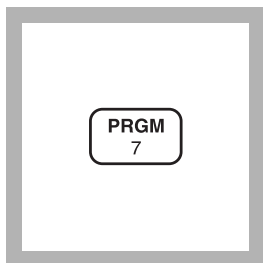
Nitrite nitrogen (NO₂-N): Method 10019

NITRITE, Low Range, Test 'N Tube (0–0.500 mg/L NO₂⁻-N)

Diazotization Method

For water, wastewater, and seawater

USEPA approved for wastewater analysis*



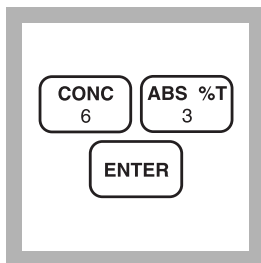
1. Enter the stored program number for nitrite nitrogen (NO₂⁻-N), Test 'N Tube.

Press: **PRGM**

The display will show:

PRGM ?

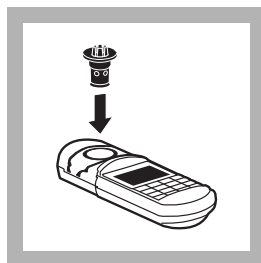
Note: For most accurate results, perform a Reagent Blank Correction using deionized water (see Section 1).



2. Press: **63 ENTER**

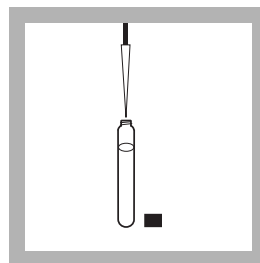
The display will show **mg/L, NO₂-N** and the **ZERO** icon.

*Note: For alternate forms (NO₂⁻, NaNO₂), press the **CONC** key.*

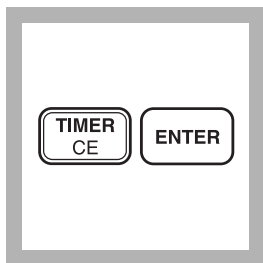


3. Insert the COD/TNT Adapter into the cell holder by rotating the adapter until it drops into place. Then push down to fully insert.

Note: For increased performance, a diffuser band covers the light path holes on the adapter. Do not remove the diffuser band.



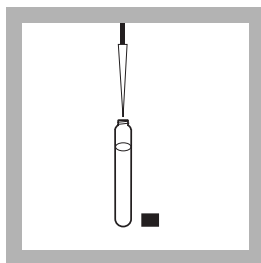
4. Fill a Test 'N Tube NitriVer® 3 Nitrite vial with 5 mL of sample. Cap and shake to dissolve powder. This is the prepared sample.



5. Press: **TIMER ENTER**

A 20-minute reaction period will begin.

Note: A pink color will develop if nitrite is present.

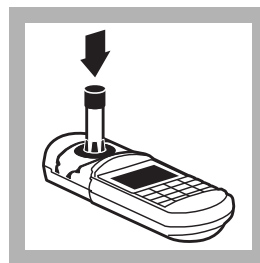


6. When the timer beeps, fill an empty Test 'N Tube vial with 5 mL of sample (the blank).



7. Clean the outside of the vials with a towel.

Note: Wipe with a damp towel and follow with a dry one to remove fingerprints and other marks.

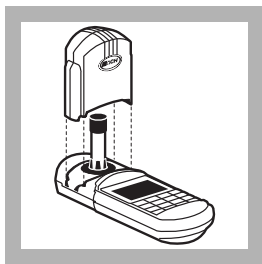


8. Place the blank in the vial adapter.

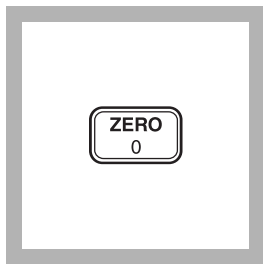
Push straight down on the top of the vial until it seats solidly into the adapter.

Note: Do not move the vial from side to side as this can cause errors.

* Federal Register, 44(85) 25505 (May 1, 1979).



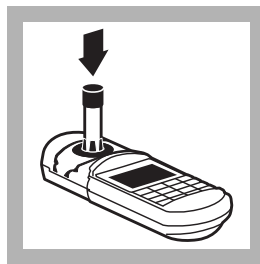
9. Cover the sample cell tightly with the instrument cap.



10. Press: **ZERO**
The cursor will move to the right, then the display will show:

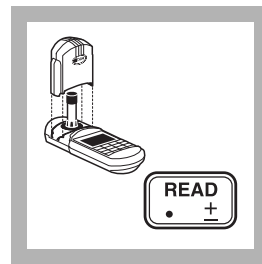
0.000 mg/L NO₂-N

Note: If the reagent blank correction is on, the display may flash "limit." See Section 1.



11. Place the prepared sample in the adapter. Push straight down on the top of the vial until it seats solidly into the adapter.

Note: Do not move the vial from side to side as this can cause errors.



12. Tightly cover the sample cell with the instrument cap.

Press: **READ**

The cursor will move to the right, then the result in mg/L nitrite nitrogen (or an alternate form) will be displayed.

Note: Standard Adjust may be performed using a prepared standard (see Section 1).

Sampling and Storage

Collect samples in clean plastic or glass bottles.

Store at 4 °C (39 °F) or lower and analyze within 48 hours. Warm to room temperature before running the test.

Do not use acid preservatives.

Remove suspended solids by filtration.

Accuracy Check

Standard Solution Method

Pipet 5.00 mL of a fresh Hach standard, 250 mg/L as NO₂⁻-N into a Class A 250-mL volumetric flask. Dilute to the line with deionized water to make a 5.00-mg/L intermediate standard. Pipet 10.00 mL of the 5.0-mg/L intermediate standard into a Class A 500-mL volumetric flask. Dilute to the line with deionized water to make a 0.100 mg/L NO₂⁻-N standard solution. Prepare immediately before use.

Run the test using the 0.100 mg/L NO₂⁻-N standard in place of the sample. Results should be between 0.090 and 0.110 mg/L NO₂⁻-N.

NITRITE, Test 'N Tube, continued

Method Performance

Precision

In a single laboratory, using a standard solution of 0.250 mg/L nitrite nitrogen and two representative lots of reagent with the instrument, a single operator obtained a standard deviation of ± 0.004 mg/L NO_2^- -N.

Estimated Detection Limit

The estimated detection limit for program 63 is 0.006 mg/L NO_2^- -N. For more information on derivation and use of Hach's estimated detection limit, see *Section 1*.

Interferences

Interfering Substance	Interference Levels
Antimonic ions	Interfere by causing precipitation
Auric ions	Interfere by causing precipitation
Bismuth ions	Interfere by causing precipitation
Chloroplatinate ions	Interfere by causing precipitation
Cupric ions	Cause low results
Ferric ions	Interfere by causing precipitation
Ferrous ions	Cause low results
Lead ions	Interfere by causing precipitation
Mercurous ions	Interfere by causing precipitation
Metavanadate ions	Interfere by causing precipitation
Nitrate	Very high levels of nitrate (>100 mg/L nitrate as N) appear to undergo a slight amount of reduction to nitrite, either spontaneously or during the course of the test. A small amount of nitrite will be found at these levels.
Silver ions	Interfere by causing precipitation
Strong oxidizing and reducing substances	Interfere at all levels

Summary of Method

Nitrite in the sample reacts with sulfanilic acid to form an intermediate diazonium salt. This couples with chromotropic acid to produce a pink-colored complex directly proportional to the amount of nitrite present.

NITRITE, Test 'N Tube, continued

REQUIRED REAGENTS

Description	Cat. No.
NitriVer® 3 Nitrite, Low Range Test 'N Tube Reagent Set (50 tests)	26083-45
Includes:	
(50) NitriVer® 3 Nitrite Test 'N Tube Vials.....*	
Vials, 6 x 100 mm, 6/pkg	22758-06
Caps, for 22758-06 vials, 6/pkg.....	22411-06
Deionized water, 100-mL.....	272-42

REQUIRED APPARATUS

Description	Quantity Required		Unit	Cat. No.
	Per Test			
COD/TNT Adapter	1		each.....	48464-00
Test Tube Rack	1-3		each.....	18641-00
Pipet, TenSette, 1 to 10 mL.....	1		each.....	19700-10
Pipet Tips for 19700-10 TenSette Pipet	1		50/pkg.....	21997-96

OPTIONAL REAGENTS

Nitrite Standard Solution, 250 mg/L as NO ₂ -N	500 mL	.....	23402-49
Water, deionized.....	4 L	.....	272-56

OPTIONAL APPARATUS

Flask, volumetric, 250 mL.....	each.....	14574-46
Flask, volumetric, 500 mL.....	each.....	14574-49
Pipet, volumetric, Class A, 10.00 mL.....	each.....	14515-38

For Technical Assistance, Price and Ordering

In the U.S.A. call 800-227-4224

Outside the U.S.A.—Contact the Hach office or distributor serving you.

* Not available separately.

Ammonium nitrogen (NH₄-N): Method 10031

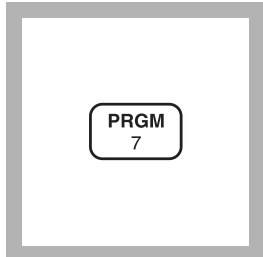
Note: Method 10031 measures ammonia nitrogen (NH₃-N) concentration which is equal to the value of ammonium nitrogen (NH₄⁺-N).

NITROGEN, AMMONIA, High Range, Test 'N Tube

(0 to 50 mg/L NH₃-N)

For water, wastewater, and seawater

Salicylate Method*

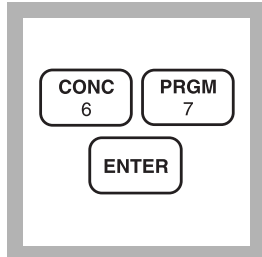


1. Enter the stored program number for nitrogen, ammonia, high range Test 'N Tube (NH₃-N) method.

Press: **PRGM**

The display will show:

PRGM ?

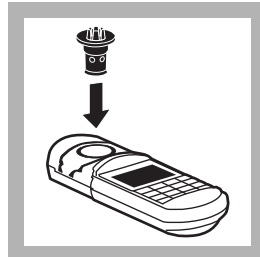


2. Press: **67 ENTER**

The display will show **mg/L, NH₃-N** and the **ZERO** icon.

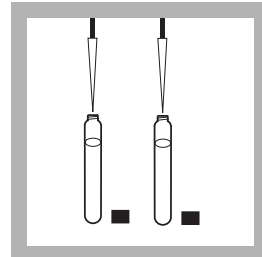
Note: For alternate forms (NH₃), press the **CONC** key.

Note: For proof of accuracy, use a 10-mg/L nitrogen, ammonia standard in place of the sample.

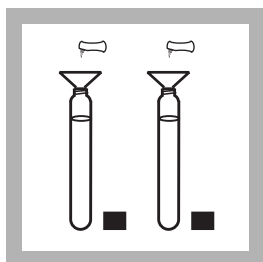


3. Insert the COD/TNT Adapter into the cell holder by rotating the adapter until it drops into place. Then push down to fully insert it.

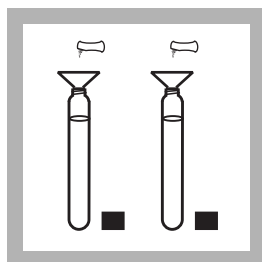
Note: For increased performance, a diffuser band covers the light path holes on the adapter. Do not remove the diffuser band.



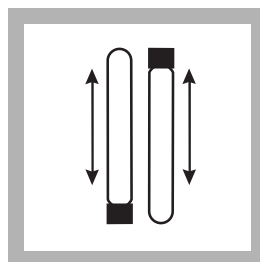
4. Remove the caps from 2 AmVer Diluent Reagent High Range Vials. Add 0.1 mL of sample to one vial (the sample). Add 0.1 mL of deionized water to the other (the blank).



5. Add the contents of 1 Ammonia Salicylate Reagent Powder Pillow for 5 mL Sample to each vial.

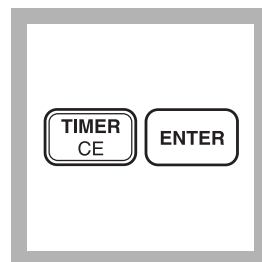


6. Add the contents of 1 Ammonia Cyanurate Reagent Powder Pillow for 5 mL Sample to each vial.



7. Cap the vials tightly and shake thoroughly to dissolve the powder.

Note: A green color will develop if ammonia is present.



8. Press:

TIMER ENTER

A 20-minute reaction period will begin.

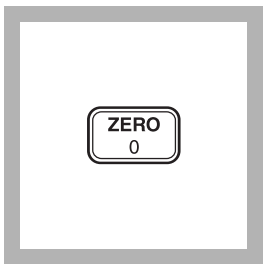
* Adapted from *Clin. Chim. Acta*, **14** 403 (1966).

NITROGEN, AMMONIA, High Range, Test 'N Tube, continued

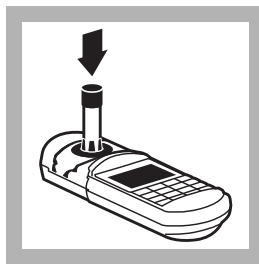


9. Clean the outside of the vial with a towel. After the timer beeps, place the blank into the vial adapter. Tightly cover the vial with the instrument cap.

Note: Wipe with a damp cloth and follow with a dry one to remove fingerprints and other marks.

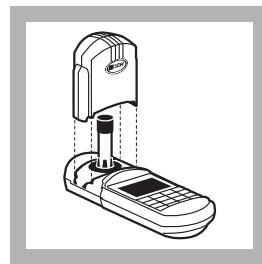


10. Press: **ZERO**
The cursor will move to the right, then the display will show:
0 mg/L NH₃-N

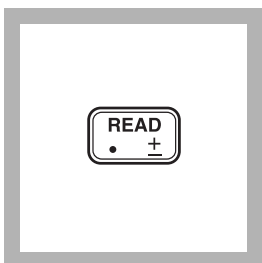


11. Place the prepared sample in the adapter. Push straight down on the top of the vial until it seats solidly into the adapter.

Note: Do not move the vial from side to side as this can cause errors.



12. Tightly cover the vial with the instrument cap.



13. Press: **READ**

The cursor will move to the right, then the result in mg/L NH₃-N will be displayed.

Note: Standard Adjust may be performed using a prepared standard (see Standard Adjust in Section 1).

NITROGEN, AMMONIA, High Range, Test 'N Tube, continued

Sampling and Storage

Collect samples in clean plastic or glass bottles. Best results are obtained with immediate analysis. If chlorine is known to be present, add one drop of 0.1 N sodium thiosulfate for each 0.3 mg/L Cl_2 in a one liter sample. Preserve the sample by reducing the pH to 2 or less with hydrochloric acid (at least 2 mL). Store at 4 °C (39 °F) or less. Preserved samples may be stored up to 28 days. Before analysis, warm samples to room temperature and neutralize with 5.0 N sodium hydroxide. Correct the test result for volume additions.

Accuracy Check

Standard Additions Method

- a) Snap the top off an Ammonia PourRite Ampule Standard, 150 mg/L $\text{NH}_3\text{-N}$.
- b) Use the TenSette Pipet to add 0.2, 0.4 and 0.6 mL of standard to three 25-mL samples. Swirl to mix.
- c) Analyze each sample as described above. The ammonia concentration should increase approximately 1.2 mg/L $\text{NH}_3\text{-N}$ for each 0.2 mL of standard added.
- d) If these increases do not occur, see *Standard Additions* in *Section 1* for more information.

Standard Solution Method

To check accuracy, use a 10 or 50 mg/L Nitrogen, Ammonia Standard Solution or use a Nitrogen, Ammonia Voluette Ampule Standard, 50 mg/L.

Method Performance

Precision

In a single laboratory, using a standard solution of 50 mg/L ammonia nitrogen ($\text{NH}_3\text{-N}$) and two representative lots of reagent with the instrument, a single operator obtained a standard deviation of ± 5 mg/L $\text{NH}_3\text{-N}$.

Estimated Detection Limit

The estimated detection limit for program 67 is 1 mg/L $\text{NH}_3\text{-N}$. For more information on the estimated detection limit, see *Section 1*.

NITROGEN, AMMONIA, High Range, Test 'N Tube, continued

Interferences

The following ions may interfere when present in concentrations exceeding those listed below.

In some lab environments, airborne cross contamination of the blank is possible. Complete preparation of the blank before opening or handling any samples or standards to avoid transfer of ammonia. If sample or standard containers have already been open, move to a separate area of the lab to prepare the blank.

Substance	Concentration and Suggested Treatments
Acidic or basic samples	Adjust to approximately pH 7. Use 1 N Sodium Hydroxide Standard Solution for acidic samples and 1 N Hydrochloric Acid Standard Solution for basic samples.
Calcium	50,000 mg/L as CaCO ₃
Glycine, hydrazine	Will cause intensified colors in the prepared sample.
Magnesium	300,000 mg/L as CaCO ₃
Iron	Eliminate iron interference as follows: 1. Determine the amount of iron present in the sample using one of the total iron procedures. 2. Add the same iron concentration to the deionized water in step 4. 3. The interference will then be successfully blanked out.
Nitrite	600 mg/L as NO ₂ ⁻ -N
Nitrate	5,000 mg/L as NO ₃ ⁻ -N
Orthophosphate	5,000 mg/L as PO ₄ ³⁻ -P
Sulfate	6,000 mg/L as SO ₄ ²⁻
Sulfide	Sulfide will intensify the color. Eliminate sulfide interference as follows: 1. Measure about 350 mL of sample in a 500 mL Erlenmeyer flask. 2. Add the contents of one Sulfide Inhibitor Reagent Powder Pillow. Swirl to mix. 3. Filter the sample through folded filter paper. Use the filtered solution in step 4.
Turbidity and color	Give erroneous high values. Samples with severe interferences require distillation. Hach recommends the distillation procedure using the Hach General Purpose Distillation Set.

NITROGEN, AMMONIA, High Range, Test 'N Tube, continued

Summary of Method

Ammonia compounds combine with chlorine to form monochloramine. Monochloramine reacts with salicylate to form 5-aminosalicylate. The 5-aminosalicylate is oxidized in the presence of a sodium nitroprusside catalyst to form a blue-colored compound. The blue color is masked by the yellow color from the excess reagent present to give a green-colored solution.

Safety

Good safety habits and laboratory techniques should be used throughout the procedure. Consult the *Material Safety Data Sheets* for information specific to the reagents used. For additional information, refer to *Section 3*.

Pollution Prevention And Waste Management

The ammonia salicylate reagent contains sodium nitroferricyanide. Cyanide solutions are regulated as hazardous wastes by the Federal RCRA. Collect cyanide solutions for disposal as reactive (D001) waste. Be sure cyanide solutions are stored in a caustic solution with pH >11 to prevent release of hydrogen cyanide gas. See *Section 3* for further information in proper disposal of these materials.

REQUIRED REAGENTS

AmVer™ Reagent Set for Nitrogen, Ammonia, High Range, TNT (25 tests)26069-45
Includes: (1) 23952-66, (1) 23954-66, (1) 272-42, * (50) AmVer HR Vials

Description	Quantity Required	Unit	Cat. No.
AmVer™ HR Reagent Test 'N Tube™ Vials	2 vials	50/pkg	*
Ammonia Salicylate Reagent Powder Pillows.....	2 pillows	50/pkg	23952-66
Ammonia Cyanurate Reagent Powder Pillows	2 pillows	50/pkg	23954-66

REQUIRED APPARATUS

COD/TNT Adapter.....	1	each.....	48464-00
Pipet, TenSette® , 0-1 mL	1	each.....	19700-01
Pipet Tips for 19700-01.....	varies	50/pkg	21856-96
Test Tube Rack	1-3	each.....	18641-00
Funnel, micro (for reagent addition)	1	each.....	25843-35

* Not available separately.

NITROGEN, AMMONIA, High Range, Test 'N Tube, continued

OPTIONAL REAGENTS

Description	Quantity Required		Cat. No.
	Per Test	Unit	
Nitrogen, Ammonia Standard Solution, 50 mg/L NH ₃ -N.....		500 mL.....	14791-50
Nitrogen, Ammonia Standard Solution, 10 mg/L NH ₃ -N.....		500 mL.....	153-49
Ammonia Standard Solution, PourRite™ ampules, 150 mg/L NH ₃ -N, 2 mL.....		20/pkg.....	21284-20
Hydrochloric Acid, ACS.....		500 mL.....	134-49
Sodium Hydroxide Standard Solution, 5.0 N		50 mL.....	2450-26
Sodium Hydroxide Standard Solution, 1.0 N		100 mL.....	1045-32
Sodium Thiosulfate Standard Solution, 0.1 N		100 mL.....	323-32
Sulfide Inhibitor Powder Pillows.....		100/pkg.....	2418-99
Sulfuric Acid, 1.00 N.....		100 mL MDB.....	1270-32
Wastewater Influent Standard, Inorganic (NH ₃ -N, NO ₃ , PO ₄ , COD, SO ₄ , TOC).....		500 mL.....	28331-49
Water, deionized.....		4 L	272-56

OPTIONAL APPARATUS

Cylinder, 25 mL, graduated, mixing	each.....	20886-40
Distillation Apparatus Set, general purpose	each.....	22653-00
Heater and Support Apparatus (for distillation), 115 VAC.....	each.....	22744-00
Heater and Support Apparatus (for distillation), 230 VAC	each.....	22744-02
Filter Paper, folded.....	100/pkg.....	1894-57
Flask, Erlenmeyer, 500 mL.....	each.....	505-49
Funnel, analytical (for filtering).....	each.....	1083-68
Jack, laboratory (use with distillation apparatus)	each.....	22743-00
pH Indicator Paper, 1 to 11 pH	5 rolls/pkg.....	391-33
Pipet Tips, for 19700-01 TenSette Pipet	1000/pkg.....	21856-28
PourRite™ Ampule Breaker	each.....	24846-00
Sample Cell, 10-20-25 mL, w/cap	6/pkg.....	24019-06

For Technical Assistance, Price and Ordering

In the U.S.A.—Call 800-227-4224

Outside the U.S.A.—Contact the Hach office or distributor serving you.

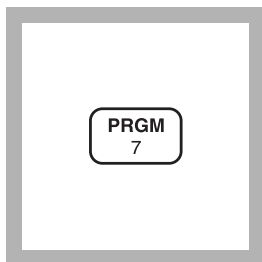
Phosphate phosphorus (PO₄-P): Method 8048

Note: Method 8048 measures phosphate (PO₄³⁻) concentration. Multiply the PO₄³⁻ value by 0.326 to acquire phosphate phosphorus (PO₄³⁻-P) concentration.

PHOSPHORUS, REACTIVE (0 to 2.50 mg/L PO₄³⁻) For water, wastewater, seawater**(Also called Orthophosphate) PhosVer 3 (Ascorbic Acid) Method***

(Powder Pillows or AccuVac Ampuls)

USEPA Accepted for wastewater analysis reporting**

Using Powder Pillows

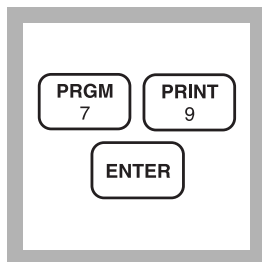
1. Enter the stored program number for reactive phosphorus, ascorbic acid method.

Press: **PRGM**

The display will show:

PRGM ?

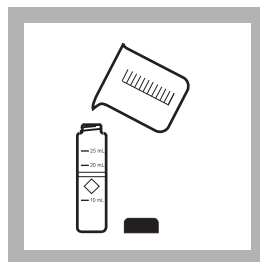
Note: For most accurate results, perform a Reagent Blank Correction using deionized water (see Section 1).



2. Press: **79 ENTER**

The display will show **mg/L, PO₄** and the **ZERO** icon.

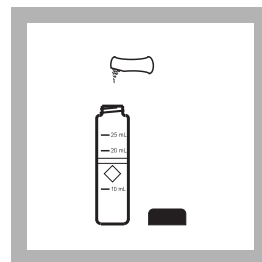
*Note: For alternate forms (P, P₂O₅), press the **CONC** key.*



3. Fill a sample cell with 10 mL of sample.

Note: For samples with extreme pH, see Interferences following these steps.

Note: Clean glassware with 1:1 HCl. Rinse again with deionized water. Do not use detergents containing phosphates to clean glassware.



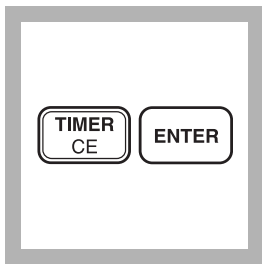
4. Add the contents of one PhosVer 3 Phosphate Powder Pillow for 10-mL sample to the cell (the prepared sample). Shake for 15 seconds.

Note: A blue color will form if phosphate is present.

* Adapted from *Standard Methods for the Examination of Water and Wastewater*.

** Procedure is equivalent to USEPA method 365.2 and Standard Method 4500-PE for wastewater.

PHOSPHORUS, REACTIVE, continued

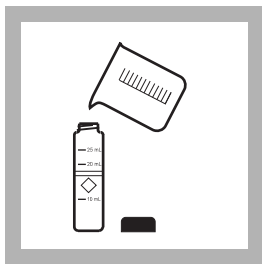


5. Press:

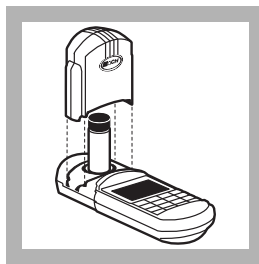
TIMER ENTER

A two-minute reaction period will begin. Perform Steps 6-8 during this period.

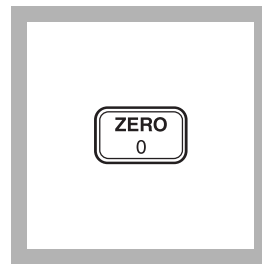
Note: If the acid-persulfate digestion was used, an 8-10 minute reaction period is required.



6. Fill another sample cell with 10 mL of sample (the blank).



7. Place the blank into the cell holder. Tightly cover the sample cell with the instrument cap.

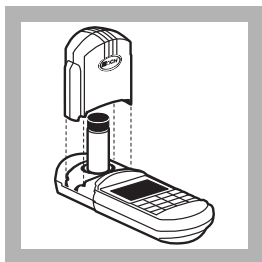


8. Press: **ZERO**

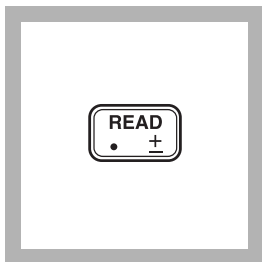
The cursor will move to the right, then the display will show:

0.00 mg/L PO₄

Note: If Reagent Blank Correction is on, the display may flash "limit". See Section 1.



9. After the timer beeps, place the prepared sample into the cell holder. Tightly cover the sample cell with the instrument cap.

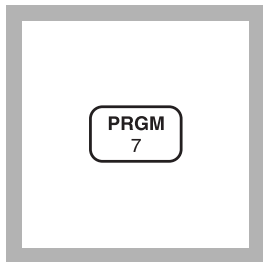


10. Press: **READ**

The cursor will move to the right, then the result in mg/L phosphate (PO_4^{3-}) will be displayed.

Note: Standard Adjust may be performed using a 2.0-mg/L PO_4^{3-} -standard; see Section 1.

Using AccuVac Ampuls



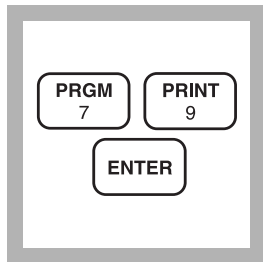
1. Enter the stored program number for reactive phosphorus-ascorbic acid method.

Press: **PRGM**

The display will show:

PRGM ?

Note: For most accurate results, perform a Reagent Blank Correction using deionized water (see Section 1).



2. Press: **79 ENTER**

The display will show **mg/L, PO4** and the **ZERO** icon.

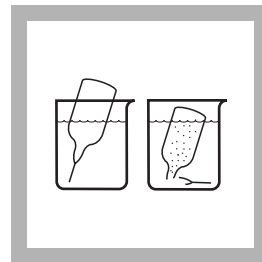
*Note: For alternate forms (P, P₂O₅), press the **CONC** key.*



3. Fill a sample cell (the blank) with at least 10 mL of sample. Collect at least 40 mL of sample in a 50-mL beaker.

Note: For samples with extreme pH, see Interferences.

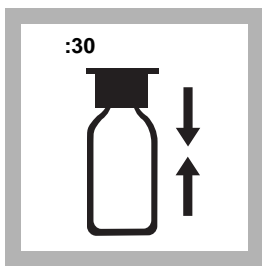
Note: Clean glassware with 1:1 HCl. Rinse again with deionized water. Do not use detergent containing phosphates to clean glassware.



4. Fill a PhosVer 3 Phosphate AccuVac Ampul with sample.

Note: Keep the tip immersed while the ampul fills completely.

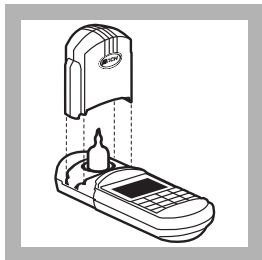
PHOSPHORUS, REACTIVE, continued



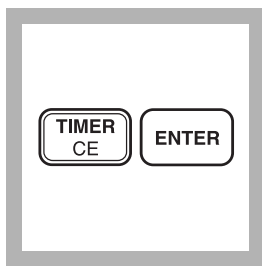
5. Place an ampul cap securely over the tip of the ampul. Shake the ampul for about 30 seconds. Wipe off any liquid or fingerprints.

Note: A blue color will form if phosphate is present.

Note: Accuracy is not affected by undissolved powder.



9. After the timer beeps, place the AccuVac ampul into the cell holder. Tightly cover the ampul with the instrument cap.

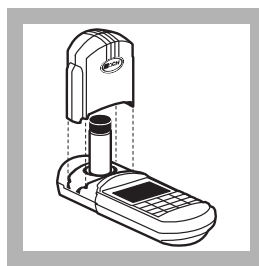


6. Press:

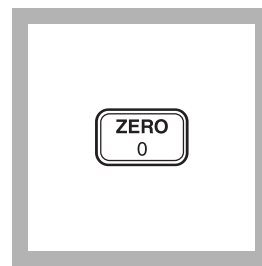
TIMER ENTER

A two-minute reaction period will begin. Perform Steps 7-8 during this period.

Note: Use an 8-10 minute reaction period if determining total phosphorus following the acid-persulfate digestion.



7. Place the blank into the cell holder. Tightly cover the sample cell with the instrument cap.

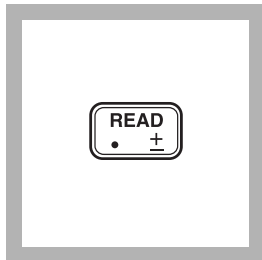


8. Press: **ZERO**

The cursor will move to the right, then the display will show:

0.00 mg/L PO₄

Note: If Reagent Blank Correction is on, the display may flash "limit". See Section 1.



10. Press: **READ**

The cursor will move to the right, then the result in mg/L phosphate (PO₄³⁻) will be displayed.

Note: Standard Adjust may be performed using a 2.0-mg/L PO₄³⁻ standard; see Section 1.

Sampling and Storage

Collect sample in plastic or glass bottles that have been cleaned with 1:1 Hydrochloric Acid Solution and rinsed with deionized water. Do not use commercial detergents containing phosphate for cleaning glassware used in this test.

Analyze samples immediately after collection for best results. If prompt analysis is impossible, preserve samples for up to 48 hours by filtering immediately and storing samples at 4 °C. Warm to room temperature before testing.

Accuracy Check

Standard Additions Method

- a) Fill three 25-mL graduated mixing cylinders with 25 mL of sample.
- b) Snap the neck off a Phosphate PourRite Ampule Standard Solution, 50 mg/L as PO_4^{3-} .
- c) Use the TenSette Pipet to add 0.1 mL, 0.2 mL, and 0.3 mL of standard, respectively, to the three mixing cylinders. Stopper each and mix thoroughly.
- d) For analysis with AccuVacs, transfer solutions to dry, clean 50 mL beakers to fill the AccuVac ampules. For analysis with powder pillows, transfer only 10 mL of solution to the sample cells.
- e) Analyze each standard addition sample as described in the procedure. The phosphate concentration should increase 0.2 mg/L PO_4^{3-} for each 0.1 mL of standard added.
- f) If these increases do not occur, see *Standard Additions* in *Section 1*.

Standard Solution Method

Prepare a 2.0 mg/L PO_4^{3-} standard solution by pipetting 4.0 mL of Phosphate Standard Solution, 50 mg/L as PO_4^{3-} , into an acid-washed Class A 100-mL volumetric flask. Dilute to volume with deionized water. Stopper and invert to mix. Use this solution in place of the sample in the procedure to insure the accuracy of the test. The mg/L PO_4^{3-} reading should be 2.00 mg/L.

PHOSPHORUS, REACTIVE, continued

Method Performance

Precision

In a single laboratory using a standard solution of 1.00 mg/L PO_4^{3-} and two lots of reagents with the instrument, a single operator obtained a standard deviation of ± 0.05 mg/L PO_4^{3-} .

In a single laboratory using a standard solution of 1.00 mg/L PO_4^{3-} and two representative lots of AccuVac ampuls with the instrument, a single operator obtained a standard deviation of ± 0.03 mg/L PO_4^{3-} .

Estimated Detection Limit (EDL)

The EDL for program 79 is 0.05 mg/L PO_4 . For more information on the estimated detection limit, see *Section 1*.

Interference

Interfering Substance	Interference Levels and Treatments
Aluminum	Greater than 200 mg/L
Arsenate	All levels
Chromium	Greater than 100 mg/L
Copper	Greater than 10 mg/L
Hydrogen sulfide	All levels
Iron	Greater than 100 mg/L
Nickel	Greater than 300 mg/L
Silica	Greater than 50 mg/L
Silicate	Greater than 10 mg/L
Turbidity or color	Large amounts may cause inconsistent results in the test because the acid present in the powder pillows may dissolve some of the suspended particles and because of variable desorption of orthophosphate from the particles. For highly turbid or colored samples, add the contents of one Phosphate Pretreatment Pillow to 25 mL of sample. Mix well. Use this solution to zero the instrument.
Zinc	Greater than 80 mg/L
Highly buffered samples or extreme sample pH	May exceed the buffering capacity of the reagents and require sample pretreatment. pH 2 to 10 is recommended.

Summary of Method

Orthophosphate reacts with molybdate in an acid medium to produce a Phosphomolybdate complex. Ascorbic acid then reduces the complex, giving an intense molybdenum blue color.

PHOSPHORUS, REACTIVE, continued

REQUIRED REAGENTS & APPARATUS (Using Powder Pillows)

Description	Quantity Required		Unit	Cat. No.
	Per Test			
PhosVer 3 Phosphate Reagent Powder Pillows				
10 mL sample size	1 Pillow	100/pkg.....	21060-69	
Sample Cell, 10-20-25 mL, w/cap	2	6/pkg.....	24019-06	

REQUIRED REAGENTS & APPARATUS (Using AccuVac Ampuls)

PhosVer 3 Phosphate Reagent AccuVac Ampuls	1 ampul	25/pkg.....	25080-25	
Beaker, 50 mL	1	each.....	500-41	
Cap, ampul, blue	1	25/pkg.....	1731-25	
Sample Cell, 10-20-25 mL, w/cap	1	6/pkg.....	24019-06	

OPTIONAL REAGENTS

Drinking Water Standard, Inorganic, F ⁻ , NO ₃ ^{-N} , PO ₄ ³⁻ , SO ₄ ²⁻	500mL	28330-49	
Hydrochloric Acid Standard Solution, 6.0 N (1:1)	500 mL.....	884-49	
Phosphate Standard Solution, 1mg/L	500mL.....	2569-49	
Phosphate Standard Solution, PourRite ampule, 50 mg/L as PO ₄ ³⁻ , 2 mL	20/pkg.....	171-20	
Phosphate Standard Solution, Voluette Ampul, 50 mg/L, 10 mL	16/pkg.....	171-10	
Sodium Hydroxide Standard Solution, 5.0 N	100 mL* MDB.....	2450-32	
Wastewater Effluent Standard, Inorganic (NH ₃ -N, NO ₃ -N, PO ₄ , COD, SO ₄ , TOC)	500 mL	28332-49	
Water, deionized	4 L.....	272-56	

OPTIONAL APPARATUS

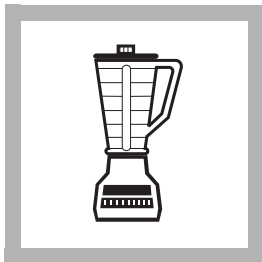
AccuVac Snapper Kit	each.....	24052-00	
Ampule Breaker Kit for 10-ml ampules.....	each.....	21968-00	
Aspirator, vacuum	each.....	2131-00	
Cylinder, graduated, mixing, 25 mL, tall (3 required)	each.....	20886-40	
Filter Holder, 47 mm, 300 mL, graduated.....	each.....	13529-00	
Filter, membrane, 47 mm, 0.45 microns	100/pkg.....	13530-00	
Flask, filtering, 500 mL.....	each.....	546-49	
Flask, volumetric, Class A, 100 mL.....	each.....	14574-42	
pH Indicator Paper, 1 to 11 pH	5 rolls/pkg	391-33	
pH Meter, <i>Sension</i> TM 1, portable with electrode	each.....	51700-10	
Pipet, 2 mL serological	each.....	532-36	
Pipet, TenSette, 0.1 to 1.0 mL TenSette Pipet.....	each.....	19700-01	
Pipet Tips, for 19700-01	50/pkg.....	21856-96	
Pipet Tips, for 19700-01	1000/pkg.....	21856-28	
Pipet Filler, safety bulb	each.....	14651-00	
Pipet, volumetric, Class A, 4.00 mL	each.....	14515-04	
PourRite Ampule Breaker Kit.....	each.....	24846-00	

Outside the U.S.A.—Contact the Hach office or distributor serving you.

* Larger sizes available.

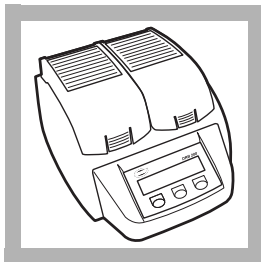
Chemical Oxygen Demand (COD): Method 8000

Reactor Digestion Method* USEPA approved for reporting wastewater analysis** Digestion



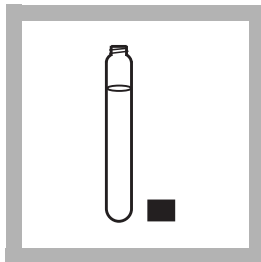
1. Homogenize 500 mL of sample for 2 minutes in a blender.

Note: For the 0-15,000 mg/L range, homogenize 100 mL of sample. Pour the blended sample into a 250-mL beaker. Stir with a magnetic stirrer while withdrawing a sample aliquot. This improves accuracy and reproducibility.



2. Turn on the DRB 200 Reactor. Preheat to 150 °C.

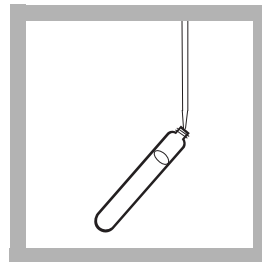
Note: See DRB 200 user manual for selecting pre-programmed temperature applications.



3. Remove the cap of a COD Digestion Reagent Vial for the appropriate range:

Sample Conc. Range (mg/L)	COD Digestion Reagent Vial Type
0 to 150	Low Range
0 to 1500	High Range
0 to 15,000	High Range Plus

Note: The reagent mixture is light-sensitive. Keep unused vials in the opaque shipping container, in a refrigerator if possible. The light striking the vials during the test will not affect results.



4. Hold the vial at a 45-degree angle. Pipet 2.00 mL (0.2 mL for the 0 to 15,000 mg/L range) of sample into the vial.

Note: For the 0-15,000 mg/L range, pipet only 0.20 mL of sample, not 2.00 mL of sample, using a TenSette Pipet. For greater accuracy analyze a minimum of three replicates and average the results.

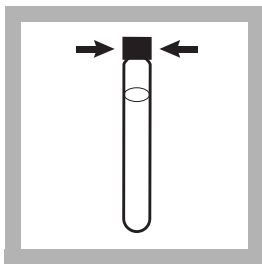
Note: Spilled reagent will affect test accuracy and is hazardous to skin and other materials. Do not run tests with vials which have been spilled. If spills occur, wash with running water.

Caution: Some of the chemicals and apparatus used in this procedure may be hazardous to the health and safety of the user if inappropriately or accidentally misused. Please read all warnings and the safety section of this manual. Wear appropriate eye protection and clothing. If contact occurs, flush the affected area with running water. Follow all instructions carefully.

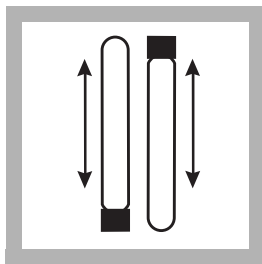
* Jirka, A.M.; Carter, M.J. *Analytical Chemistry*, 1975, 47(8). 1397.

** *Federal Register*, April 21, 1980, 45(78), 26811-26812. The 0-15,000 mg/L range is **not** USEPA approved.

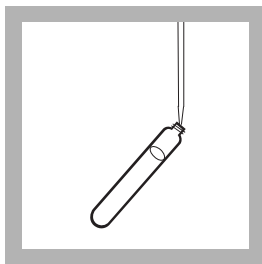
OXYGEN DEMAND, CHEMICAL, continued



5. Replace the vial cap tightly. Rinse the outside of the COD vial with deionized water and wipe the vial clean with a paper towel.

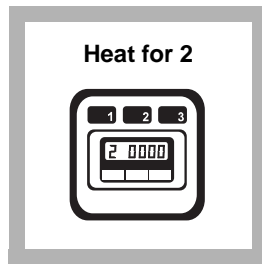


6. Hold the vial by the cap and over a sink. Invert gently several times to mix the contents. Place the vial in the preheated DRB 200 Reactor.
Note: The vial will become very hot during mixing.



7. Prepare a blank by repeating Steps 3 to 6, substituting 2.00 mL (0.2 mL for the 0 to 15,000 mg/L range) deionized water for the sample.
Note: Be sure the pipet is clean.

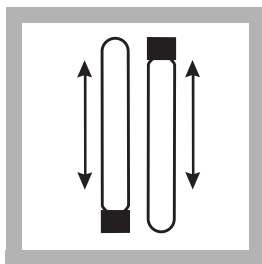
Note: One blank must be run with each set of samples. Run samples and blanks with vials from the same lot number (lot # is on the container label).



8. Heat the vials for 2 hours.
Note: Many samples are digested completely in less than two hours. If desired, measure the concentration (while still hot) at 15 minute intervals until the reading remains unchanged. Cool vials to room temperature for final measurement.



9. Turn the reactor off. Wait about 20 minutes for the vials to cool to 120 °C or less.



10. Invert each vial several times while still warm. Place the vials into a rack. Wait until the vials have cooled to room temperature.
Note: If a pure green color appears in the reacted sample, measure the COD and, if necessary, repeat the test with a diluted sample.

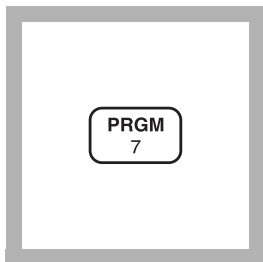


11. Use one of the following analytical techniques to measure the COD:

- Colorimetric method, 0-150 mg/L COD
- Colorimetric method, 0-1,500 mg/L COD
- Colorimetric method, 0-15,000 mg/L COD

OXYGEN DEMAND, CHEMICAL, continued

Colorimetric Determination, 0 to 150 mg/L COD

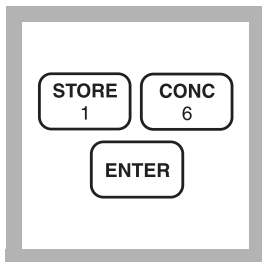


1. Enter the stored program number for chemical oxygen demand (COD), low range.

Press: **PRGM**

The display will show:

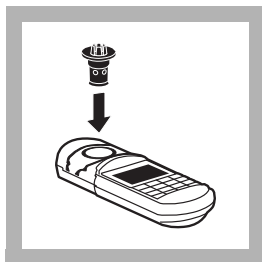
PRGM ?



2. Press: **16 ENTER**

The display will show **mg/L, COD** and the **ZERO** icon.

Note: For alternate form (O_2), press the **CONC** key.

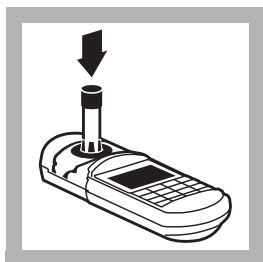


3. Insert the COD/TNT Adapter into the cell holder by rotating the adapter until it drops into place. Then push down to fully insert it.

Note: For increased performance, a diffuser band covers the light path holes on the adapter. Do not remove the diffuser band.



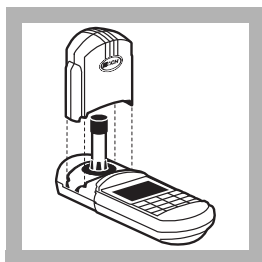
4. Clean the outside of the blank with a towel. *Note:* Wiping with a damp towel, followed by a dry one, will remove fingerprints or other marks.



5. Place the blank in the adapter.

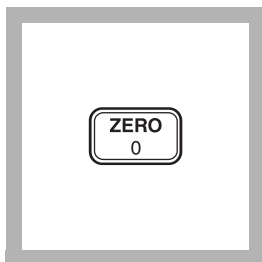
Push straight down on the top of the vial until it seats solidly into the adapter.

Note: Do not move the vial from side to side as this can cause errors.



6. Tightly cover the vial with the instrument cap.

Note: The blank is stable when stored in the dark. See Blanks for Colorimetric Determination following these procedures.



7. Press: **ZERO**

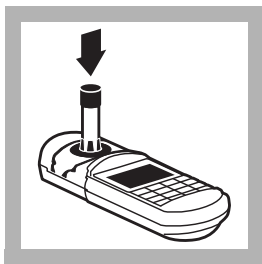
The cursor will move to the right, then the display will show:

0 mg/L COD



8. Clean the outside of the sample vial with a towel.

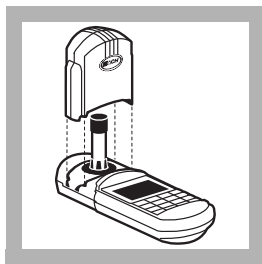
OXYGEN DEMAND, CHEMICAL, continued



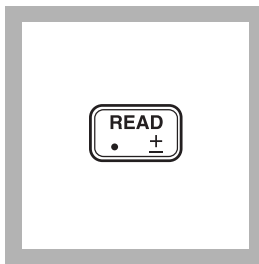
9. Place the sample vial in the adapter.

Push straight down on the top of the vial until it seats solidly into the adapter.

Note: Do not move the vial from side to side as this can cause errors.



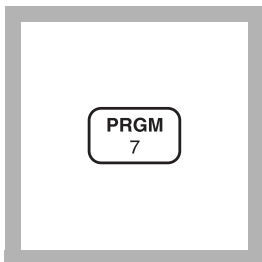
10. Tightly cover the vial with the instrument cap.



11. Press: **READ**

The cursor will move to the right, then the result in mg/L COD will be displayed.

Colorimetric Determination, 0 to 1,500 and 0 to 15,000 mg/L COD

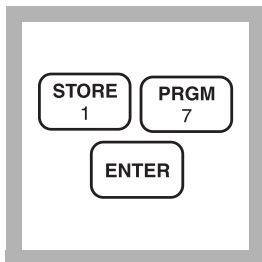


1. Enter the stored program number for chemical oxygen demand, high range.

Press: **PRGM**

The display will show:

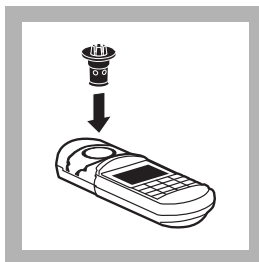
PRGM ?



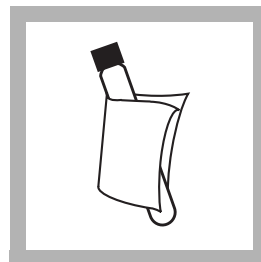
2. Press: **17 ENTER**

The display will show **mg/L, COD** and the **ZERO** icon.

*Note: For alternate form (O₂), press the **CONC** key.*

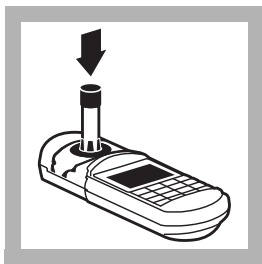


3. Insert the COD/TNT Adapter into the cell holder by rotating the adapter until it drops into place. Then push down to fully insert it.



4. Clean the outside of the blank with a towel.
Note: Wiping with a damp towel followed by a dry one will remove fingerprints or other marks.

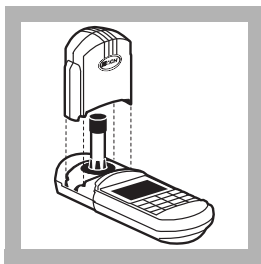
OXYGEN DEMAND, CHEMICAL, continued



5. Place the blank in the adapter.

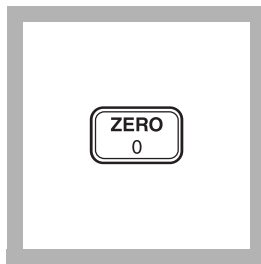
Push straight down on the top of the vial until it seats solidly into the adapter.

Note: Do not move the vial from side to side as this can cause errors.



6. Tightly cover the sample cell with the instrument cap.

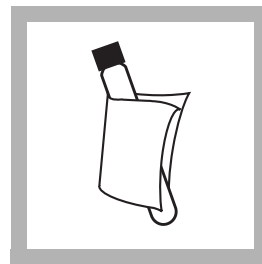
The blank is stable when stored in the dark. See Blanks for Colorimetric Determination following these procedures.



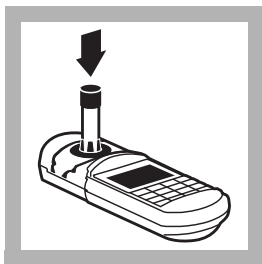
7. Press: **ZERO**

The cursor will move to the right, then the display will show:

0 mg/L COD



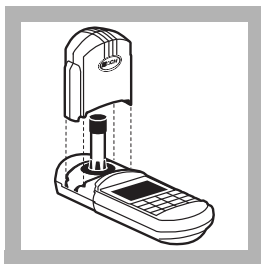
8. Clean the outside of the sample vial with a towel.



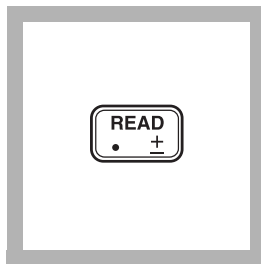
9. Place the sample in the adapter.

Push straight down on the top of the vial until it seats solidly into the adapter.

Note: Do not move the vial from side to side as this can cause errors.



10. Tightly cover the sample cell with the instrument cap.



11. Press: **READ**

The cursor will move to the right, then the result in mg/L COD will be displayed.

Note: When using High Range Plus COD Digestion Reagent Vials, multiply the reading by 10.

Note: For most accurate results with samples near 1,500 or 15,000 mg/L COD, repeat the analysis with a diluted sample.

Sampling and Storage

Collect samples in glass bottles. Use plastic bottles only if they are known to be free of organic contamination. Test biologically active samples as soon as possible. Homogenize samples containing solids to assure representative samples. Samples treated with sulfuric acid to a pH of less than 2 (about 2 mL per liter) and refrigerated at 4 °C can be stored up to 28 days. Correct results for volume additions; see *Correction for Volume Additions* (Section 1) for more information.

Accuracy Check

Standard Solution Method

Check the accuracy of the 0 to 150 mg/L range with a 100 mg/L standard. Prepare by dissolving 85 mg of dried (120 °C, overnight) potassium acid phthalate (KHP) in 1 liter of deionized water. Use 2.0 mL as the sample volume. The expected result will be 100 mg/L COD. As an alternative, dilute 10 mL of 1000-mg/L COD Standard Solution to 100 mL to make a 100-mg/L standard.

Check the accuracy of the 0 to 1,500 mg/L range by using either a 300 mg/L or 1000 mg/L COD Standard Solution. Alternatively, prepare a 500 mg/L standard by dissolving 425 mg of dried (120 °C, overnight) KHP. Dilute to 1 liter with deionized water. Use 2.0 mL of one of these solutions as the sample volume.

Check the accuracy of the 0 to 15,000 mg/L range by using a 10,000 mg/L COD standard solution. Prepare the 10,000 mg/L solution by dissolving 8.500 g of dried (120 °C, overnight) KHP in 1 liter of deionized water. Use 0.2 mL of this solution as the sample volume; the expected result will be 10,000 mg/L COD.

Method Performance

Precision

Program #16: In a single laboratory, using a standard solution of 100 mg/L COD and two representative lots of reagent with the instrument, a single operator obtained a standard deviation of ± 2 mg/L COD.

Program #17: In a single laboratory, using a standard solution of 1000 mg/L COD and two representative lots of reagent with the instrument, a single operator obtained a standard deviation of ± 16 mg/L COD. For more information on Hach's precision statement, see *Section 1*.

OXYGEN DEMAND, CHEMICAL, continued

Estimated Detection Limit (EDL)

The EDL for program 16 is 4 mg/L COD. The EDL for program 17 is 30 mg/L COD. For more information on derivation and use of Hach's estimated detection limit, see *Section 1*.

Alternate reagents

Mercury-free COD2 Reagents can provide a mercury-free testing option for non-reporting purposes. For process control applications, COD2 reagents will eliminate mercury waste and save on disposal costs. These reagents are fully compatible with test procedures and calibration curves programmed into the DR/2400 spectrophotometer. Determine chloride and ammonia for accurate results.

Note: Mercury-free COD2 reagents are not approved for USEPA reporting. Request a copy of the COD Reagent Vial Information Brochure, Lit. No. 1356, for more information about specific applications.

Interferences

Chloride is the primary interference when determining COD concentration. Each COD vial contains mercuric sulfate that will eliminate chloride interference up to the level specified in column 1 in *Table 1*. Samples with higher chloride concentrations should be diluted. Dilute the sample enough to reduce the chloride concentration to the level given in column 2.

If sample dilution will cause the COD concentration to be too low for accurate determination, add 0.50 g of mercuric sulfate (HgSO_4) to each COD vial before the sample is added. The additional mercuric sulfate will raise the maximum chloride concentration allowable to the level given in column 3.

Table 1

	Column 1	Column 2	Column 3
Vial Type Used	Maximum Cl^- concentration in sample (mg/L)	Maximum Cl^- concentration of diluted samples (mg/L)	Maximum Cl^- concentration in sample when 0.50 HgSO_4 added (mg/L)
Low Range	2000	1000	8000
High Range	2000	1000	4000
High Range Plus	20,000	10,000	40,000

Blanks for Colorimetric Determination

The blank may be used repeatedly for measurements using the same lot of vials. Store it in the dark. Monitor decomposition by measuring the absorbance at the appropriate wavelength (420 or 610 nm). Zero the instrument in the absorbance mode, using a vial containing 5 mL of deionized water and measure the absorbance of the blank. Record the value. Prepare a new blank when the absorbance has changed by about 0.01 absorbance units.

Summary of Method

The mg/L COD results are defined as the mg of O₂ consumed per liter of sample under conditions of this procedure. In this procedure, the sample is heated for two hours with a strong oxidizing agent, potassium dichromate. Oxidizable organic compounds react, reducing the dichromate ion (Cr₂O₇²⁻) to green chromic ion (Cr³⁺). When the 0-150 mg/L colorimetric method is used, the amount of Cr⁶⁺ remaining is determined. When the 0-1,500 mg/L or 0-15,000 mg/L colorimetric method is used, the amount of Cr³⁺ produced is determined. The COD reagent also contains silver and mercury ions. Silver is a catalyst, and mercury is used to complex the chloride interference.

Pollution Prevention and Waste Management

Final samples will contain mercury (D009), silver (D011), and chromium (D007) at concentration levels regulated by the Federal RCRA. Please see *Section 3* for further information on proper disposal of these materials.

REQUIRED REAGENTS

Description	Qty/Test	Unit	Cat. No.
Select the appropriate COD Digestion Reagent Vial:			
Low Range, 0 to 150 mg/L COD.....	1 to 2 vials	25/pkg.....	21258-25
High Range, 0 to 1,500 mg/L COD.....	1 to 2 vials	25/pkg.....	21259-25
High Range Plus, 0 to 15,000 mg/L COD	1 to 2 vials	25/pkg.....	24159-25
Water, deionized.....	varies	4 L.....	272-56

REQUIRED APPARATUS

Blender, Osterizer, 120 V, 14 speed.....	1	each.....	26160-00
Blender, Osterizer, 240 V, 14 speed.....	1	each.....	26160-02
DRB 200 Reactor, 110 V, 15 x 16 mm tubes		LTV082.53.40001	

OXYGEN DEMAND, CHEMICAL, continued

REQUIRED APPARATUS (continued)

Description	Qty/Test	Unit	Cat. No.
DRB 200 Reactor, 220 V, 15 x 16 mm tubes		LTV082.52.40001	
COD/TNT Adapter.....	1.....	each	48464-00
Pipet, TenSette, 0.1 to 1.0 mL.....	1.....	each	19700-01
Pipet Tips, for 19700-01 TenSette Pipet	1.....	50/pkg	21856-96
Pipet, volumetric, Class A, 2.00 mL	1.....	each	14515-36
Pipet Filler, safety bulb	1.....	each	14651-00
Test Tube Rack.....	1 to 2 racks	each	18641-00

ALTERNATE REAGENTS*

COD2, LR, 0 to 150 mg/L COD	1-2 vials	25/pkg	25650-25
COD2, HR, 0 to 1500 mg/L COD.....	1-2 vials	25/pkg	25651-25
COD2, HR, 0 to 1500 mg/L COD.....	1-2 vials	150/pkg	25651-15
COD2, HR, 0 to 15,000 mg/L COD.....	1-2 vials	25/pkg	28343-25

OPTIONAL REAGENTS

Description	Unit	Cat. No.
COD Digestion Reagent Vials, 0 to 150 mg/L COD	150/pkg	21258-15
COD Digestion Reagent Vials, 0 to 1,500 mg/L COD	150/pkg	21259-15
COD Standard Solution, 300 mg/L	200 mL	12186-29
COD Standard Solution, 1000 mg/L	200 mL	22539-29
Mercuric Sulfate.....	28.3 grams	1915-20
Oxygen Demand Standard (BOD, COD, TOC), 10-mL Ampules.....	16/pkg	28335-10
Potassium Acid Phthalate, ACS.....	500 g	315-34
Potassium Dichromate Standard Solution, 0.25 N.....	1000 mL*	1809-53
Sulfuric Acid, ACS	500 mL**	979-49
Wastewater Effluent Standard, Inorganic (NH ₃ -N, NO ₃ -N, PO ₄ , COD, SO ₄ , TOC)	500 mL	28332-49
Wastewater Influent Standard, Inorganic (NH ₃ -N, NO ₃ -N, PO ₄ , COD, SO ₄ , TOC)	500 mL	28331-49

OPTIONAL APPARATUS

Balance, analytical, 115 V.....	each	28014-01
Balance, analytical, 230 V.....	each	28014-02
Beaker, 250 mL	each	500-46H
Cylinder, graduated, 5 mL.....	each	508-37
DRB 200 Reactor, 110 V, 21 x 16 mm and 4 x 20 mm	LTV082.53.42001	
DRB 200 Reactor, 220 V, 21 x 16 mm and 4 x 20 mm.....	LTV082.52.42001	
DRB 200 Reactor, 110 V, 9 x 16 mm and 2 x 20 mm.....	LTV082.53.30001	

* Mercury-free COD2 reagents are not approved for USEPA reporting. Request a copy of the COD Reagent Vial Information Brochure, Lit. No. 1356, for more information about specific applications.

** Contact Hach for larger sizes.

OXYGEN DEMAND, CHEMICAL, continued

OPTIONAL APPARATUS (continued)

Description	Unit	Cat. No.
DRB 200 Reactor, 220 V, 9 x 16 mm and 2 x 20 mm	LTV082.52.30001	
Electromagnetic Stirrer, 120 V, with electrode stand.....	each.....	45300-01
Electromagnetic Stirrer, 230 V, with electrode stand.....	each.....	45300-02
Flask, volumetric, Class A, 1000 mL	each.....	14574-53
Flask, volumetric, Class A, 100 mL	each.....	14574-42
pH Paper, 1 to 11 pH units.....	5 rolls/pkg.....	391-33
Pipet, serological, 5 mL	each.....	532-37
Pipet Tips, for 19700-01 TenSette Pipet	1000/pkg.....	21856-28
Pipet, volumetric, Class A, 10 mL.....	each.....	14515-38
Spoon, measuring, 0.5 g.....	each.....	907-00
Stir Bar, 22.2 x 4.76 mm (7/8" x 3/16").....	each.....	45315-00
Stir Bar Retriever	each.....	15232-00
Timer.....	each.....	26304-00

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The Qurm Environmental Information Center Project

Technical Document 3
Mangrove Plantation Guideline

March 2014

JICA Expert Team

Table of Contents

1. Introduction	1
1.1 Objective of the Guideline	1
1.2 Objective of mangrove plantation	1
2. Selection of plantation site	4
2.1 Natural conditions.....	4
2.2 Social conditions	5
2.3 Others	5
2.4 Consultation of stakeholders	6
3. Plantation by seedling transplantation method	7
3.1 Seed collection, treatment and storage	7
3.2 Preparation of seedling.....	10
3.3 Transplanting of seedling.....	15
4. Plantation by Direct Sowing Method	19
4.1 Seed collection and treatment	19
4.2 Direct sowing	19

Appendix

Appendix 1 Field check list and evaluation sheet for site selection

1. Introduction

1.1 Objective of the Guideline

The Mangrove Plantation Guideline (hereinafter abbreviated as “Guideline”) was prepared based on the knowledge and experiences gained through the plantation activities conducted since 2001 by the Ministry of Environment and Climate Affairs (MECA) through the cooperation of Japan International Cooperation Agency (JICA).

The objective of the Guideline is to assist those who plan to implement mangrove plantation in Oman and other middle-east countries where *Avicennia marina* grows. However, the Guideline may also be applicable for other countries and mangrove species perhaps with some modifications.

The Guideline provides detailed descriptions on the plantation procedures, in particular the “seedling transplantation method”, which is the main method employed by MECA. This method conducts plantation by transplanting seedlings that were artificially grown in a seedling nursery. The Guideline also provides descriptions for an alternative plantation method termed “direct sowing method”. This method conducts plantation by sowing seeds directly at the plantation site. Table 1.1 compares the advantages and disadvantages of both methods.

Table 1.1: Comparison of advantages and disadvantages of “seedling transplantation method” and “direct sowing method”

	Seedling Transplantation Method	Direct Sowing Method
Cost	High	Low
Nursery	High cost to construct nursery	Low cost as no need to construct nursery
Necessary input	High input for materials and labourers to produce seedlings	Low input as no need to produce seedlings
Transportation	High cost for seedling transportation	Low cost for seed transportation
Number of seeds required	Need relatively less amount of seeds compared to direct sowing method	Need large amount of seeds due to low root-taking rate
Field work	Need equipment and labourers for seedling transplantation	Easy and require no equipment and labourers
Root-taking rate	High	Low

Although “seedling transplantation method” requires high cost for nursery construction, seedling production, transportation and transplantation, the root-taking rate of the transplanted seedlings are relatively high. On the other hand, the cost of “direct sowing method” is relatively low but has lower root-taking rate. The best method should be selected according to the objective of plantation and the characteristics of the plantation site.

1.2 Objective of mangrove plantation

Mangrove plantation is generally conducted to compensate lost mangrove area (e.g. through development) or to create new mangrove area. Mangrove plantation is also conducted as mangroves provide various benefits to the people and environment. Followings are some examples of benefits that can be derived through plantation:

- Provides precious greenery as recreational and educational sites to the coastal area, which is especially significant in arid countries like Oman.



Fig. 1.1: Plantation to create recreational and educational sites

- Provides habitats and feeding area for numerous animals including fishes, crabs and birds.



Fig. 1.2: Plantation to enrich biomass and biodiversity

- Provides protection of shorelines against erosion.



Fig. 1.3: Plantation as countermeasures against erosion

- Improves coastal water quality by capturing silt and absorbing pollutants.



Fig. 1.4: Plantation to improve coastal water quality

Mangrove plantation should be planned by considering the benefits mentioned above. However, despite the various benefits, it is also important to consider negative aspects of mangrove plantation when planning plantation such as:

- Conflict with land use (e.g. plantation in private land or in communal land).



Fig. 1.5: Conflict with existing land use through plantation

- Reduction of bird feeding ground.



Fig. 1.6: Reduction of bird feeding ground through plantation

2. Selection of plantation site

Selection of an appropriate plantation site is important in order to perform successful mangrove plantation. The following section describes the factors to consider for site selection. A field check list and evaluation sheet for site selection was prepared (see Appendix 1), which can be used for evaluating the candidate site at the field (a soft copy of Appendix 1 is included in the attached CD).

2.1 Natural conditions

(1) Meteorology

Meteorological conditions such as temperature, wind direction and wind speed should be considered in the site selection process. Areas subject to cold winter temperature and/or constant strong winds are generally unsuitable for plantation.

(2) Hydrology

Hydrological conditions such as sea water exchange, current regime and wave action should be considered in the site selection process. Following are some important factors to consider:

- Regular water exchange is important for the growth of seedlings. Avoid plantation in areas where water exchange is limited.
- Avoid plantation in areas that are subject to high waves and strong current, as it will hinder settlement of seedlings.

(3) Intertidal zone

Since plantation is basically conducted in the intertidal zone, check the area available for plantation by studying the width and slope of the intertidal zone. In general, a wide intertidal zone is more suitable for plantation.

(4) Soil properties

Areas with thin soil layer are not suitable for plantation as it will hinder root growth. The depth of the soil layer should be at least more than 15 cm. In addition, soils with anoxic conditions, high salinity and muddy texture are unsuitable for plantation.



Fig. 2.1: Unsuitable soil properties for plantation (left: anoxic soil, right: high salinity soil)

(5) Water quality

Areas with high water salinity (more than 50 ‰) and low DO concentration are generally unsuitable for plantation.

(6) Fauna

Mangrove plantation can have adverse impacts on animals that feed and live in the intertidal zone. While some of these animals may coexist with mangroves, some may not be as adaptable. One of the main issues that have been raised recently, is that mangrove plantation will reduce the feeding area of birds, as many bird species prefer to feed at exposed intertidal areas. So study the bird feeding areas carefully and avoid plantation if it will significantly reduce existing bird feeding areas.

2.2 Social conditions

(1) Risk of animal grazing

Areas with high risk of grazing by domestic animals such as camels, goat and sheep should be avoided.



Fig. 2.2: Grazing of mangrove by domestic animals

(2) Existing land use

Mangrove plantation can alter the existing land use of the local residents. Therefore, avoid plantation in areas that are heavily used by the local residents (e.g. boat landing, recreational activities).

(3) Future development plan

Avoid plantation in areas that are within or near to areas proposed for future development such as road and port construction, as these development activities will likely have adverse impacts on the planted seedlings.

2.3 Others

(1) Past distribution of mangrove forest

If available, try to collect information (e.g. aerial photos, satellite image) of past mangrove distribution. For sites where mangroves grew in the past, reforestation should be promoted for the recovery of mangrove forest. Priority should be given for such site.

(2) Future expansion potential of mangrove forest

Consider the potential area for future expansion of the mangrove forest, by studying the topography, tidal range and other factors. Reconsider plantation if such expansion will have adverse effects on natural or social conditions.

(3) Accessibility and necessary cost

Preferably, the plantation site should be relatively easy to access as plantation activities require seedling transportation and maintenance works. The cost of transplantation should also be considered through cost and benefit analysis. The possibility of alternative low cost methods (e.g. direct sowing method) should also be considered.



Fig.2.3: Difficulties encountered during seedling transportation

2.4 Consultation of stakeholders

The local residents should be consulted prior to selecting the plantation site to avoid future problems. A strong willingness of the local residents to plant and maintain mangrove forest is also important for successful plantation.



Fig. 2.4: Consultation of local stakeholders

3. Plantation by seedling transplantation method

3.1 Seed collection, treatment and storage

(1) General characteristics of *Avicennia marina* seed

A. marina seeds cannot be stored for long periods because they are viviparous. In other words, the seeds have no dormant period and keep growing even after detachment from the mother tree. Therefore, the seeds are delicate and deteriorate easily especially in hot and humid conditions.

A. marina seeds have a pericarp (thin skin that coats the seed) for floatation in seawater and protection from dehydration. The seed sinks to the seafloor once the pericarp is removed, which usually takes between 6 hours to 2 days. These characteristics should be taken into consideration for seed collection, treatment and storage.

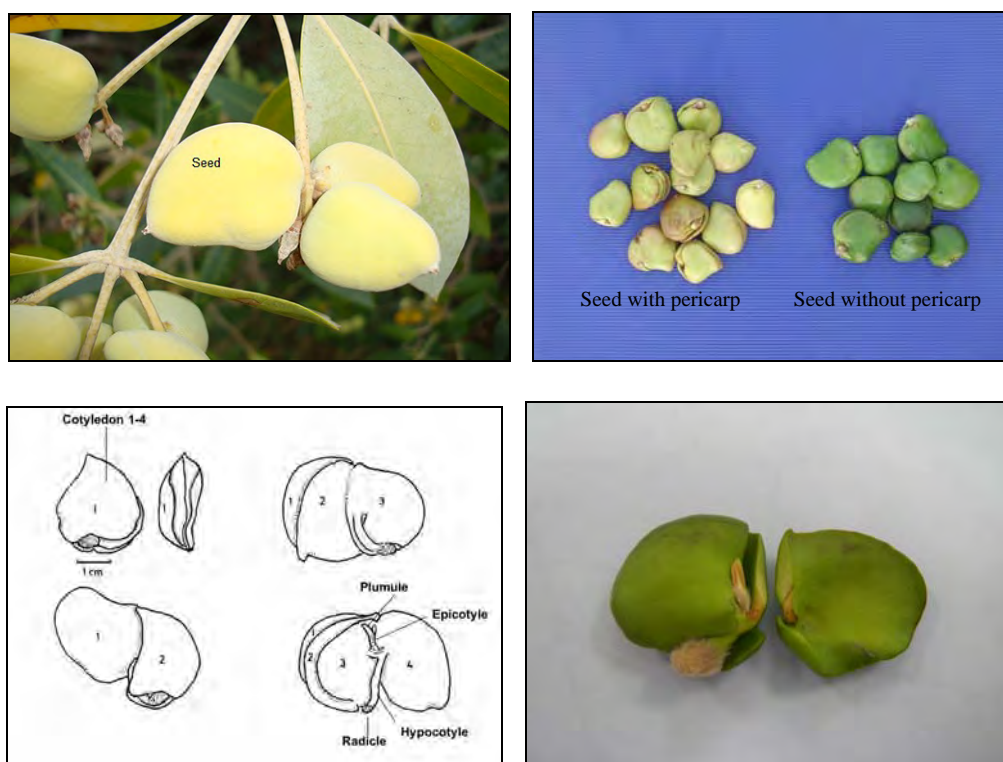


Fig. 3.1: Characteristics of *A. marina* seed

(2) Seed collection

(i) Timing and season

The fruition season of mangrove should be clarified before starting plantation project. In Oman, seeds can be collected from early July-August in the northern region. In the Dhofar region, seeds can be collected during two seasons: in May-June and December-January. Prior to the seed collection works, make sure the nursery is prepared for sowing as seeds cannot survive for long periods after collection.

(ii) Seed collection site

Following are some factors that should be considered when selecting the seed collection site:

- Seeds should be collected from a healthy and matured mangrove forest.
- The seed collection site should be easily accessible for the workers to carry out the task.
- Preferably, seeds should be collected from mangroves near the nursery site.

(iii) Collection of seeds

Following are some factors that should be considered when collecting seeds:

- Size of seed should be relatively large, preferably weighing more than 3 grams with pericarp. Do not collect fallen seeds on ground.
- Seeds with a tiny pin hole on the surface of pericarp should be excluded, as it is a sign of insect infestation.
- Since the branches of mangrove trees are fragile, it is recommended not to climb up the trees for seed collection.
- Since seeds are bruised easily, seeds should be collected carefully. Bruised seeds are easily infected by fungi. Seeds cannot survive once it is infected by fungi.



Fig. 3.2: Seed collection and collected seeds

(3) Seed treatment

(i) Purpose of treatment

Seeds are treated mainly to remove pericarp, which is easily affected by fungi and can then spread to the whole seed. Since the treated seeds cannot be stored for a long time, only the necessary amount of seeds should be treated.

(ii) Necessary equipment

- Large water containers (e.g. 70-100 liters) for seed treatment.
- Small buckets or water pump to draw water.

(iii) Procedure

Step-1: Put the collected seeds into a container. The volume of the seeds should be less than one sixth ($1/6$) of the volume of the container to avoid damage to the seeds by their weight. Then fill the container with fresh seawater and soak the seeds for around 24 hours (around 6

hours in case of stored seeds). After a while, the seawater in the container will change its color to brown. So, change the water at least every 2 hours.

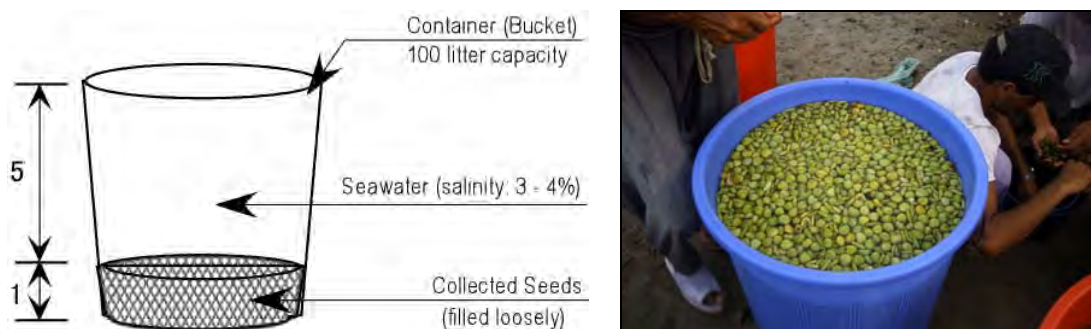


Fig. 3.3: Soaking of collected seeds

Step-2: After soaking for a while, the pericarp of the seeds will usually peel off by themselves. If not, they should be peeled off by hand. Healthy naked seeds will sink to the bottom of the container. Remove the pericarp from the container as they can damage the seeds.

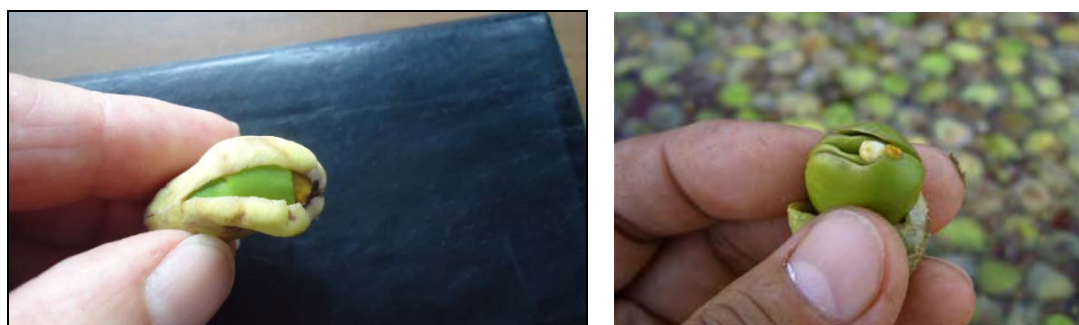


Fig. 3.4: Removal of pericarp

If the pericarp is infected by fungus (left photo below), the underlying seed is also usually infected (right photo below). Since fungus infected seeds cannot grow, remove all such infected seeds during the peeling off process. Also remove naked seeds that keep floating as they are usually infected by insects.



Fig. 3.5: Infected pericarp and seeds

Step-3: Transfer the healthy naked seeds (i.e. seeds at the bottom of the container) into another container filled with fresh seawater. Soak the seeds for another 6 hours or more to remove mucus around seeds. The wastewater used for soaking the seeds should not be reused.

(4) Seed storage

If the collected seeds cannot be sowed immediately, they can be stored for 10 to 15 days if done properly. Following are some tips for seed storage:

- Do not remove the pericarp when storing seeds.
- Store the seeds in a cool and dry shaded area or under air conditioned room. Air temperature should be less than 26 degrees, and make sure the seeds are dry. The seeds should not be piled on top of each other, but instead should be spread evenly on the floor.
- Regularly turn the seeds upside down to release heat and moisture to avoid fungus infestation on pericarp. Fungus often appears if the seedlings are piled. Seeds cannot survive once the surface is infected by fungus.
- Check and remove damaged seeds (e.g. fungus and insect infected).
- Do not store the seeds in a refrigerator, as it may get cold burn and die.

3.2 Preparation of seedling

Seedlings are usually grown in a seedling nursery. There are two types of nurseries: a “permanent type” and “temporary type”. A “permanent type” nursery is a fixed structure and is usually constructed if there is a constant demand for seedlings. A “temporary type” nursery is much simpler without any fixed structure, and can be employed among others if seedling demand is temporary or construction of a “permanent type” nursery is too costly or difficult. See Section 3.2 (6) for more explanation on “temporary type” nursery.

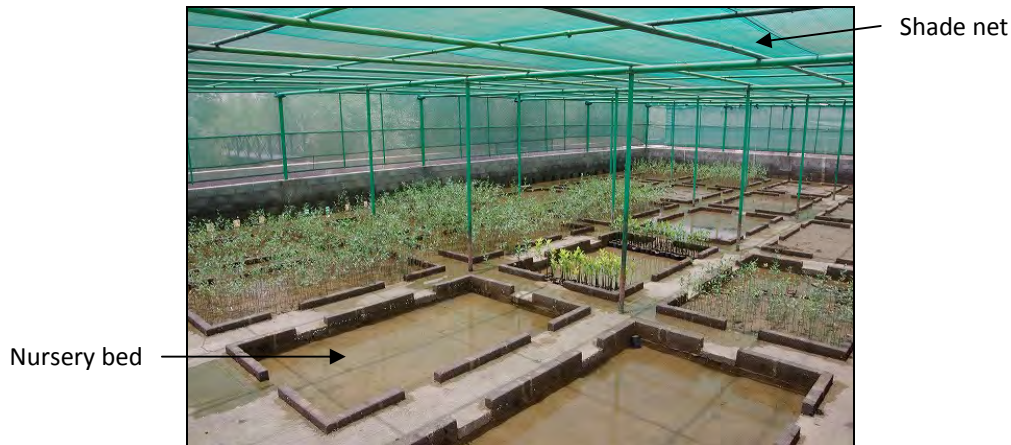


Fig. 3.6: General structure of “permanent type” nursery

The procedures of seedling preparation are explained by using “permanent type” nursery.

(1) Location and size of nursery

The location and size of the nursery should be determined by considering the following:

- Location of the planned plantation sites
- Seedling demand
- Accessibility for operation and maintenance

- Accessibility to irrigation seawater and sandy soil for seedling pots
- Risk of natural hazards (e.g. floods)

(2) Irrigation of seedlings

There are two types of irrigation method: pump irrigation method and tidal irrigation method. In general, tidal irrigation is suitable if the water source has daily tidal fluctuation. On the other hand, pump irrigation is suitable if the water source has no or only limited tidal fluctuation. Details of each method are described below:

(i) Tidal irrigation

Tidal irrigation is highly recommended as the seedlings are irrigated automatically through tidal fluctuation. However, the level of water intake and nursery bed must be carefully considered for effective irrigation. In general, water intake level can be determined by applying the following formula:

$$\text{Water intake level} = (\text{Lowest-H} + \text{Highest-L})/2$$

Lowest-H: lowest high tide level within the year

Highest-L: Highest low tide level within the year

The following figure shows the basic structure and water intake level of tidal irrigation nursery.

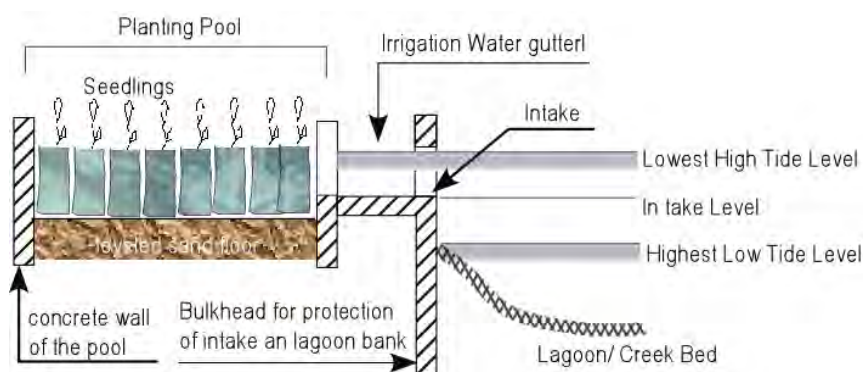


Fig. 3.7: Basic structure and water intake level of tidal irrigation nursery

(ii) Pump irrigation

In case of the pump irrigation method, irrigation water should be filled in the planting pool by operating a pump and drainage gate. The seedlings should be inundated at least once per day. A drainage gutter and drain outlet is also required for proper drainage, which should be higher than the highest high tide level (in case there is tidal fluctuation). The following figures show the basic structure of pump irrigation nursery.

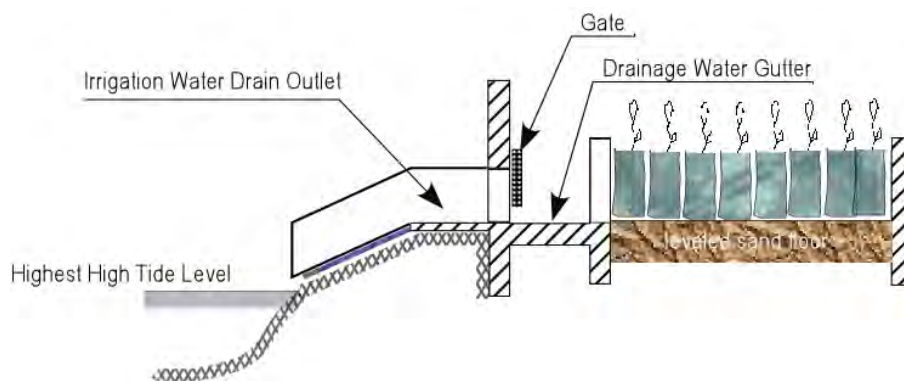


Fig. 3.8: Basic structure of pump irrigation

(3) Shading of seedlings

A shade net can be installed in the nursery to prevent damage of young seedlings from direct sunlight and hot dry wind. The following figure shows an example of shade net structure.

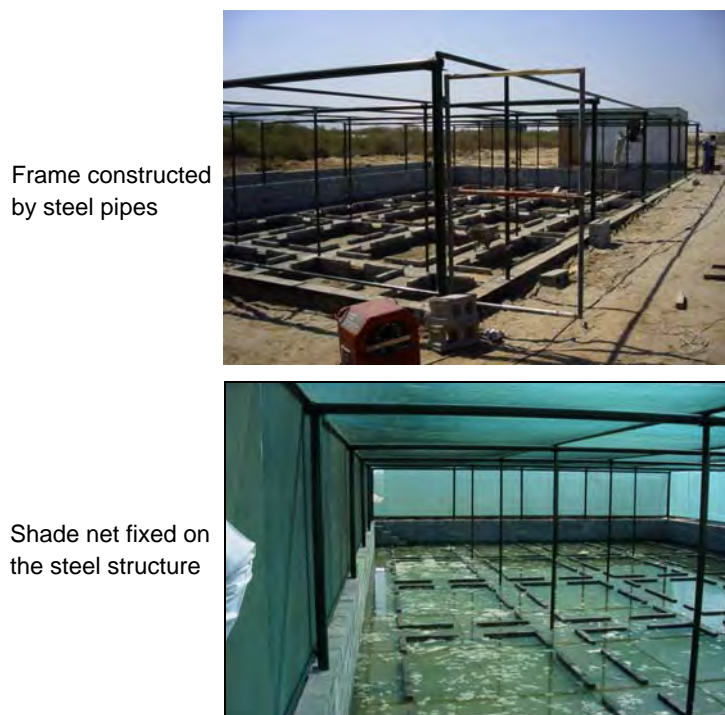


Fig. 3.9: Structure of shade net

If possible, the shade net should be removable as excessive shading may promote spindly growth¹ of seedlings.

(4) Sowing of seeds

After removing the pericarp, seeds should be sown as soon as possible. Following are some tips for seed sowing:

¹ Spindly growth: Plants growing under insufficient sunlight and excess fertilization may become overly tall. Such plants tend to be weak against diseases and other stresses.

- An agricultural vinyl pot can be used as a seedling pot. Typical pots used are 10 cm diameter and 25 cm height with punched holes for water to drain.
- Normal beach sand at the site or near the nursery should be used for soil. Silt or muddy soil should not be used.
- Sow 1 seed per pot. Remove pots with dead seed (change to black color) and replace by new pot with a healthy seed. This is because dead seeds are quickly infested by fungi and bacteria, which can spread to the other healthy seeds.
- One third ($1/3$) to half ($1/2$) of the seed should be out of sand as shown in the figure below.

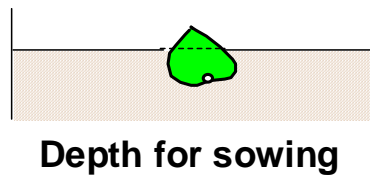


Fig. 3.10: Sowing depth of seeds



Fig. 3.11: Young shoots after 7-10 days after sowing



Fig. 3.12: Seedling growth 4 months after sowing

(5) Operation and maintenance

Main activities after seed sowing are irrigation management and shade control. Make sure the nursery is regularly inundated and drained properly. The following maintenance works are also required to keep the nursery in good condition:

- Steel pipes used for the nursery should be maintained especially for the part inundated by seawater, as it can quickly corrode. One of the examples shown in the figure is to protect the bottom of the steel pipe by PVC pipe and concrete.



Fig. 3.13: Protection of steel pipe from seawater

- Shade net should be periodically cleaned in order to keep the light conditions constant. Furthermore, shade net should be replaced from time to time.



Fig. 3.14: Cleaning of shade net

(6) Temporary nursery

The structure of the temporary nursery is much simpler than permanent type. Construction materials are usually available at the site and has minimal requirement of concrete structures. Number of planting pool to be constructed should be determined by calculating the number of seedling to be required for the designated planting area and planting schedule. Following figure shows the basic design of the temporary nursery.

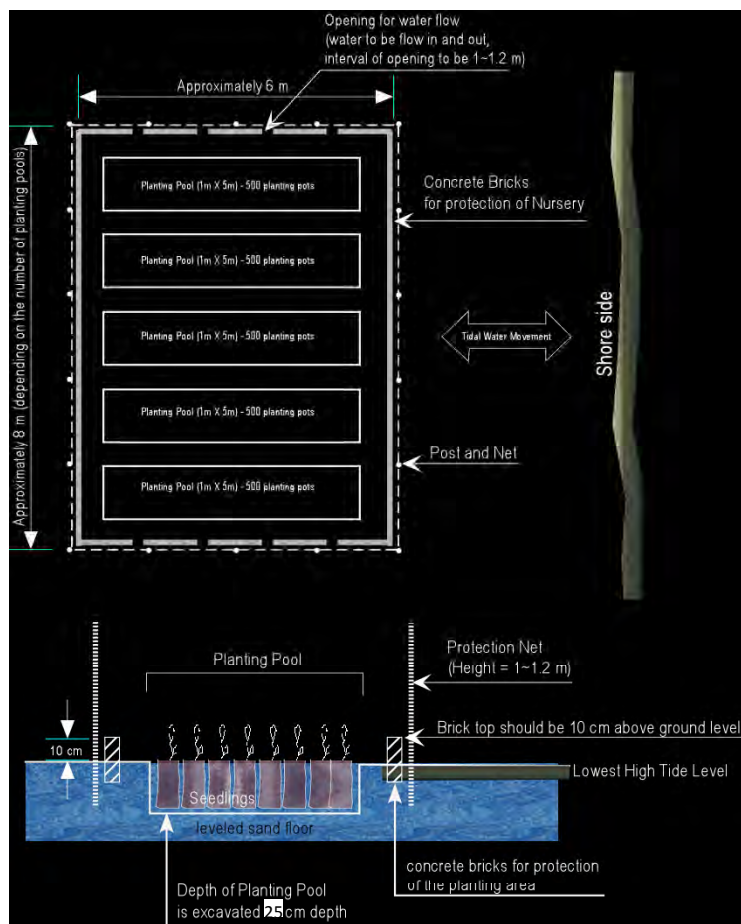


Fig. 3.15: Basic design of temporary nursery

3.3 Transplanting of seedling

In general, seedlings should be transplanted among others by considering the following:

- The upper half of the intertidal zone (between mean water level and high water level) is generally suitable for transplanting
- Area with very slow current and no strong wave
- Soil with good drainage (e.g. sand)
- Water salinity less than 50 ppt (5%)

(1) Procedure for transplanting

(i) Timing and season

Seedlings can be transplanted about 6 months after sowing. Therefore, in Oman, transplantation is usually conducted around January-February in Northern Regions, and in November-December and June-July in the Dhofar region.

(ii) Necessary equipment

- Truck and wheel barrow for transportation of seedling, pots and equipment.



Fig. 3.16: Truck and wheel barrow for seedling transportation

- Trowels or shovels for digging and backfilling.

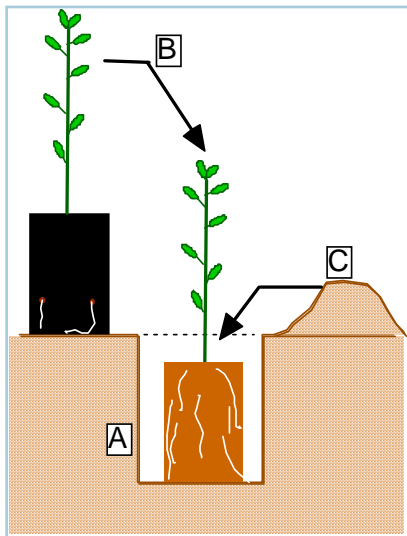


Fig. 3.17: Trowels and shovels for digging and backfilling

- Measuring rope (e.g. 50 m) with 1 m interval mark
- Compass bearing to determine direction of the measuring rope
- GPS for recording the transplanted location.

(iii) Procedure

- Start transplanting work at the time of lowest tide.
- Stretch a measuring rope at the designated planting area and dig a hole at constant interval (e.g. 1 m) along the rope.
- Transplant seedlings at the hole prepared by referring to the following figure.



- A: Dig a hole a little bit deeper than the pot
- B: Remove the plastic pot and put the seedling with soil without damaging roots
- C: Backfill the hole with soil and compact moderately

Fig. 3.18: Process of seedling transplantation

- To protect the seedlings from waves and seaweeds, the frontline of plantation area should be planted densely. Recommended planting density is (0.7-1.0 m) × (0.7-1.0 m).
- Following is a brochure that can be distributed during transplantation events, which provides basic plantation procedures with illustrations.



Fig. 3.19: Brochure explaining the basic procedure of seedling transplantation

- Upon completion of the plantation works, record the coordinates of the perimeter of the planted area with GPS.

(2) Monitoring of seedling

The transplanted seedlings should be regularly monitored (e.g. 1 month) to observe their growth and health, as well as to identify any natural and human threats. The monitoring method is described in the “Mangrove Monitoring Guideline (Technical Document 2).

4. Plantation by direct sowing method

4.1 Seed collection and treatment

Seed collection and treatment for direct sowing method is generally same as seedling transplantation method.

4.2 Direct sowing

Compared to the seedling transplantation method, the direct sowing method is low in cost as it requires no seedling production in the nursery. Furthermore, the growth speed of the seedling is faster for direct sowing because the sown seeds extend their root system smoothly in the soil after sowing. On the other hand, the transplanted seedlings need certain period for extending new root system in the dug pit and consequently seedling growth is slow during this period.

(1) Location for direct sowing

Basic conditions required for the planting site are the same as the seedling transplantation method. However, the adjacent waters need to be very calm to avoid seed dispersal. The direct sowing method can also be applicable in deep swampy areas where people cannot enter to work.

(2) Sowing procedure

Sowing season is dependent on the seed collection time. It can be July-August in northern regions, and May-June and December-January in Dhofar Region.

Compared to the transplantation method, large number of seeds can be used for direct sowing. Although the germination rate of each seed in direct sowing may be lower, it can be compensated by the sheer quantity of seeds available.

Seeds maybe sown by scattering or by sowing them into the soil. In the later case, depth of sowing should be adjusted according to the soil conditions. In sandy areas seed should be placed 3 cm under surface and covered with sand. While in muddy or silty areas, half of the seed should be out of mud.



Fig. 4.1: Sowing of seeds by scattering

Appendix 1 Field check list and evaluation sheet for site selection

Attachment-1: Field Checklist for Site Selection (Observation Sheet)

Date: _____ **GPS Northing:** _____ **Tide during survey (high/low):** _____

Location: _____ **GPS Easting:** _____ **Existing mangrove tree (matured tree/seedlings):** _____

No.	Points to be checked	Favorable condition for plantation (5 point)	Medium condition for plantation (3 point)	Unavorable condition for plantation (1 point)	Evaluation					Note
					5	4	3	2	1	
1	Situation of the mouth of khawr	Mouth of khawr is opened throughout the year	Mouth of khawr is occasionally closed	Mouth of khawr is closed throughout the year	5	4	3	2	1	
2	Situation of the tidal current and ocean wave	Tidal current and wave are calm throughout the year	Tidal current and wave are occasionally strong	Tidal current and wave are strong throughout the year	5	4	3	2	1	
3	Extent of intertidal zone	Intertidal zone is wide and flat	Intertidal zone is medium and rather slopy	Intertidal zone is narrow and steep	5	4	3	2	1	
4	Thickness of the soil layer	Enough soil depth for root growth more than 15cm	Limited soil depth for root growth less than 15cm	No soil layer at all	5	4	3	2	1	
5	Smell of hydrogen sulfide from subsurface soil layer	No smell of hydrogen sulfide from soil layer at all	Some smell of hydrogen sulfide in some places	Strong smell of hydrogen sulfide at everywhere	5	4	3	2	1	
6	Salinity level of water	Average water salinity is very low (less than 2%)	Average water salinity is similar to ordinary sea water (3-4%)	Average water salinity is very high (more than 5%)	5	4	3	2	1	
7	Situation of the grazing activity potential	No grazing activity potential at all	Occasional grazing activity potential seasonally	Heavy grazing activity potential due to the situation	5	4	3	2	1	
8	Land use situation by the local community	No human activity in the site	Occasional human activity in the site	Heavy human activity in the site	5	4	3	2	1	
9	Access from the main road to the site for plantation and maintenance	Easy access from the main road to the site by road	Moderate access from the main road to the site with rough road	Difficult access from the main road to the site without road	5	4	3	2	1	
10	Utilization as birds feeding ground	No use as birds feeding ground	Some use as birds feeding ground	High use as birds feeding ground	5	4	3	2	1	
11	Coastal development plan	No plan for future development	Some paper plan for future development	Practical plan for future development	5	4	3	2	1	

Field Checklist for Site Selection (Sample Evaluation Sheet)

Date: 2013/10/4

GPS Northing:563513

Tide during survey (hig/low): Surveyed during low tide

Location: Grim

GPS Easting:2630736

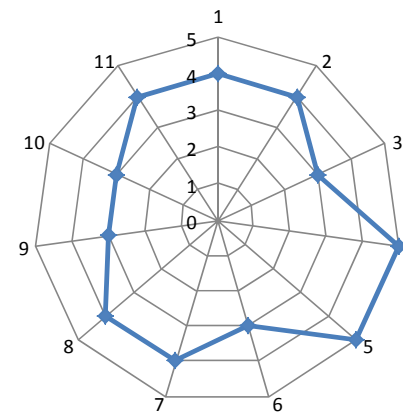
Existing mangrove tree: Both matured trees and seedlings were available

No.	Points checked	Evaluation	Note
1	Situation of the mouth of khawr	4	Better to ask local people
2	Situation of the tidal current and ocean wave	4	Generally calm but some wind ripple was observed
3	Extent of intertidal zone	3	Generally flat and more or less wide area
4	Thickness of the soil layer	5	Deep enough
5	Smell of hydrogen sulfide from subsurface soil layer	5	No smell at all
6	Salinity level of water	3	Better to check several places
7	Situation of the grazing activity potential	4	No symptom was observed on mangrove leaves
8	Land use situation by the local community	4	Site is adjacent to the residential area of the local people
9	Access from the main road to the site for plantation and maintenance	3	Need to pass rough road
10	Utilization as birds feeding ground	3	Several species of birds were observed
11	Coastal development plan	4	Better to ask local people

Satellite Image or Google Earth Image



Evaluation Result



The Qurm Environmental Information Center Project

Technical Document 4
Mangrove Protection Guideline

March 2014

JICA Expert Team

Table of Contents

1	Introduction	1
1.1	Objective of the Guideline	1
1.2	Legal framework related to mangrove ecosystem protection	1
2	Potential threats to mangrove ecosystem and recommended protective measures	2
2.1	Coastal development	2
2.2	Tourism	4
2.3	Waste dumping	5
2.4	Mangrove utilization	6
2.5	Collection of fauna	7
2.6	Invasive species	7
2.4	Overgrowth of algae	8

1 Introduction

1.1 Objective of the Guideline

The Mangrove Protection Guideline (hereinafter abbreviated as “Guideline”) was prepared mainly to assist the staffs of QEIC/MECA responsible for managing and protecting the mangrove ecosystem in Oman. The Guideline explains potential threats to mangrove ecosystems in Oman and recommended measures to counter against these threats, which includes practical as well as regulatory measures. Note that the Guideline focuses on protecting not only the mangrove forest but also the various fauna that constitute the mangrove ecosystem.

1.2 Legal framework related to mangrove ecosystem protection

Existing laws and regulations related to mangrove protection are as follows:

- The Law on Conservation of the Environment and Prevention of Pollution (Royal Decree No. 114/2001)
- The Law on Nature Reserves and Wildlife Conservation (Royal Decree No. 6/2003)
- Decision No 20/90 regarding the rules regulating and specifying coastal setbacks

Although there are no direct descriptions about mangroves in these laws and regulations, relevant articles are as follows.

Royal Decree No. 114/2001

This law is the basic environmental law of Oman. Article 21 prohibits cutting down, uprooting or damage of any tree, shrub or grass in public forests, without obtaining a permit from the Ministry. Article 33 penalizes anyone who cuts down tree in conservation area by either imprisonment for a term not exceeding one month or with fine not less than RO 10 and not more than RO 500. Since mangroves are basically public forests, these articles are applied.

Royal Decree No. 6/2003

This law is the basic law regarding nature reserves and wildlife conservation. Nature reserves are designated by Royal Decree as stipulated in Article 10. QNR and khwars of the Dhofar region are nature reserves with mangrove distribution. QNR and khwars of the Dhofar region are designated as nature reserve through Royal Decree 38/75 and Royal Decree 49/97, respectively.

Article 13 stipulates the development of management plan. The management plan is required to designate the nature reserve into public zone, specially protected zone and zone for research/education purposes.

Decision No 20/90

The Decision specifies setbacks for coastal areas including sandy beaches and khwars, which is where mangroves are commonly distributed. Setbacks of sandy beaches and khwars are specified as 150 m from the maximum end of tidemark. However, setbacks may be specified as 50 m for beaches where the construction developments have limited impact on the environment.

2 Potential threats to mangrove ecosystem and recommended protective measures

2.1 Coastal development

1) Threats

Coastal development may adversely affect mangrove ecosystem in various ways. While development in mangrove area is basically prohibited in Oman, it is important to be aware that development activities outside of mangrove areas can also affect mangrove ecosystem, which may somewhat be a more gradual and long-term process.

Port construction, including marinas, is one of the major threats to mangroves in Oman. An example can be seen at Khawr Harmul at Liwa. Following the construction of Port of Sohar at a location approximately 2.5 km southeast from Khawr Harmul, severe beach erosion and accretion occurred along the coastline, and as a result, the mouth of Khawr Harmul had moved 200-300 m from the original location. Figure 1 shows how the location of the mouth of Khawr Harmul has changed before and after port construction. Such movement of the mouth will have changed significantly the hydrology of the mangrove forest, and as a result threaten the long-term survival of the mangroves. In extreme case, the mouth of Khawr Harmul could eventually close through sediment accretion, which will have devastating impacts on the mangrove ecosystem as there will be no more seawater inflow from the mouth.

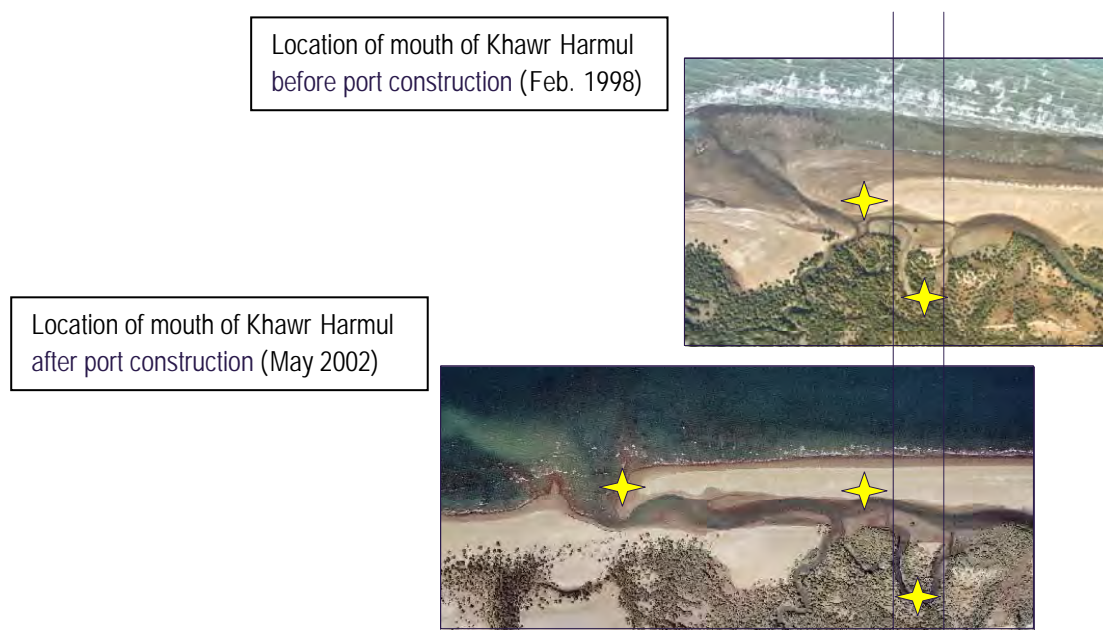


Figure 1 Location of mouth of Khawr Harmul before and after port construction

Road construction in the vicinity of the mangrove forest may also have adverse impacts. For example, when roads are built, the underlying soil is compressed and this results in soil compaction. This as a consequence, may alter the hydrology of the mangrove area (e.g. hindrance of water drainage), and as a result affect mangrove health.

Construction activities may also impact mangrove ecosystems. Following are some examples:

- Pollution of lagoon water by discharge of construction wastewater (see Figure 2)
- Disturbance to fauna (e.g. birds) by emission of loud noise (e.g. pile-driving works)
- Accumulation of dust on mangrove leaves by dust dispersion



Figure 2 Wastewater discharge into QNR

2) Protective measures

Establishment of buffer zone

To protect mangrove ecosystem from encroaching development activities, a “buffer zone” may be established outside the periphery of mangrove forest (see Figure 3). While people will be free to enter the buffer zone, no industrial, commercial or housing structures will be allowed to be built inside the buffer zone, including temporary structures (e.g. access road). However, small-scale structures that are used for recreational purposes (e.g. boardwalk, huts) may be exempted. The width of the buffer zone may be determined on a site-by-site basis, by taking into account the characteristics of each site.

A buffer zone may also help to remove pollutants contained in wastewater (e.g. from septic tanks) through its soil purification function, and consequently prevent or minimize pollutants reaching the mangrove area.

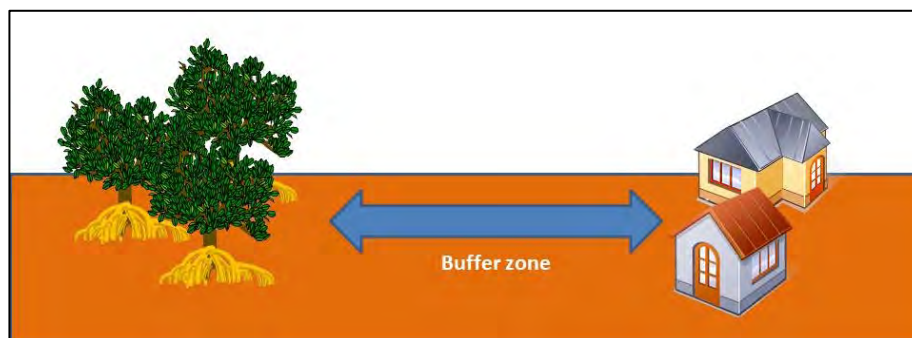


Figure 3 Concept of buffer zone

Implementation of EIA

Any development projects with potential impacts on mangrove ecosystem should be required to undertake an Environmental Impact Assessment (EIA) study. The EIA study should include among others a detailed baseline study, analysis of alternatives, impact assessment and environmental management plan. Following are some important points to be covered by the EIA:

- The EIA should have a detailed and rational description on the site selection process, including an analysis of alternative development sites.

- The baseline study should be based on a comprehensive field survey, including both physical (e.g. water quality) and biological environment. Seasonal variations in the environment (e.g. migratory patterns of birds) should be taken into account when planning the timing of field surveys.
- Impacts on hydrology (both groundwater and surface water) and topography of the mangrove forest are one of the major concerns, and hence should be assessed in detail by for example employing a numerical simulation model. If significant changes are predicted, impacts of such changes to the mangrove ecosystem should be assessed in detail including long-term impacts.
- A detailed environmental management plan should be provided if any impacts on mangrove ecosystem are predicted. The environmental management plan should include cost, schedule and the organization responsible for implementing the mitigation measures and monitoring activity.

2.2 Tourism

1) Threats

Mangrove forests have high potential for tourism as it can readily provide opportunities for people to enjoy greenery and its rich biodiversity. While tourism in mangrove forests should be encouraged, it could have adverse impacts on mangrove ecosystem, if conducted in an uncontrolled manner. Possible impacts of tourism include:

- Disturbance of benthic organisms by tourists trampling over their habitats (e.g. burial of crab burrows)
- Disturbance of sensitive wildlife by inconsiderate behaviour of tourists (e.g. chasing or scaring off birds)
- Collecting of animals by tourists
- Littering and defecation by tourists

2) Protective measures

In order to promote sustainable tourism, certain facilities and rules should be set to avoid or minimize adverse impacts. Following are some recommended measures:

- To minimize disturbance to benthic habitat, tourist should be allowed to walk only along designated pathways. Boardwalks may be constructed for this purpose (see Figure 4).
- Number of tourists entering the mangrove forest should be limited to prevent unnecessary disturbance to wildlife. A no-entry period may be established to allow recovery of animals.
- Shouting or generating loud noise should be prohibited.
- Collection of wildlife should be prohibited.
- Littering should be strictly prohibited and should be taken back by the tourist.
- Toilets should be installed at appropriate locations.
- Signboards should be installed that shows the prohibition rules.



Figure 4 Boardwalk in QNR

2.3 Waste dumping

1) Threats

Mangrove forests could end-up as a convenient place for dumping wastes, as the dumped waste will be hid by the trees and not be as visible as dumping in open space. Waste dumped in the upstream area or sea may also end-up in the mangrove forest by flood, current and tidal movement. Following are some potential adverse impacts of waste dumping:

- Wastes can bury habitats of benthic organisms (e.g. crabs).
- Animals could consume wastes by mistaking them as food.
- Wastes (e.g. plastic bag) can entangle on young mangrove trees and consequently bend or uproot the stem by acting like a sail in windy condition (see Figure 5).
- Wastes (e.g. plastic bag) can entangle or bury aerial roots and consequently hinder respiration of mangrove trees (see Figure 5).
- Toxic pollutants such as PCBs can leak out from wastes (e.g. electrical products) and pollute the forest and kill animals.
- Food waste could attract unwanted animals such as rats.



Figure 5 Impacts of waste on mangrove forest

2) Protective measures

Illegal waste dumping is a common occurrence among localities where their waste collection system is inadequate or enforcement of proper waste disposal is weak. Strengthening of the local waste management is hence the first priority. Following are some additional measures that could be implemented:

- Implementation of education and awareness campaigns (e.g. beach clean) to reduce illegal dumping.
- Signboards may be installed at mangrove areas that are prone to waste dumping (e.g. mangrove areas located adjacent to roads). Fences and surveillance cameras may also be installed if signboards are ineffective.

2.4 Mangrove utilization

1) Threats

Mangrove trees have been utilized by local people as building materials (see Figure 6), animal fodder, firewood and so on. While these activities are now prohibited in Oman, they are still an ongoing practice in some rural areas. If these activities continue on an unsustainable manner, it may threaten the existence of mangrove forest.



Figure 6 Hut made from mangrove

2) Protective measures

Although cutting or damaging of mangrove tree is prohibited, it may be difficult to enforce such rules in rural areas due to their remote locations. The local people may also feel that they have the right to use mangroves, as such practices may have been conducted traditionally for many years. In such case, as a comprise solution, MECA may as an exception allow the use of mangrove, providing that it will be conducted in a sustainable manner. Following are some suggestions of sustainable use of mangrove:

- Leaf grazing may be allowed with mature trees that grow along fringes of dense mangrove forest. On the other hand, leaf grazing should not be allowed with young trees or where mangrove density is low. Also a “no-grazing period” may be established to allow mangrove leaf regeneration.
- Use of mangrove for building material and firewood may be allowed providing that only dead or near-dead branches (e.g. branches with no or very few leaves) are selected. This may in fact

improve the condition of the forest, as it will enhance aeration within the forest and hence reduce risk of fungi growth.

In any case, MECA should discuss thoroughly with the local stakeholders about how to sustainably use mangrove, and develop a “mangrove management plan”. The management plan should include information such as:

- Areas where mangrove utilization is allowed
- Areas where mangrove utilization is strictly prohibited
- Period when mangrove utilization is prohibited

Where mangrove utilization is strictly prohibited, fences and notice signboards may be installed around the area to prevent people entering.

2.5 Collection of fauna

1) Threats

Mangrove forests are known to provide habitat for various fauna including commercial fish and crab species. Collecting such fauna for food or selling, even at small quantity, may have significant adverse impacts on mangrove ecosystem, especially in Oman where most forests are relatively small and hence have limited carrying capacity of fauna. Reduction of fauna will also result in less food available for migratory birds. Mangrove forests also function as a nursery for young fishes and crabs, and collecting such fauna may result in reduction of local marine resource.

2) Protective measures

In principal, fauna collection should be prohibited at all mangrove forests for reasons stated above. An exception may be applied to relatively large mangrove forest and where its local population is small enough that collection can be conducted on a sustainable basis. However, even in such case, rules such as the following should be applied:

- Catching of juvenile fish should be avoided by using nets with large mesh size.
- A no-fishing period should be applied to allow recovery of fish stock.
- Only mature crabs should be caught. A size limit should be established for each species.

In any case, MECA should discuss thoroughly with the local stakeholders about how to sustainably use the fauna resource, and develop a “fauna management plan”. The management plan should include information such as:

- Prohibited collection methods
- Permitted mesh size
- Size limit for all target species
- No collection period

2.6 Invasive species

1) Threats

Invasive species may have significant impacts on the mangrove ecosystem. For example, *Prosopis juliflora* is an invasive plant species that has colonized many areas of Oman, and some are seen

along fringes of mangrove forest (see Figure 7). Since, *Prosopis juliflora* is known to be relatively salt tolerant, they could possibly invade into existing mangrove areas if conditions become more favorable for their growth.



Figure 7 Example of invasive plant species

During a recent fish survey at QNR, a tilapia species was collected, which are generally considered as an invasive species (see Figure 8). They may be a possible threat to the native species of QNR through competition for food and nest space. One tilapia species (*Oreochromis mossambicus*) is nominated as IUCN's "100 of the World's Worst Invasive Alien Species".



Figure 8 Tilapia species caught in QNR

2) Protective measures

It is very hard to completely remove invasive species once they become established in the area. Therefore, it is important to detect invasive species in advance through monitoring activities and implement proactive measures before they proliferate to irreversible levels. The cause of such intrusion of invasive species should also be investigated and measures taken to prevent any recurrences. MECA should also make a list of invasive species that have risk of intrusion into mangrove areas.

2.7 Overgrowth of algae

1) Threats

Some algae species increase explosively when conditions are suitable (e.g. excess of nutrients) and can accumulate to form visible filamentous algae mats (see Figure 9). These algae mats, when they entangle on mangrove trees, can have a wide range of adverse effects (e.g. hindrance to mangrove respiration by smothering the aerial roots). Young mangrove seedlings are also vulnerable to algae, as they can cover-up the entire seedling including the leaves (see Figure 9). This can hinder photosynthesis as well as stress the stem with its weight.



Figure 9 Algae covering aerial root (left) and seedlings (right)

2) Protective measures

In order to minimize entanglement of algae on young seedlings, nets may be installed in front of the seedlings. If done properly, algae should entangle onto the net and not reach the seedlings. However, once algae are entangled onto the seedlings, the only option will be to remove by hand. Such work could be conducted as a part of environmental education by inviting local schools and/or relevant organizations.

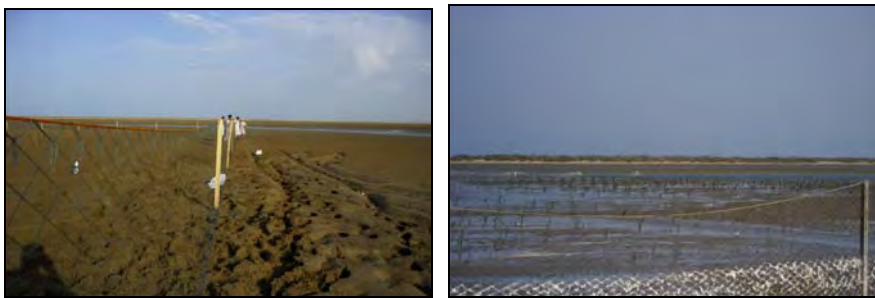


Figure 10 Examples of net installation

The Qurm Environmental Information Center Project

Technical Document 5

**Guideline for Development of Environmental
Education Program**

March 2014

JICA Expert Team

Table of Contents

1. Objectives of environmental education	1
1.1 General objectives of environmental education	1
1.2 Setting of environmental education objective	1
2. Preparation of environmental education materials	2
3. Development of environmental education programs	5
3.1 Development of environmental education modules.....	5
3.2 Formulation of environmental education program.....	7
3.3 Evaluation of environmental education program.....	7
3.4 Examples of environmental education program	8

Appendix

Appendix 1 Environmental education materials prepared through the Project (CD)

Appendix 2 Activity sheet of developed environmental education modules

Appendix 3 Examples of evaluation format (CD)

Appendix 4 Record of environmental education programs conducted through the Project

1. Objectives of environmental education

1.1 General objectives of environmental education

The objectives of environmental education are described in the Tbilisi Declaration (1977) adopted at the intergovernmental meeting organized by UNESCO in 1977. Table 1 shows the objective of environmental education endorsed by the Tbilisi Declaration.

Table 1 Objectives of environmental education endorsed by the Tbilisi Declaration

Category	Objective
Awareness	To help social groups and individuals acquire an awareness and sensitivity to the total environment and its allied problems.
Knowledge	To help social groups and individuals gain a variety of experience in, and acquire a basic understanding of, the environment and its associated problems.
Attitudes	To help social groups and individuals acquire a set of values and feelings of concern for the environment and the motivation for actively participating in environmental improvement and protection.
Skills	To help social groups and individuals acquire the skills for identifying and solving environmental problems.
Participation	To provide social groups and individuals with an opportunity to be actively involved at all levels in working toward resolution of environmental problems.

Source: Tbilisi Declaration, UNESCO, 1977

1.2 Setting of environmental education objective

The objective of the environmental education should be first determined by considering the following points:

- Target group of environmental education
- What the target group should know?
- How much / deep target group should know?

Table 2 shows examples of some of the topics that could be covered for education programs of mangrove ecosystem.

Table 2 Example topics for mangrove ecosystem education programs

No	Topic	Contents
1	Characteristics of mangrove tree	What is mangrove?
		Mangrove diversity
		Mangrove distribution in Oman and the world
		Characteristics of <i>Avicennia marina</i>
		Adaptation to stressful environment (high salinity, low oxygen)
		Reproduction of mangrove (viviparous seeds)
2	Characteristics of mangrove ecosystem	Fish (e.g. main types, what they eat, many juvenile fish)
		Crabs (e.g. main types, main habitats, what they eat)
		Snails (e.g. main types, main habitats, what they eat)
		Birds (e.g. residential and migratory birds, migratory route/season)
		Other fauna (worms, insects, microorganisms)
		Food chain of mangrove ecosystem

Technical Document 5 Guideline for Development of Environmental Education Program

No	Topic	Contents
3	Benefits of mangrove ecosystem	Provides precious greenery
		Nursery for various fauna
		Feeding and resting area for birds
		Coastline protection
		Place for relaxation
		Potential source of income for locals (e.g. ecotourism, honey production)
		Water purification
		CO ₂ fixation
4	Threats to mangrove ecosystem	Animal grazing
		Overgrowth of algae
		Intrusion of invasive species
		Coastal development (e.g. ports and roads)
		Discharge of wastewater
		Waste dumping
5	QEIC's activities to protect mangrove ecosystem	Plantation activity
		Environmental education activity
		Training activity
		Monitoring activity

Prepared by JICA Expert Team

2. Preparation of environmental education materials

Education materials should be developed by considering the objective and characteristics of the target groups. For example, the characteristics of mangrove ecosystem can be explained by a booklet with illustrations. Games and quiz may be used then to obtain a further understating of the ecosystem. Table 3 shows education materials prepared by the Project. A soft copy of the education materials are included in attached CD Appendix 1.

Table 3 Environmental education materials prepared by the Project

No	Type	Name	Description	
1	Brochure	Basic procedure of mangrove seedling transplantation	A brochure explaining the procedure of mangrove transplantation	
2		Importance of mangrove ecosystem	A brochure introducing the importance of mangrove ecosystem	
3	Poster	Food chain of mangrove ecosystem	A poster explaining the mangrove food chain	
4		Mangrove forest in Oman	A poster showing the distribution of mangrove forests in Oman	
5		Mahut Island	A poster explaining the characteristics of Mahut Island	
6		Qurm Nature Reserve	A poster explaining the characteristics of QNR	
7		Khwar Sawadi	A poster explaining the characteristics of khwar Sawadi	
8		Game	Mangrove quiz	Quiz for learning about mangrove
9			Field bingo	Bingo cards that can be used for field bingo activity
10	Card puzzle		Puzzle for learning about mangrove animals	
11	Field guide	Animals of mangrove forest in Oman	A field guide showing the common animals found in mangrove forests in Oman	
12	Booklet	Do you know mangroves?	An illustrative booklet for children explaining the mangrove ecosystem	
13		QEIC Learning Book	A booklet for learning about mangrove ecosystem	
14	Panels	Introduction on mangrove ecosystem	Panels explaining the mangrove ecosystem	
15	Video	Wonder trees in the sea	A short video showing the tidal changes in mangrove forest	
16	Certificate	My-tree certificate	A certificate and field note used for mangrove monitoring activities	

Prepared by JICA Expert Team

Following are examples of some of the materials mentioned in the above table.

Mangrove quiz:

Questions related to mangroves and mangrove ecosystem will be asked, which is composed by multiple choice, yes or no question, or open question. An example of the mangrove quiz is shown in Figure 1.

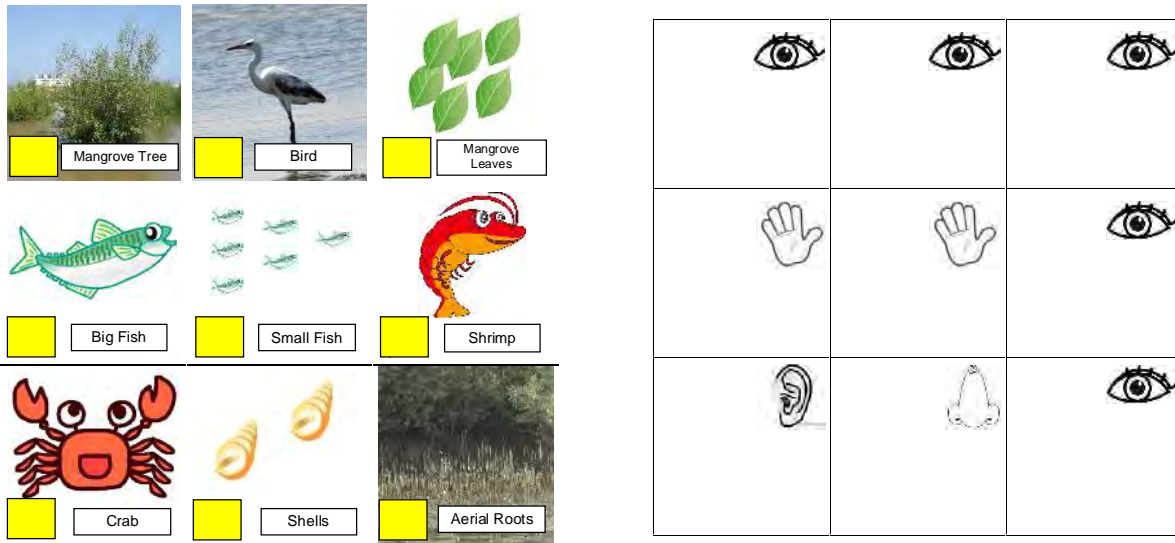


Prepared by JICA Expert Team

Figure 1 Examples of mangrove quiz

Field bingo:

The bingo card is prepared, including components of mangrove ecosystems, such as bird, fish, crab, and shell. The bingo card will be used in the field, to identify the components described on the card. An example of the bingo cards is shown in Figure 2.



Prepared by JICA Expert Team

Figure 2 Examples of field bingo

3. Development of environmental education programs

3.1 Development of environmental education modules

In order to diversify the education programs, many types of modules should be developed by considering the objective, target group and timing. Also consider the following characteristics in the learning process:

- What I hear ... I forget.
- What I see ... I remember.
- What I do ... I understand.

Therefore, it is important to incorporate participatory activities into the education program, so that the participants can experience firsthand the mangrove ecosystem, such as wildlife observation and mangrove plantation. Table 4 shows the environmental education modules developed through the Project.

Table 4 Environmental education modules developed through the Project

No	Module name	Contents	Objective	Target group	Timing
1	Nature game: Role play	Teaching the relationship of each component of mangrove ecosystem through role play using drawings of the components.	Understanding relationship of components of mangrove ecosystem	Students	Throughout the year
2	Nature game: Searching cards	Searching cards and making a sentence which describes characteristics of mangrove.	Understanding mangroves	Students	Throughout the year
3	Card puzzle	Completing a photo of common birds of mangrove forest by combining pieces of the photo.	To learn common birds of mangrove forest	Any target group	Throughout the year
4	Jigsaw puzzle	Completing a drawing of mangrove ecosystem by combining jigsaw puzzle pieces.	To learn animals of mangrove ecosystem	Any target group	Throughout the year
5	Field bingo	Field bingo card including mangrove, fish, crab, shrimp, shell, and bird as components of mangrove ecosystem.	To learn animals of mangrove ecosystem	Any target group	Except for summer
6	Mangrove quiz	Asking questions regarding mangroves and mangrove ecosystem.	Understanding mangroves and mangrove ecosystem	Any target group	Throughout the year
7	Bird watching	Observing birds in mangrove forest.	To learn common birds of mangrove forest	Any target group	Except for summer
8	Fish catching	Catching fish and other aquatic fauna by using cage or seine net.	To learn common aquatic fauna of mangrove forest	Students	Throughout the year
9	Mangrove cultivation in plastic bottle	Growing a mangrove seedling by hydroponics using a plastic bottle.	Understanding mangrove growth process	Any target group	July – Sep. (when seeds are available)
10	Drawing	Drawing a painting of	Understanding	Students	Except for

Technical Document 5 Guideline for Development of Environmental Education Program

No	Module name	Contents	Objective	Target group	Timing
	competition	mangroves and mangrove ecosystem.	mangroves and mangrove ecosystem		summer
11	Introduction of mangrove ecosystem (1)	Explanation of mangroves and mangrove ecosystem, and observing them.	Understanding mangroves and mangrove ecosystem	Any target group	Except for summer
	Introduction of mangrove ecosystem (2)	Introduction of mangrove ecosystem and the benefits and threats to the ecosystem.	To understand about mangrove ecosystem and the benefits and threats.	Any target group	Except for summer
12	Introduction of mangrove nursery	Explanation of mangrove nursery and important points of seedling transplantation.	To learn how to plant mangrove seedlings	Any target group	Except for summer
13	Mangrove plantation	Planting mangrove seedlings and monitoring their growth by tagging.	To learn how to plant mangrove seedlings	Any target group	October - April
14	Observation of planted seedlings	Observing planted mangrove seedlings at the planted site.	Understanding mangroves	Any target group	Except for summer
15	Cleaning	Cleaning the planted site, and observing the planted seedlings.	Maintaining growing environment of mangroves	Any target group	Except for summer
16	Mangrove monitoring	Participants will select a mangrove tree to monitor its growth. Participants will receive a certificate for their tree.	Enhancing awareness to conserve mangrove forest	Any target group	Except for summer

Prepared by JICA Expert Team

Details of each module should be recorded into an “Activity sheet”, which includes information such as target group, goal of the module, required materials and time table. Table 5 shows the format of the “Activity sheet”. The “Activity sheet” of each module in Table 4 is attached as Appendix 2.

Table 5 Format of “Activity sheet”

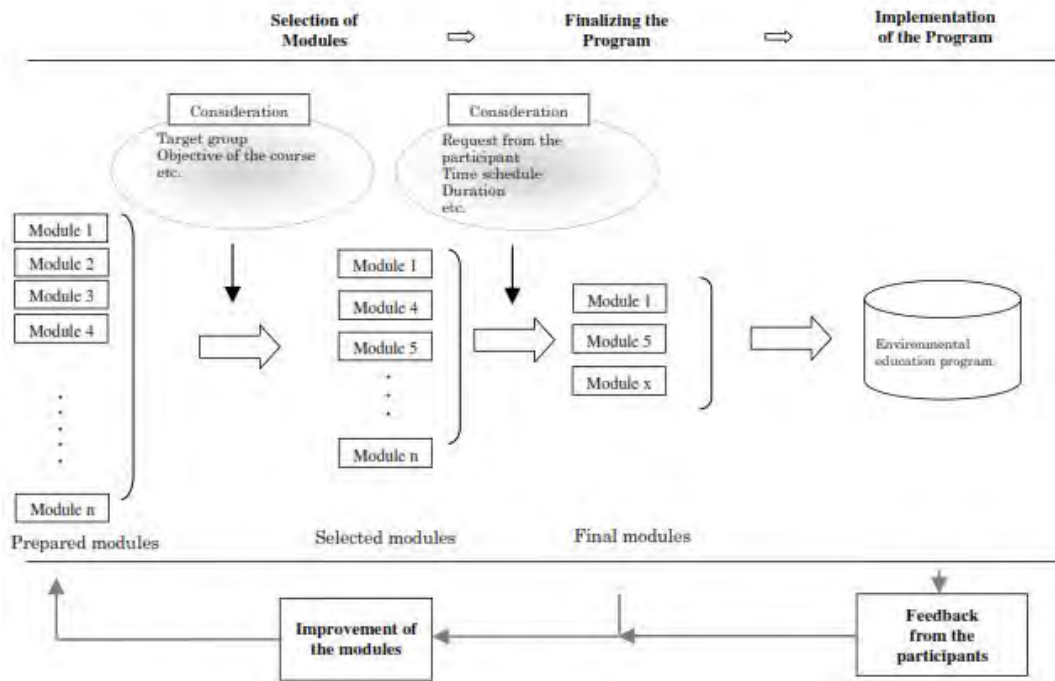
ITEM	DESCRIPTION
Name of activity	
Category of activity	
Target group	KG Primary Secondary General
Number	
Time required	
Time to implement	
Place to implement	Indoor Outdoor
Required materials	
Goal of the activity	
Remarks	

Time	Activity	Description	Materials

Prepared by JICA Expert Team

3.2 Formulation of environmental education program

An environmental education program can be formulated by selecting and combining the developed modules. Modules should be selected by considering the objective, target group, season, time limitation and so on. Figure 3 shows necessary steps to formulate an environmental education program.



Prepared by JICA Expert Team

Figure 3 Steps to formulate an environmental education program

3.3 Evaluation of environmental education program

Evaluation of the program is important: 1) to identify the effects of the program and 2) to identify good and bad points of the program. The evaluation results are then referred to improve or create new programs. Evaluation may be conducted by obtaining feedback from the participants. There are various evaluation methods such as: questionnaire, putting-a-sticker method and evaluation quiz. Format for such evaluation method are attached in Appendix 3. Following are some of the main questions that could be asked to the participants:

- What did you enjoy most about today's activities?
- What did you learn during today's activities?
- What do you want to do to conserve the mangrove ecosystem?
- Your comments & suggestions for today's activities

Internal evaluation is also important. Following are some questions that could be asked within the

staffs:

- Today's good and bad points
- Have we achieved the goal of the program (degree of achievement (%))
- How we can improve the program

3.4 Examples of environmental education program

Examples of environmental education program for different target groups (primary school, private company, local community) are shown in Tables 6-8. An example environmental education program for QNR is shown in Table 9.

**Table 6 Example of environmental education program for primary schools
(conducted at school)**

Time	Activity	Module no.*	Required materials	Venue
09:00 – 09:10	Introduction of mangrove forest in Oman	11	Poster	Class room
09:10 – 09:40	Understanding mangrove ecosystem through role play	1	Card	Class room
09:40 – 10:00	Understanding animals of mangrove ecosystem	3	Card puzzle	Class room
10:00 – 10:15	Evaluation by participants		Feedback sheet	Class room

*: Details of the module are described in Table 4.

Prepared by JICA Expert Team

**Table 7 Example of environmental education program for private companies
(conducted at QNR)**

Time	Activity	Module no.*	Required materials	Venue
09:00 – 09:10	Introduction of mangrove forests in Oman	11	Poster	Shade hall
09:10 – 09:20	Understanding food chain in mangrove ecosystem	11	Poster Brochure	Shade hall
09:20 – 09:30	Visiting mangrove nursery	12	-	Nursery
09:30 – 09:45	Observing mangrove forest	11	Photo list	Boardwalk
09:45 – 10:15	Monitoring of mangrove	16	Tree measure	Mangrove area
10:15 – 10:30	Evaluation by participants		Feedback sheet	Shade hall

*: Details of the module are described in Table 4.

Prepared by JICA Expert Team

**Table 8 Example of environmental education program for local community
(conducted at mangrove plantation site)**

Time	Activity	Module no.*	Required materials	Venue
09:00 – 09:15	Introduction of mangrove forests in Oman	11	Poster	Planting site
09:15 – 09:30	Understanding food chain in mangrove ecosystem	11	Poster Brochure	Planting site
09:30 – 09:40	Planting mangrove seedlings	13	Brochure	Planting site
09:40 – 09:50	Cleaning the planting site	15	-	Planting site
09:50 – 10:00	Evaluation by participants		Feedback sheet	Planting site

*: Details of the module are described in Table 4.

Prepared by JICA Expert Team

Table 9 Example of environmental education program in QNR

Time	Activity	Module no.*	Required materials	Venue
09:00 – 09:10	Introduction of mangrove forests in Oman	11	Poster	Shade hall
09:10 – 09:20	Understanding food chain in mangrove ecosystem	11	Poster Brochure	Shade hall
09:20 – 09:30	Visiting mangrove nursery	12	-	Nursery
09:30 – 09:45	Observing mangrove forest	11	Photo list	Boardwalk
09:45 – 10:15	Bird watching	7	Photo list, telescope	Mudflat
10:15 – 10:30	Evaluation by participants		Feedback sheet	Shade hall

*: Details of the module are described in Table 4.

Prepared by JICA Expert Team

Record of environmental education programs conducted through the Project is attached in Appendix 4 as references for the development of education programs.

Appendix 1

Environmental education materials prepared through the
Project (CD)

Appendix 1 Environmental education materials prepared through the Project

Soft copies of the environmental education materials listed in the following table are stored in the attached CD.

No	Type	Name	Folder no. in the CD
1	Brochure	Basic procedure of mangrove seedling transplantation	1
2		Importance of mangrove ecosystem	2
3	Poster	Food chain of mangrove ecosystem	3
4		Mangrove forest in Oman	4
5		Mahut Island	5
6		Qurm Nature Reserve	6
7		Khwar Sawadi	7
8	Game	Mangrove quiz	8
9		Field bingo	9
10		Card puzzle	10
11	Field guide	Animals of mangrove forest in Oman	11
12	Booklet	Do you know mangroves?	12
13		QEIC Learning Book	13
14	Panels	Introduction on mangrove ecosystem	14
15	Video	Wonder trees in the sea	15
16	Certificate	My-tree certificate	16

Appendix 2

Activity sheet of developed environmental education
modules

1. Nature game: Role play game on mangrove ecosystem

a) Activity sheet

Activity sheet (Nature Game)

ITEM	DESCRIPTION
Name of Activity	Role Play Game on Mangrove Ecosystem
Category of Activity	Nature Game
Target Group	<input checked="" type="radio"/> KG <input checked="" type="radio"/> Primary <input checked="" type="radio"/> Secondary <input type="radio"/> High <input type="radio"/> University <input type="radio"/> General
Number	Up to 30
Time required	30 minutes
Time to implement	Throughout the year
Place to implement	<input checked="" type="radio"/> Indoor <input checked="" type="radio"/> Outdoor
Materials used	Cards: described components of mangrove ecosystem such as mangroves, fish, crab, bird, and etc. (refer to the photos below) Brochure: Importance of mangrove ecosystem (Use material No.2 in the attached CD)
Goal of the Activity	Learn about the mangroves and mangrove ecosystem through the nature game, especially relationship among the components.

b) Timetable

Timetable (Nature Game)

Time	Activity	Description	Materials
09:00 – 09:05	Introduction of game method	Providing a card to participants and explaining method of the game.	Cards of mangrove ecosystem components
09:05 – 09:20	Conducting role play game	Explaining the relationship among the ecosystem components.	- ditto -
09:20 – 09:30	Reviewing	Explaining the mangrove ecosystem based on the brochure.	Brochure

c) Photographs of the activity



Sample of the cards



Role play game with the cards

Photographs of the activity (Nature Game)

2. Nature game: Searching cards

a) Activity Sheet

Activity sheet (Nature game)

ITEM	DESCRIPTION
Name of Activity	Searching cards on Mangrove Ecosystem
Category of Activity	Nature Game
Target Group	<input checked="" type="radio"/> KG <input checked="" type="radio"/> Primary <input checked="" type="radio"/> Secondary <input type="radio"/> High <input type="radio"/> University <input type="radio"/> General
Number	Up to 30
Time required	30 minutes
Time to implement	Throughout the year
Place to implement	<input checked="" type="radio"/> Indoor <input checked="" type="radio"/> Outdoor
Materials used	Cards: written a word to make a sentence which describes the characteristics of mangroves and mangrove ecosystem (refer to the photos below). Brochure: Importance of mangrove ecosystem (Use material No.2 in the attached CD)
Goal of the Activity	Learn about the mangroves and mangrove ecosystem through the nature game.

b) Timetable

Timetable (Nature game)

Time	Activity	Description	Materials
09:00 – 09:05	Introduction of game method	Explaining method of the game.	
09:05 – 09:20	Conducting searching cards game	Searching cards in the field to make a sentence.	Cards describing mangroves and mangrove ecosystem
09:20 – 09:30	Reviewing	Explaining the mangrove ecosystem based on the brochure.	Brochure

c) Photographs of the activity



Searching cards and making a sentence



Completed sentence with the cards

Photographs of the activity (Nature game)

**3. Card puzzle
4. Jigsaw puzzle**

a) Activity sheet

Activity sheet (Card puzzle)

ITEM	DESCRIPTION
Name of Activity	Card Puzzle
Category of Activity	Game
Target Group	<input checked="" type="radio"/> KG <input checked="" type="radio"/> Primary <input checked="" type="radio"/> Secondary <input type="radio"/> High <input type="radio"/> University <input type="radio"/> General
Number	Up to 30
Time required	30 minutes
Time to implement	Throughout the year
Place to implement	<input checked="" type="radio"/> Indoor <input type="radio"/> Outdoor
Materials used	Game: Photo cards of bird, fish, and crab in mangrove forests will be cut into 5 to 10 pieces (Use material No.10 in the attached CD).
Goal of the Activity	Learn about creatures in mangrove forests through playing the game.

b) Timetable

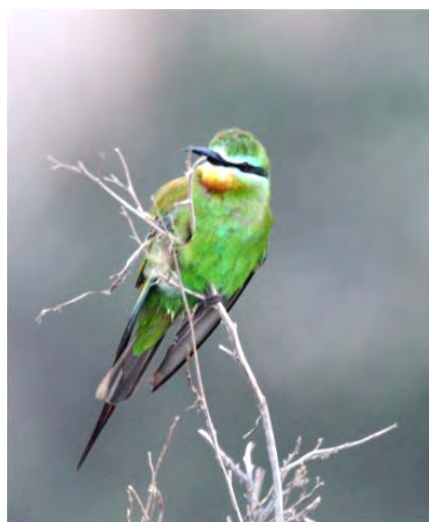
Timetable (Card puzzle)

Time	Activity	Description	Materials
09:00 – 09:05	Introduction of game method	Showing a photo card to participants and explaining method of the game.	Game
09:05 – 09:20	Playing the card puzzle game	Completing a photo by combining each piece of the photo card.	- ditto -
09:20 – 09:30	Reviewing	Explaining the name and characteristics of the creature shown on the photo card.	- ditto -

c) Photographs of the activity



A photo card cut in pieces



A completed photo card

Photographs of the activity (Card puzzle)

5. Field bingo
a) Activity sheet

Activity sheet (Field bingo)

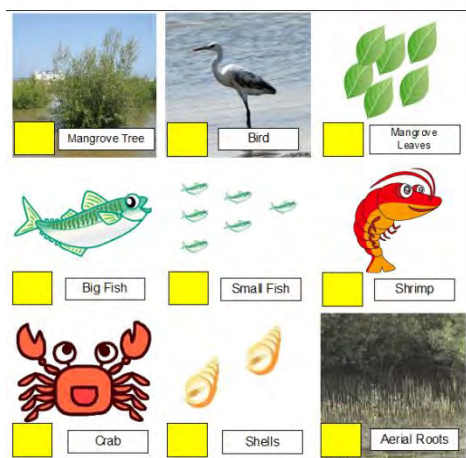
ITEM	DESCRIPTION
Name of Activity	Field Bingo
Category of Activity	Game
Target Group	<input type="checkbox"/> KG <input checked="" type="checkbox"/> Primary <input checked="" type="checkbox"/> Secondary <input checked="" type="checkbox"/> High <input type="checkbox"/> University <input type="checkbox"/> General
Number	Up to 30
Time required	30 minutes to 1 hour
Time to implement	Throughout the year (except for summer season)
Place to implement	X Indoor <input checked="" type="checkbox"/> Outdoor
Materials used	Game: Field bingo (Type 1, Type 2, and Type 3 (Use material No.9 in the attached CD)) Brochure: Importance of mangrove ecosystem (Use material No.2 in the attached CD)
Goal of the Activity	Learn about the mangroves and mangrove ecosystem by observation through conducting the field bingo game.

b) Timetable

Timetable (Field bingo)

Time	Activity	Description	Materials
09:00 – 09:10	Introduction of game method	Providing a field bingo card to participants and explaining method of the game.	Game
09:10 – 09:40	Conducting bingo game	Try to find mangrove ecosystem components which are listed on the bingo card.	- ditto -
09:40 – 09:50	Reviewing	Explaining the mangrove ecosystem based on the brochure.	Brochure

c) Photographs of the activity



Example of the field bingo card



Playing bingo game with the card

Photographs of the activity (Field bingo)

6. Mangrove quiz

a) Activity sheet

Activity sheet (Mangrove quiz)

ITEM	DESCRIPTION
Name of Activity	Mangrove Quiz
Category of Activity	Quiz
Target Group	△ KG ⊙Primary ⊙Secondary ⊙High ○University ○General
Number	Up to 30 persons
Time required	30 minutes
Time to implement	Throughout the year
Place to implement	⊙ Indoor ⊙ Outdoor
Materials used	Game: Mangrove quiz (Arabic and English version (Use material No.8 in the attached CD)) Brochure: Importance of mangrove ecosystem (Use material No.2 in the attached CD)
Goal of the Activity	Learn about the mangroves and mangrove ecosystem through the quiz.

b) Timetable

Timetable (Mangrove quiz)

Time	Activity	Description	Materials
09:00 – 09:05	Brief explanation of Mangrove quiz	Explaining that the quiz covering mangroves and mangrove ecosystem.	
09:05 – 09:20	Conducting Mangrove Quiz	Selecting any card (from No.1 to No.10) and let participants answer the quiz.	Game
09:20 – 09:30	Reviewing	Explaining the mangrove ecosystem based on the brochure.	Brochure

c) Photographs of the activity



Mangrove quiz cards



Participants answer the question

Photographs of the activity (Mangrove quiz)

7. Bird watching

a) Activity sheet

Activity sheet (Bird watching)

ITEM	DESCRIPTION
Name of Activity	Bird watching
Category of Activity	Nature observation
Target Group	<input type="checkbox"/> KG <input checked="" type="checkbox"/> Primary <input checked="" type="checkbox"/> Secondary <input checked="" type="checkbox"/> High <input type="checkbox"/> University <input type="checkbox"/> General
Number	Up to 30
Time required	30 minutes to 1 hour
Time to implement	Throughout the year (except for summer season)
Place to implement	<input checked="" type="checkbox"/> Indoor <input checked="" type="checkbox"/> Outdoor
Materials used	Field guide: Animals of mangrove forest in Oman (Use material No.11 in the attached CD) Binoculars, Telescopes Brochure: Importance of mangrove ecosystem (Use material No.2 in the attached CD)
Goal of the Activity	Learn about birds in the mangrove forest by observation in the field.

b) Timetable of the activity

Timetable (Bird watching)

Time	Activity	Description	Materials
09:00 – 09:10	Introduction of the method of bird watching	Providing the common birds list of participants and explaining the method.	Field guide
09:10 – 09:40	Conducting bird watching	Watching birds at the tidal flat area, and checking the name of birds.	Field guide Binoculars and telescopes
09:40 – 09:50	Reviewing	Explaining the mangrove ecosystem based on the brochure.	Field guide Brochure

c) Photographs of the activity



Bird watching with a telescope



Searching a bird using the bird list

Photographs of the activity (Bird watching)

8. Fish catching

a) Activity sheet

Activity sheet (Fish catching)

ITEM	DESCRIPTION
Name of Activity	Fish catching
Category of Activity	Nature observation
Target Group	<input checked="" type="radio"/> KG <input checked="" type="radio"/> Primary <input checked="" type="radio"/> Secondary <input type="radio"/> High <input type="radio"/> University <input type="radio"/> General
Number	Up to 30
Time required	30 minutes
Time to implement	Throughout the year
Place to implement	X Indoor <input checked="" type="radio"/> Outdoor
Materials used	Fish cage, food for fish (i.e. bread), seine net (optional) Field guide: Animals of mangrove forest in Oman (Use material No.11 in the attached CD)
Goal of the Activity	Knowing about aquatic fauna of mangrove forest

b) Timetable

Timetable (Fish catching)

Time	Activity	Description	Materials
09:00 – 09:05	Introduction of the method	Explaining the method.	Fish cage and food for fish
09:05 – 09:20	Catching fish by the cage	Explaining the characteristics of fish caught in the cage.	- ditto -
09:20 – 09:30	Reviewing	Explaining the mangrove ecosystem based on the photo list.	Field guide

c) Photographs of the activity



Cage for catching fish



Catching fish by the cage

Photographs of the activity (Fish catching)

9. Mangrove cultivation in a plastic bottle

a) Activity sheet

Activity sheet (Mangrove cultivation)

ITEM	DESCRIPTION
Name of Activity	Mangrove cultivation in a plastic bottle
Category of Activity	Growing mangroves
Target Group	<input checked="" type="radio"/> KG <input checked="" type="radio"/> Primary <input checked="" type="radio"/> Secondary <input checked="" type="radio"/> High <input checked="" type="radio"/> University <input checked="" type="radio"/> General
Number	Up to 30
Time required	30 minutes
Time to implement	July – September (when seeds are available)
Place to implement	<input checked="" type="radio"/> Indoor <input checked="" type="radio"/> Outdoor
Materials used	Plastic bottle (1.5L) and seeds of mangrove
Goal of the Activity	Growing a mangrove seedling by hydroponics using a plastic bottle to know about mangroves.

b) Timetable

Timetable (Mangrove cultivation)

Time	Activity	Description	Materials
09:00 – 09:05	Introduction of the method	Explaining the method.	
09:05 – 09:20	Cutting plastic bottle	Cut a plastic bottle as shown in the photo, and place a mangrove seed.	Plastic bottle (1.5L) and seeds of mangrove
09:20 – 09:30	How to grow mangrove	Explaining important points to grow mangrove in plastic pot.	

c) Photographs of the activity



Planting a mangrove seed in a bottle



Growing a mangrove seedling in a bottle

Photographs of the activity (Mangrove cultivation)

10. Drawing competition

not prepared

11. Introduction of mangroves and mangrove ecosystem (1)

a) Activity sheet

Activity sheet (Introduction of mangroves and mangrove ecosystem)

ITEM	DESCRIPTION
Name of Activity	Introduction of mangroves and mangrove ecosystem
Category of Activity	Nature observation
Target Group	☉ KG ☉ Primary ☉ Secondary ☉ High ☉ University ☉ General
Number	Up to 30
Time required	30 minutes
Time to implement	Except for summer
Place to implement	☉ Indoor ☉ Outdoor
Materials used	Poster: Food chain in mangrove ecosystem (Use material No.3 in the attached CD) Brochure: Importance of mangrove ecosystem (Use material No.2 in the attached CD) Field guide: Animals of mangrove forest in Oman (Use material No.11 in the attached CD)
Goal of the Activity	Understanding mangroves and mangrove ecosystem.

b) Timetable

Timetable (Introduction of mangroves and mangrove ecosystem)

Time	Activity	Description	Materials
09:00 – 09:10	Introduction of mangrove ecosystem	Explaining mangroves and mangrove ecosystem	Poster Brochure
09:10 – 09:25	Observing mangrove forest	Observing mangrove forest through board walk	Field guide
09:25 – 09:30	Reviewing	Explaining the mangrove ecosystem based on the photo list.	

c) Photographs of the activity



Explanation of the food chain
Photographs of the activity (Introduction of mangroves and mangrove ecosystem)



Observing mangrove forest through board walk
Photographs of the activity (Introduction of mangroves and mangrove ecosystem)

11. Introduction of mangroves and mangrove ecosystem (2)**a) Activity sheet****Activity sheet (Introduction of mangroves and mangrove ecosystem)**

ITEM	DESCRIPTION
Name of Activity	Introduction on mangrove ecosystem
Category of Activity	Lecture in the field at QNR
Target Group	KG Primary Secondary High <input type="radio"/> University <input checked="" type="radio"/> General
Number	Preferably less than 20 participants
Time required	45-60 minutes
Time to implement	Throughout the year
Place to implement	<input checked="" type="checkbox"/> Indoor <input checked="" type="checkbox"/> Outdoor
Materials used	Panels: Introduction on mangrove ecosystem (Use material No.14 in the attached CD) Fish catching equipment Field guide: Animals of mangrove forest in Oman (Use material No.11 in the attached CD) Brochure: Importance of mangrove ecosystem (Use material No.2 in the attached CD) Video (optional): Wonder trees in the sea (Use material No.15 in the attached CD)
Goal of the Activity	To learn about the basics of mangrove and mangrove ecosystem

b) Timetable**Timetable (Introduction of mangroves and mangrove ecosystem)**

Time	Activity	Description	Materials used
15 minutes	Explanation of mangrove tree	Explain the following using panels at the shed or boardwalk - What is mangrove? - Adaptations to low oxygen conditions - Adaptation to high salinity - Reproduction methods	Panels 1, 2, 3, 4 of material No.14 in the attached CD
15 minutes	Explanation of mangrove ecosystem	Explain the following using panels at the boardwalk - Common mangrove fauna (e.g. fish, crabs, birds and others) and their characteristics - Mangrove food chain	Panels 5, 6, 7, 8, 9 of material No.14 in the attached CD
15 minutes	Catching of fish (if high tide)	Catch fish at the boardwalk using fish cage and show it with portable aquarium	Fish cage, small hand net, bucket, aquarium Field guide
15 minutes	Explanation of benefits and threats to mangrove ecosystem	Explain the following using panels at the shed - Why conserve the mangrove ecosystem - Threats to mangrove ecosystem	Panels 10, 11 of material No.14 in the attached CD

12. Introduction of mangrove nursery

a) Activity sheet

Activity sheet (introduction of mangroves nursery)

ITEM	DESCRIPTION
Name of Activity	Introduction of mangrove nursery
Category of Activity	Growing mangroves
Target Group	<input checked="" type="radio"/> KG <input type="radio"/> Primary <input type="radio"/> Secondary <input type="radio"/> High <input type="radio"/> University <input type="radio"/> General
Number	Up to 30
Time required	30 minutes
Time to implement	Except for summer
Place to implement	X Indoor <input checked="" type="radio"/> Outdoor
Materials used	Poster: Mangrove forests in Oman (Use material No.4 in the attached CD) Posters: (Use material No.5-7 in the attached CD, optionally)
Goal of the Activity	Knowing how to plant mangrove seedlings.

b) Timetable

Time table (introduction of mangroves nursery)

Time	Activity	Description	Materials
09:00 – 09:10	Introduction of mangrove forests in Oman	Explaining mangrove forests in Oman	Poster
09:10 – 09:20	Observing mangrove nursery	Observing mangrove nursery to understand how to grow mangrove seedling	

c) Photographs of the activity



Explanation of mangrove forests in Oman



Visiting the mangrove nursery at QNR

Photographs of the activity (Introduction of mangroves nursery)

13. Mangrove plantation

a) Activity Sheet

Activity sheet (Transplantation of mangrove seedlings)

ITEM	DESCRIPTION
Name of Activity	Transplantation of mangrove seedlings
Category of Activity	Growing mangroves
Target Group	<input checked="" type="radio"/> KG <input checked="" type="radio"/> Primary <input checked="" type="radio"/> Secondary <input checked="" type="radio"/> High <input checked="" type="radio"/> University <input checked="" type="radio"/> General
Number	Up to 30
Time required	30 minutes
Time to implement	Except for summer
Place to implement	X Indoor <input checked="" type="radio"/> Outdoor
Materials used	Brochure: Basic procedure of mangrove seedling transplanting (Use material No.1 in the attached CD)
Goal of the Activity	Knowing how to plant mangrove seedlings.

b) Timetable

Timetable (Transplantation of mangrove seedlings)

Time	Activity	Description	Materials
09:00 – 09:10	Introduction of transplantation method	Explaining important points to be followed in transplanting mangrove seedlings	Brochure
09:10 – 09:20	Moving to transplanting site	Moving to transplanting site with mangrove seedlings	Mangrove seedlings
09:20 – 09:30	Transplanting mangrove seedlings	Transplanting mangrove seedlings at the site.	Mangrove seedlings

c) Photographs of the activity



Delivering mangrove seedlings



Transplanting mangrove seedlings

Photographs of the activity (Transplantation of mangrove seedlings)

14. Observation of planted seedlings

not prepared

15. Cleaning

a) Activity sheet

Activity sheet (Cleaning of mangrove plantation site)

ITEM	DESCRIPTION
Name of Activity	Cleaning of mangrove plantation site
Category of Activity	Nature conservation
Target Group	☉ KG ☉ Primary ☉ Secondary ☉ High ☉ University ☉ General
Number	Up to 30
Time required	30 minutes
Time to implement	Except for summer
Place to implement	X Indoor ☉ Outdoor
Materials used	Plastic bags, plastic gloves
Goal of the Activity	Maintaining a growing environment of mangroves.

b) Timetable

Timetable (Cleaning of mangrove plantation site)

Time	Activity	Description	Materials
09:00 – 09:05	Distributing plastic bags and groves	Explaining the method.	Plastic bags, plastic gloves
09:05 – 09:20	Picking up garbage	Picking up garbage at the planting site.	- ditto -
09:20 – 09:30	Reviewing	a) Classifying the picked up garbage and examining from where do they come. b) Weighing the garbage for competition.	

c) Photographs of the activity



Cleaning of mangrove forest at QNR



Group photo after the cleaning activity

Photographs of the activity (Cleaning of mangrove plantation site)

16. Mangrove monitoring

a) Activity sheet

Activity sheet (Mangrove monitoring)

ITEM	DESCRIPTION
Name of Activity	My-tree monitoring program
Category of Activity	Field work at QNR
Target Group	KG Primary Secondary High <input type="radio"/> University <input checked="" type="radio"/> General
Number	Around 20 participants
Time required	60 minutes
Time to implement	Throughout the year
Place to implement	<input checked="" type="checkbox"/> Indoor <input type="checkbox"/> Outdoor
Materials used	Tree measure, tape measure, tree tag Field note and certificate (Use material No.16 in the attached CD)
Goal of the Activity	To learn the mangrove monitoring method as well as to follow-up growth status

b) Timetable

Timetable (Mangrove monitoring)

Time	Activity	Description	Materials used
10 minutes	Explanation of monitoring method	- Explain how to measure tree height and trunk circumference. - Explain how to check tree health.	Tree measure, tape measure, field note, tree tag
15 minutes	Selection of tree	- Split the group into groups of three. - Each group will select a tree and name it.	
20 minutes	Measure tree height and trunk circumference	- Measure tree height and trunk circumference and fill in the field sheet. Also tag the tree. - Assess tree health and fill in the field sheet.	
15 minutes	Issue my-tree certificate	- Distribute certificate	Certificate

Appendix 3

Examples of evaluation format (CD)

Three types of feedback sheets are stored in the attached CD.

Feedback Sheet (1) : Questionnaire type

Feedback Sheet (2) : Sign board type

Feedback Sheet (3) : Quiz type

Appendix 4

Record of environmental education programs conducted through
the Project

1. Reports of the Environmental Education Program conducted with the Project

1.1 Report of the Environment Education Program on the World Wetlands Day 2012

An environment education program was carried out on the occasion of the World Wetlands Day by MECA with the participation of Ministry of Tourism on the 6th February, 2012 at the QNR (Qurm Nature Reserve). More than 200 of students from different schools were invited to the event, consisting of Indian School, Philippine School, International School, and orphanage supported by the Ministry of Social Development. The event activities included lecture about mangroves and their ecosystem, observation of nursery and QNR (through board walk), transplanting mangrove seedlings, and nature games. The approximate timetable of the event was as follows;

Time	Activity	Remarks
08:30	Arriving at QNR (Indian & Philippine School)	
09:15 – 09:20	Opening Speech (Mr. Ali Kiyumi)	
09:20 -	Lecture on mangroves and their ecosystem, observation of nursery and QNR.	Dr. Ahmed, Mr. Bader, and Ms. Aida guided the students.
09:50	Transplanting mangrove seedlings.	Each student was provided a mangrove seedling, and each of them experienced the transplantation.
10:30	Taking group photos.	
10:40 -	Break	Snacks, water, soft drinks were served.
11:05 -	Nature game (1): Understanding mangrove ecosystem through card game.	Conducted by Ms. Aida.
11:35 –	Nature game (2): Making a sentence by composing words written on pieces of board.	Conducted by Ms. Aida. “Mangrove forests provide a nursery for lobsters, crabs and oysters.”
11:50 –	Coloring drawings.	Wetland drawings prepared by the Ramsar Center.
12:15	Closing.	

【Comments on the Event】

- In spite of having big number of students in the event, the facilitators controlled the participants quite good manner, and the event was well-organized.
- Two kinds of nature game were conducted, which were very interested and gave impressive impact to the participated students.
- It would be necessary to evaluate impact of the event in some way, therefore a questionnaire was given to some of the participants. The result of the questionnaire survey is attached to this report as an annex.
- After closing the event, workers collected containers of snack and drink which were littered by the participants. This kind of event is also good occasion to teach children not to litter rubbish but to put it in the wastebasket, in order to save our environment.
- Similarly, polyethylene bags for seedlings were left at the transplanting site, which shall be collected by the participated students, not by workers.
(Note: When they had another transplantation event at the QNR later, they asked to the participated students to collect the polyethylene bags in a garbage bag.)

【Photographs of the World Wetlands Day Event】



Opening speech by Mr. Ali Kiyumi



Philipino students at the mangrove nursery

Appendix 4 Record of environmental education programs conducted through the Project



Observing mangrove forest through board walk



Delivering mangrove seedling to students



Transplanting mangrove seedlings



Group photo at the transplanting site



Nature game on mangrove ecosystem (1)



Nature game on mangrove ecosystem (2)

1.2 Questionnaire Survey on the World Wetlands Day Event

a) **Background of the survey**

On the occasion of the world wetlands day, MECA (Ministry of Environment and Climate Affairs) invited students of different schools in Muscat to an environment education program at the QNR (Qurm Nature Reserve) on February 6, 2012. The program included various activities for the students focusing on wetlands and mangrove ecosystem. A questionnaire survey was carried out to identify the impact of the event on the participated students. This brief report describes the result of the questionnaire survey.

b) **Respondents of the survey**

- a) Name of the School: Philippine School, Muscat, Oman
- b) Total number of the respondents: 29
- c) Age:

Age	15	16	17	18	TOTAL
Number	8	18	2	1	29

Appendix 4 Record of environmental education programs conducted through the Project

d) Sex:

Sex	Female	Male
Number	13	15

e) Nationality:

Nationality	Filipino	Filipino-Indian	Omani	Iraqi	Thai
Number	23	3	1	1	1

c) Results of the survey

Q1. Was the wetland day event interesting for you?

Almost all of them answered “yes” to the question 1.

Answer	Yes	No
Number	28	1

Answer	Yes		No	
Sex	Female	Male	Female	Male
Number	13	14	0	1

The major reasons are mentioned with the number of answers as follows;

- Because it was interesting. (It was fun / Planting plants was fun.) 7
- Because it is my first time to plant mangrove. 5
- Because I learned new things about mangroves. 5
- Because we learned something about mangrove plantation. 5
- Because I learned a lot. 5
- Because I had learned some very valuable information. 1

Q2. Have you got something new from the event?

Most of them got something new, namely 24 students (83%) answered “yes”.

Answer	Yes	No
Number	24	5

Answer	Yes		No	
Sex	Female	Male	Female	Male
Number	13	11	0	4

The major points which they got from the event are as follows;;

- I learned about mangroves. 8
- How to plant mangroves and how they live. 6
- I learned new things and gained new experience. 4
- I learned many things. 4
- T-shirt & cap. 4
- I learned that Qurm means Mangrove. 2
- The kind of plant it was and the salt from water going to the leaves. 1
- Maybe. 1

Q3. Did you find anything to be modified in order to improve the event?

Most of them seemed to be satisfied with the event, and 20 students (69%) answered “no”.

Answer	Yes	No
Number	8	20

Answer	Yes		No	
Sex	Female	Male	Female	Male
Number	3	5	9	10

According to their opinion, the points to be improved are as follows;

- Provide boots next time. 3
- It would have been better if we were providing with protective gloves. 1
- If you don't mind to modify the way / road. 1
- Field trips to mangrove must be organized. 1
- The lake on the nipa hut is not clean. 1
- More workers to help expand the event. 1
- Because the event was really organized so there's no need for improvement. 1

Q4. Do you want to do something to conserve wetland/mangrove ecosystem in Oman?

Most of them want do something, and 23 students (79%) answered “yes”.

Answer	Yes	No
Number	23	6

Answer	Yes		No	
Sex	Female	Male	Female	Male
Number	12	11	1	4

The followings are the details which they want to do;

- Plant more Mangroves. 7
- I'd like to join other environment campaigns about mangrove ecosystem and others. 5

Appendix 4 Record of environmental education programs conducted through the Project

- I would like to help. 4
- Conserve wetlands with the others. 3
- Inform people about mangroves. 1
- Preserve the water. 1
- Because it was fun. 1
- Because it also helps our nature to be balance. 1

2. Report on the Environment Education Program on the World Wetlands Day 2013

An environment education program was carried out on the occasion of the World Wetlands Day on the 2nd of February, 2013 at the QNR. Some 80 participants from different schools were invited to the event, consisting of Dorat Al Khaleeji school, orphanages supported by the Ministry of Social Development, and students of SQU. The event was observed by the minister of MECA, and the counselor and the secretary of the Japanese Embassy. The event activities included lecture about mangroves and mangrove ecosystem, observation of nursery and QNR through board walk, transplanting mangrove seedlings, cleaning the reserve, bird watching, and drawing & coloring. The approximate timetable of the event was as follows;

Time	Activity	Remarks
08:30	Arriving of participants to QNR	
09:15 – 09:20	Orientation of the today's Program (Mr. Bader) Opening Speech (Dr. Ahmed Al Saidi)	
09:20 -	Lecture on mangroves and their ecosystem, observation of nursery and QNR.	Ms. Aziza and Mr. Bader guided the participants.
09:50-10:30	Bird Watching	Participated children were instructed by Mr. Waheed, Diwan's wildlife biologist.
10:30-11:00	Transplanting mangrove seedlings. Cleaning the nature reserve.	Each student was provided a mangrove seedling, and each of them experienced the transplantation.
11:00-11:30	Drawing and coloring pictures.	Conducted by Ms. Aida and Ms. Aziza.
11:30 -	Break	Snacks, water, soft drinks were served.
11:45	Closing	

【Notes on the Event】

- The number of the participants was around 80 which was smaller than the last year's event, so the facilitators were able to control the participants in good manner, and the event was well-organized.
- Bird watching was instructed by Mr. Waheed, Diwan wildlife biologist, and common birds list was prepared prior to the activity. In addition, purchased equipment (such as telescope and binoculars) was effectively used in the activity. Because of all these well-arrangement, the bird watching activity was successful, and the participants learned and enjoyed a lot.
- Some of the education materials such as field bingo, mangrove quiz, and puzzle, were not used because of time shortage. The contents of program and their time allocation shall be discussed more carefully before conducting the event.
- At the break, snacks and drinks were provided to the participants. Many of the children put rubbish in the wastebasket by themselves, which was good action to save our environment.

【Photographs of the World Wetlands Day Event】



Opening speech by Dr. Ahmed Al Saidi



Explanation of mangrove nursery by Ms. Aziza

Appendix 4 Record of environmental education programs conducted through the Project



Observing mangrove forest through board walk



Group photo at the mangrove forest



Bird watching at the tidal flat (Ms. Aida)



Explaining the activity to the Minister (Mr. Badar)



Transplanting mangrove seedlings



Cleaning the nature reserve

3. Environmental Education Programs for School Children at Duqm

3.1 Environmental Education Program for at the Durf transplanting site

Date: May 15, 2013
Time: 8:30 - 9:30 am
Target Group: School children of Al Shamukh school
Number of Participants: 4 elementary school boys and 9 secondary school girls
Persons in Charge: Bader, Aida, Aziza, and Koto

- ✓ An environmental education program was conducted at Durf transplanting site with inviting school children of AsShamukh school.
- ✓ The contents of the program were introduction of mangroves, transplanting of mangrove seedlings and bird watching.
- ✓ A brochure of "Basic procedure of mangrove seedling transplanting" was delivered to the participated children, and important points of transplanting were explained to them.
- ✓ The brochure with lots of illustrations was understandable for the school children, which was useful to them to conduct the transplanting in proper way.

3.2 Environmental Education Program for at Al Shamukh school

Date: May 16, 2013
Time: 8:10 - 9:30 am
Target Group: School children of Al Shamukh school
Number of Participants: 20 boys and 35 girls
Persons in Charge: Bader, Aida, Aziza, and Koto

- ✓ An environmental education program was conducted at AsShamukh school, on the next day of the transplanting activity at Durf.
- ✓ The contents of the program were explanation of mangroves and mangrove ecosystem (by using PPT presentation by Ms. Aida; 10 minutes), showing a mangrove movie prepared by MECA, and questions and answers about mangroves.
- ✓ Reactions from the participants; Some of the school children said the program was interesting and informative. The brochure of transplanting procedure was easy to understand. It was the first time to know about mangroves, and it is necessary to plant more mangroves. Some of the students said more school visit is required.

[Durf transplanting site]



Environmental Education at Durf



Bird watching at Durf

Appendix 4 Record of environmental education programs conducted through the Project



Holding a mangrove seedling as instructed



Transplantation at the Durf site

[As Shamukh School]



Presentation on mangrove by Ms. Aida



Q&A on mangrove



Presenting a memorial gift



As Shamukh School

4. Environmental Education Program for Al Bustan Palace Hotel Staff

Date: November 11, 2013 (Monday)
Time: 8:00 - 10:45 am
Target Group: Staff of Al Bustan Palace Hotel
Number of Participants: 11
Persons in Charge: Bader, Harada, and Koto

Time	Activity	Education Materials used
08:10 am	Arrival	
08:20	Explanation of Mangrove Forests in Oman	Poster: Mangrove Forests in Oman
08:30	Distributing brochure and photo sheet	Brochure: Mangrove Ecosystem Photo sheet: Animals of Mangrove Forest in Oman
08:40	Explanation of mangroves and mangrove ecosystem	Poster: Food Chain in Mangrove Ecosystem,
08:55	Observing Mangrove Nursery	
09:10	Observing Mangrove Forest through Board Walk	
09:20	Moving to Mangrove Planting Site	
09:30	Bird Watching	Photo sheet: Animals of Mangrove Forest in Oman
09:40	Cleaning	
09:52	Group Photo	
10:00	Transplanting Mangrove Seedlings	
10:15	Feedback	Feedback sheet
10:45	Leaving QNR	

Education Materials Used:

- 1) Poster: Mangrove Forests in Oman
- 2) Poster: Food Chain of Mangrove Ecosystem
- 3) Mangroves in the Sultanate of Oman (MECA)
- 4) Brochure: Importance of Mangrove Ecosystem
- 5) Photo sheet: Animals of Mangrove Forest in Oman
- 6) Feedback sheet (Questionnaire)

4.1 Results of the Questionnaire Survey

a) Please rate today' activity.

	Excellent	Good	OK	Poor	Very poor
Activity	10	0	0	0	0
Venue	9	1	0	0	0
Staff	10	0	0	0	0
Date	9	0	1	0	0
Time	9	0	1	0	0

b) Please describe the today's activity in a simple word or sentence.

Very informative	2
First time to see / to plant mangrove	2
Great time	2
Unforgettable	1
Interesting	1
Beneficial	1
Learning	1
Presentation, walk the forest, visit the nursery, clean the forest, bird watching and Planting mangroves	1

c) What was the most interesting for you?

Bird watching	3
Seeing different species (birds and crabs)	1

Appendix 4 Record of environmental education programs conducted through the Project

Transplanting mangrove tree	2
Nursery / growing mangrove tree	2
Presentation	2
Knowing how mangrove grows	1
A lot of activity	1
The location in middle of big city.	1
Enjoyed with family	1

d) Did you find anything to be modified in order to improve the activity?

No	9
All is great / All great	(2)
Yes, Add more activities and venue of activity	1

e) Do you want to attend this activity again in the future?

Yes	10
on regular basis	
for sure always	
for sure	
I like to get more information about this	
No	0

f) Information on the participants

Age	20s	30s	40s
Number	3	5	2

Sex	female	male
Number	6	4

Nationality	Omani	Sudanese	Polish	Slovakian	Philipino	Sri Lanka	Korean
Number	4	1	1	1	1	1	1



Explanation of Mangrove Forests in Oman



Distributing Brochure of Mangrove Ecosystem

Appendix 4 Record of environmental education programs conducted through the Project



Explanation of the Food Chain



Visiting the Mangrove Nursery



Observing Mangrove Forest



Bird Watching



Group Photo after Cleaning Activity



Feedback of the program

5. Environmental Education Program for 1st Oman Cub Scouts

Date: October 30, 2013
Time: 16:30 - 18:00
Target Group: Cub Scouts Children
Number of Participants: around 30
Persons in Charge: Bader, Harada, and Koto

Based on the request from the 1st Oman Cub Scouts on September 28, 2013, an environmental education program on mangroves and mangrove ecosystem was prepared and conducted on October 30, 2013. The number of participants was around 30 cub scout children aged from 8 to 10, and around 15 teachers and parents of the participated children. The timetable of the program along with the education materials used is shown as below;

Time	Activity	Education Materials used
04:15 pm	Arrival	
04:35	Taking attendance	
04:40	Explanation of mangroves and mangrove ecosystem	Poster on food chain in mangrove ecosystem, Photo sheet of animals in mangrove forest
04:50	Observing mangrove forest through board walk	
04:55	Fish catching	Fish cage
05:10	Field bingo game	Field bingo card
05:20	Nursery	
05:30	Feedback	Feedback sheet and stickers
05:40	Observing planting site of mangrove seedlings	
06:00	Leaving QNR	

Education Materials Used:

- 1) Poster: Food Chain of Mangrove Ecosystem (for children)
- 2) Photo sheet: Animals of Mangrove Forest in Oman
- 3) Field Bingo Card
- 4) Feedback board (for children)

Based on the steps to prepare environmental education program, suitable program modules were selected according to the target group, objective, time and request from the participants. Then, the program was formulated with timetable and necessary education materials to be used. It was good opportunity to share the idea of these steps among Omani counterparts and Japanese experts.

As one of the method of feedback for children, putting-a-sticker method was examined instead of the questionnaire method. Each participant placed a sticker to the most favorite activity among the program, and number of the stickers showed which activity they liked.



Welcoming the participants Explanation of the Food Chain

Appendix 4 Record of environmental education programs conducted through the Project



Explanation of animals in mangrove forest



Observing mangrove forest with photo sheet



Fish catching



Filling bingo card



Observing mangrove nursery



Feedback of the program

6. Environmental Education Program for HTC, Ministry of Manpower

Date: November 11, 2013 (Monday)
Time: 12:30 - 14:10 am
Target Group: Female Students of HTC
Number of Participants: 21
Persons in Charge: Bader, Mohammed, Harada, and Koto

Time	Activity	Education Materials used
12:35	Arrival	
12:40	Explanation of Mangrove Forests in Oman	Poster: Mangrove Forests in Oman
12:50	Distributing brochure and photo sheet	Brochure: Mangrove Ecosystem Photo sheet: Animals of Mangrove Forest in Oman
13:00	Explanation of mangroves and mangrove ecosystem	Poster: Food Chain in Mangrove Ecosystem,
13:05	Explanation of equipment for soil & water monitoring	
13:10	Observing Mangrove Nursery	
13:25	Observing Mangrove Forest through Board Walk	
13:45	Feedback	Feedback sheet
13:55	Bird Watching	Photo sheet: Animals of Mangrove Forest in Oman
14:10	Leaving QNR	

Education Materials Used:

- 1) Poster: Mangrove Forests in Oman
- 2) Poster: Food Chain of Mangrove Ecosystem
- 3) Mangroves in the Sultanate of Oman (MECA)
- 4) Brochure: Importance of Mangrove Ecosystem
- 5) Photo sheet: Animals of Mangrove Forest in Oman
- 6) Feedback sheet (Questionnaire)

6.1 Results of the Questionnaire Survey

a) Please rate today' activity.

	Excellent	Good	OK	Poor	Very poor
Activity	15	6	0	0	0
Venue	11	6	2	0	0
Staff	16	5	0	0	0
Date	11	5	3	2	0
Time	7	8	3	1	2

b) Please describe the today's activity in a simple word or sentence.

Very interesting	5
Interesting	4
Excellent	4
Perfect	1
Nice	3
Get new / good knowledge	3
Useful and important	1
Amazing	1
Visit and mangrove	1
Conserving mangrove, conserving Oman	1
Fun day	1
Fantastic	1
No Answer	3

c) What was the most interesting for you?

Irrigation system (watering)	8
Movement of sea water	

Appendix 4 Record of environmental education programs conducted through the Project

The way of cultivation	
How drinking of mangrove	
Living things	5
Living things part	
See the mangrove trees and the animals which there like birds	
Birds, animals	
Snails and crabs	
Mollusks	
New information about mangroves	3
The function of mangrove roots	3
Mangrove & presentation	1
The interactive session with staff especially with the head Mr. Baloushi.	1
How they make the place for this type of plant	1

d) Did you find anything to be modified in order to improve the activity?

No	13
Everything they did	
Yes	8
More walking beds to be built	
More facility for visiting	

e) Do you want to attend this activity again in the future?

Yes	21
I would love to come close to nature and be a part of this experience	
To stay more time.	
100%	
No	0

f) Information on the participants

Age	22	23	24	31	33
Number	15	3	1	1	1

Sex	female	Male
Number	18	3

Nationality	Omani	Indian
Number	20	1



Explanation of Mangrove Forests in Oman



Distributing Brochure of Mangrove Ecosystem

Appendix 4 Record of environmental education programs conducted through the Project



Explanation of the Food Chain



Equipment for Soil & Water Monitoring



Visiting the Mangrove Nursery



Observing Mangrove Forest



Feedback of the program



Bird Watching