9 = ▌ שׁ ךּ ♠ ♯ ɔ Ⱬ̎

REGIONAL ORGANIZATION
FOR THE PROTECTION OF
THE MARINE ENVIRONMENT
KUWAIT

Dist.: RESTRICTED
ROPME/WG-172/2
Original: ENGLISH
28 September 2016

Scientific Committee Meeting on Monitoring and Assessment of Sand and Dust Storms in ROPME Sea Area

Dubai, UAE, 26-28 September 2016

REPORT OF THE MEETING

TABLE OF CONTENTS

INTRODUCTION

In accordance with Decision CM 16/7 of the Council-16 and the recommendation of the Technical Workshop on SDS held in Dubai, UAE during 11-12 October 2015, the Scientific Committee Meeting on Monitoring and Assessment of Sand and Dust Storms in ROPME Sea Area was convened in Dubai, UAE from 26 to 28 September 2016. The Meeting was organized in cooperation with NFP-UAE, JICA, GEOMAR (Germany) and the University of Birmingham (UK). The objective of the Meeting was to prepare the scientific programme and a work plan for the assessment of SDS impacts in the RSA and to deliberate and finalize the scientific programme for a "Pilot Study" and a "Baseline Assessment".

ATTENDANCE

The Meeting was attended by designated senior experts from ROPME Member States, international consultants, experts from JICA and Professional Staff of ROPME Secretariat. The list of participants is attached as Annex I to this Report.

AGENDA ITEM 2: OPENING OF THE MEETING

1.1 The Meeting was opened at 9:00 am on Monday, 26 September 2016 with a welcome statement by the representative of the Ministry of Climate Change and Environment (MOCCAE), UAE, Mr. Salim Akram. In his statement, he warmly welcomed the participants to Dubai and wished them a very successful Meeting. He also appreciated the efforts of ROPME Secretariat towards the implementation of the Council Decision 16/7 and recommendations of the Technical Workshop of October 2015. He highlighted the need to better understand the extent of impacts of SDS on the marine environment of the RSA, a subject which has never been studied in the Region. The statement (in Arabic) is attached as Annex VII to this Report.

1.2 On behalf of ROPME, Dr. Hassan Mohammadi, ROPME Coordinator, welcomed the participants and conveyed the warm greetings and well wishing of H.E. Dr. Abdul Rahman Al-Awadi, Executive Secretary of ROPME**.** He commented that desertification and land use change is a major environmental challenge in the Middle East, with increasing impacts on the ROPME Sea Area ecosystems through enhanced dust inputs. The proposed pilot study should be immediately followed by a baseline assessment. However, since dust inputs are strongest in northern part of RSA, the Pilot Study should focus on this area, but could have wider coverage to represent the Region.

AGENDA ITEM 3: ORGANIZATION OF THE WORK

2.1 Election of Chairman and Rapporteur

The Meeting unanimously elected Mr. Salim Akram as Chairman and Dr. Zongbo Shi as Rapporteur of the Meeting.

2.2 Introduction of Participants

The participants introduced themselves to the Meeting by name, agency and area of expertise.

AGENDA ITEM 4: ADOPTION OF THE AGENDA

3.1 The Meeting discussed and adopted the Provisional Agenda, which is attached as Annex II to this Report.

AGENDA ITEM 5: EXPERIENCE FROM OUTSIDE THE REGION (JAPANESE CASE STUDY) BY DR. MASAO MIKAMI, JMBS, JAPAN

5.1 Dr. Mikami of Japan Meteorological Business Support Center (JMBS) presented a case study for the assessment of SDS impact on the marine environment in Japan entitled "*Monitoring and Modeling of Dust Storm and its Impact to the Ocean".* He showed that the Characteristics of Asian dust is complex due to the complex ground surface condition and topography. And that the snow cover and seasonal change of vegetation will affect the outbreak of dust storm in the North-eastern Asia.

In order to monitor the wind erosion process in the region, the author has conducted field campaigns in cooperation with China and Mongolia. And, based on the observational information, a new dust emission scheme has been incorporated into the new global dust model, MASINGAR, which is now used for operational dust forecast information by JMA.

In the presentation, international cooperation through WMO and TEMM was also introduced and comments were made on dust impact on the atmospheric environment and the ocean ecosystem.

AGENDA ITEM 6 : CURRENT MONITORING AND RESEARCH ACTIVITIES IN THE REGION

6.1 Dust Fallout Properties Within Dust Storms Frequent Paths in the ROPME Sea Area By Dr. Ali Aldousari, KISR, Kuwait.

Dr Ali M. Al-Dousari presented the major dust storm trajectories in the world with a particular focus in paths that fall into ROPME Sea Area. The amount of dust, in addition to particles distributions and statistical parameters within these trajectories were also discussed for comparison between the trajectories. Maps were presented for fallen dust amounts, physical and chemical properties in Kuwait. The dust properties that were mentioned in the presentation are:

- The amount of fallen dust monthly and annually for 2 years
- The particle size and statistical parameters
- The mineralogy of fallen dust
- The major and trace elements

- The pollen amount and type distribution
- The Total Petroleum Hydrocarbon in the dust
- The BET-surface area of dust parts
- The organic matter
- The acidity (pH)

The presentation also had estimated the amount of dust that fallen into ROPME Sea Area in 2006 and 2011. The presentation emphasizes on the adaptation methods that were applied in Kuwait, mainly using native plants, to prevent re-suspension (re-movement) of dust particles after first deposition. Therefore, it was highly recommended to use native plants within source areas of dust.

6.2 Effect of Mineral Dust on Ocean Productivity and Biogeochemistry of the Northern ROPME Sea Area. By Dr. Turki Al-Said, KISR, Kuwait

Dr.Turki started his presentation explaining that Kuwait is subjected to severe dust and sand storms. Aeolian dust is an important source of iron to marine photosynthetic organisms. The deposition of atmospheric dust is the primary process supplying trace metals such as Al, Mn and Fe to the surface ocean. Few studies have been conducted to understand the effect of dust on the biological activity in Kuwait's waters. Incubation experiment which involve spiking of aeolian dust rich in essential micronutrients (Co, Cu, Fe, Ni, Zn, Mn) increase phytoplankton growth reaching red tide proportions. Dust impact is a major ecological force in the formation of algal blooms and detailed study on effect of dust on the biological abundances and associated processes in Kuwait waters is urgently needed.

Dr. Turki presented the results of a recent completed project showing that concentrations of metals (Fe, Cu and Zn) were comparable with other coastal regions and much lower than previously reported data.

He presented the objective of the new anticipated project of KISR with the National Institute of Oceanography, India (NIO) which aims to assess the sources and effect of mineral dust fluxes on ocean biogeochemical processes in the northern RSA through: (a) estimation of the atmospheric deposition of mineral dust, identification of sources, and its soluble fraction (inorganic leachable ions and nutrients); (b) evaluation of effects of mineral dust fluxes on ocean biology and chemistry; and (c) providing a database of mineralogy, geochemical and isotopic characteristics of mineral dust and the soluble component of mineral dust for future reference.

Thus, the study will help to understand carbon sequestration via the chemical and biological pathways. Incubation experiments will be carried out by applying dust particles collected from different locations in Kuwait to phytoplankton assemblages. During the project, seawater samples will be collected for chemical and biological analysis to understand the impact of the dust on primary production and its possible role in carbon sequestration. Routine measurements will include monthly sampling of fundamental biogeochemical parameters such as dissolved oxygen, pH, nutrients and chlorophyll-a. Seasonal measurements will be carried out for dissolved organic carbon and alkalinity to understand the impact on the carbonate system. Project tasks were identified and each task activities including analysis and measurements were described. Dr Turki emphasized that the anticipated project will provide valuable data. Available instruments to be utilized during the future work were also cited.

6.3 MASDAR, UAE (earth.masdar.ac.uae)

In a short intervention by the representative of MASDER in the meeting, he expressed the willingness to participate in the programme through making available to the programme the information and data in the following activities:

- Satellite observation for chl.
- Ocean modelling of currents.
- Wolfgang atmospheric modelling.
- Tricho blooms in the UAE region in periods with T 24-28 C.

AGENDA ITEM 7: STATUS OF EXISTING CAPACITY FOR SAND AND DUST STORMS MONITORING IN THE RSA (PROF. ERIC ACHTERBERG)

The programme of the first day of the meeting ended by two presentations of Prof. Achterberg. In the first presentation he briefed the participants with the aim, objectives and expected outcomes of the proposed pilot project, baseline study and long-term programme for monitoring and assessment of impacts of dust on the RSA.

In his second presentation, Prof. Achterberg presented details of the outcomes of the circulated questionnaire which aims to establish the monitoring and research capacity on dust and ocean biogeochemistry within the ROPME Member States.

Annex III includes an evaluation report on the received responses from Member States from which the following points can be highlighted:

- Five countries (Bahrain, Iraq, I.R. Iran, Kuwait and UAE) have sent details on existing atmospheric and seawater column sampling and analysis
- Amount of monitoring undertaken is extensive and very useful to the planned SDS monitoring programme
- Substantial amount of particulate matter and gas monitoring using direct light attenuation sensors or gas sensors
- Particulate aerosol sampling for dry deposition undertaken at a good number of sampling sites in the region
- Satellite observations and ground based remote sensing activities is undertaken in a number of countries
- Limited amount of aerosol modelling is undertaken. It will be important to engage the modellers in the planned dust programme
- Good amount of water sampling undertaken. Sampling for nutrients is common with some metal analyses
- Water sampling stations are well distributed around the region which is very useful to the monitoring programme
- Substantial amount of air quality data available from member states

Prof. Achterberg concluded that the outcomes of this questionnaire is of great importance and provides excellent information which will be used to develop a coherent and inclusive scientific programme for the proposed regional study.

AGENDA ITEM 8: ELEMENTS OF THE MONITORING PROGRAMME OF FALLEN DUST IMPACTS ON THE MARINE ENVIRONMENT OF THE ROPME SEA AREA

Prof. Achterberg briefly explained the aims and objectives of the research programme and recommended that the programme should be implemented in three phases

- Phase I: Pilot study
- Phase II: Baseline
- Phase II: Long-term programme

Coordinator of ROPME, Dr. Mohammadi, then suggested that the pilot study represent the RSA and include UAE, Kuwait, Iraq and Iran. It is possible that one more country can join the pilot study, e.g., Qatar, Bahrain, or Saudi Arabia. However, the training and capacity development during the pilot study phase will be provided for all countries. He also commented that future programmes (baseline and long-term) should extend to the wider areas including the Sea of Oman.

After some debate on the approaches to be adopted in the discussions, the committee members agreed to go through the concept paper (Annex IV) point by point, including research aim/objectives and the research programme. This will lead to a final agreement on the details of the Scientific Programme.

8.1 <u>Overall aim:</u>

The committee members debated and agreed that the overall aim of the pilot study is to provide initial data for developing a one year baseline monitoring programme (BAISDS-2019), and the specific objectives should include:

- Setting up capacity to undertake aerosol sampling with high and low volume aerosol collectors
- Collecting aerosol and seawater samples (using clean techniques) at 3 to 5 stations over a period of 2 months
- Measuring total and soluble elements and compounds in the collected aerosol samples
- Measurements of trace elements, nutrients, organic compounds, carbonate chemistry, chlorophyll a and indicators of ecosystem structure in the collected water samples
- Determining the biological impact of aerosols in selected samples
- Identifying potential sources and transport pathways of mineral and anthropogenic aerosols in the region
- Identifying gaps and needs of baseline monitoring programme

8.2 <u>Target elements, compounds and biological impact assays</u>

The committee agreed that the target elements, compounds, and biological impact assays should include:

- Essential elements for microorganisms (e.g., Fe, Co, N, P, Si)
- Toxic elements (Cu, Pb, PAHs) and elements that may be involved in nuisance bloom development (N, P)
- Mineralogy using X-ray Diffraction
- Quantitative source apportionment of PM/soluble and total trace elements

- atmospheric modelling of trace element and nutrient deposition, constrained by remote sensing of total aerosol deposition rates in combination with ground measurements
- Water sampling: chemistry and biology including carbonate chemistry linking inputs from atmosphere, river and sediment
- Enhance and validate a local physical biogeochemical ocean model with improved aerosol supply fluxes and biological impact quantifications
- Data on criteria anthropogenic gases, such as ozone, SO2, NOx and PM are to be collected to identify origin of collected air masses
- LIDAR observations (at least one operational in Kuwait) will be performed to support atmospheric modelling. Multispectral (UV to PIR) atmospheric aerosol optical depth (AOD) will be performed using manual photometers in the frame of the Maritime Aerosol Network (MAN) components of AERONET

Elements, compounds, gases and physical measurements	**Matrix**
Na, Mg, Al, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ag, Cd, Sn, Hg, Pb, U, P, OC/EC, PAHs, molecular tracers	Collected aerosols (total fraction)
Na, Mg, Al, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ag, Cd, Sn, Hg, Pb, U, chlorite, sulphate, ammonium, nitrate, phosphate, silicic acid, sulphate, DOC	Water soluble aerosol fraction
Al, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ag, Cd, Hg, Pb, U, ammonium, nitrate, phosphate, silicic acid, DOC, dissolved inorganic carbon and total alkalinity	Surface seawater samples
Ozone, VOCs, NOx and SO_2 at selected stations	Gas phase
Aerosol optical depth (AOD, using manual photometer)	Atmosphere
XRD-EM mineral analysis	Particulate aerosol samples

The committee recommended that standardized methodology in sampling and analysis of aerosol and water should be developed, and training should be provided to the regional partners from different participating countries. ROPME has recognized that it is important to train capacity in other labs in the region and an intercomparison exercise should be carried out when samples are collected at one place and shared and analyzed by different labs. It was agreed that both particulate matter (dust) and seawater reference materials need to be purchased (after notifying ROPME) for an anonymous proficiency test exercise for the pilot study.

The committee recommended that national agencies in the region are to submit critical gas and particulate matter monitoring data for the research programme.

Some committee members mentioned to include both soluble and particle phase in seawater, sediment release of nutrients and metals, coral reefs and seagrass, persistent organic matter and organic mercury and tin within the programme. The committee debated on these issues and agreed that all the above aspects are important but they are out of scope of this particular study. However, we should explore the possibility to collaborate with other ongoing programmes and consider using case studies on the above aspects, e.g., carry out sampling at one site during the programme. Dr. Hassan Awad then suggested that during the pilot project, we need to test as many analytes as possible in order to select some for future analysis in the baseline assessment on basis of the pilot study. The Chairperson and Dr. Mohammadi recommended that radio-isotopes should also be measured but we need to find out how much materials are needed for radio-isotope analysis at MESL/IAEA of Monaco.

Further discussions focused on the biological impact of dust. It was recommended that seawater should be taken at 50 m depth and the following parameters to be measured:

- Chlorophyll a
- Photosynthetic efficiency (stressed by pollution or nutrient limitation)
- Microbial composition (HPLC analysis, genomic analysis)

In addition, dust microcosm experiments should be carried out on a routine analysis. It was decided that Dr.Turki Al-said from KISR to send the list of instruments needed for seawater analysis using the standard procedure to ROPME and the consultants, and Prof. Achterberg to send the recommended procedure for the biological impact assessment to ROPME. However, the committee recognized that this is too complicated for the pilot study but should be included in the baseline measurements.

8.3 Criteria and selection of suitable sampling sites

The committee agreed on the criteria and selection of suitable sampling sites

- Cost and effective
- Should consider wind patterns, representative locations, and anthropogenic activities
- Selection of sites: should change “conducted” to “studied” when talking about air back trajectories and air quality prediction
- Existing ROPME reference sites are to be carefully considered to benefit from historical data
- Existing and planned regional initiatives

Baseline sampling sites (after pilot):

- Include a number of stations: e.g, 8 stations and including the Sea of Oman
- Offshore sampling: using available ships (cruises) in coming years; samplers on oil/gas platform, including rigs; possible to have two stations over the RSA
- Qatar: potential to have sampling station available already but may not be available to do all analyses as planned in the programme (need more training/equipment). Therefore, Qatar will not be able to make all the analyses as in the programme; but can provide air quality data

8.4 Sampling protocols and sample types

The committee agreed on the following standard sampling protocols such as those proposed by GEOTRAES

- Aerosol, one high volume with quartz filter and one low volume using PTFE filter; all partners should use the same brand of samplers if possible; suggested to use as feasible the automatic samplers (up to 15 samples per time) to reduce workload. The committee suggested that one type of equipment to be used for all sites (e.g., Digitel and Partisol for aerosol sampling) and all should be calibrated before the campaign.

- Water column: water samples should be collected at sites close to aerosol samples. Surface water: 20 cm to 1m depth; water samples should be taken on monthly basis, and AOD and aerosol samples on a daily basis.
- nutrient analysis should be using certified reference material KANSO
- Trace metal sampling of seawaters: for this project it is suggested to sample using clean hose and pump for sampling shallow waters.
- Trace metal analysis: isotope dilution ICPMS with Seafast sample preparation system; other appropriate techniques considered as well
- Need to train the sampling and analysis methods that are easy to handle and clean; should be part of the training process.

The possibility of implementing the sampling protocol in each country was widely discussed and the following points were raised:

- **Iraq**: has TSP/PM10/PM2.5 samplers; water samples by hand; no equipment for depth water; analysis for part of the parameters
- **Kuwait**: TSP samplers under purchase; able to do a good number of the analyses; pump and CTD for water sampling; can share sample for pilot study
- **UAE**: 41 onshore or offshore air quality monitoring stations (SO2/NOx, PM10) with five stations for PM2.5 and dust fall collector; chemical analysis of dust fall; CDT… ranges of approaches
- **Qatar:** PM2.5/PM10 raw data, no TSP
- **Bahrain**: willing to participate; but no TSP samplers
- **Saudi Arabia**: water hand sampling; unclear
- **Iran**: no one was present in the meeting
- **Oman**: no one was present in the meeting

Biological impact of aerosols (microorganism community)

- Culture experiments
- Microcosms on cruises
- Possible mesocosm experiment
- Indicators via Bioassays: simple approach on same species
- KISR: culture lab of specific species and able to run on the real water samples (plan to do on real water samples with phytoplankton in this pilot study)
- ROPME Coordinator questioned how could we extrapolate the data to RSA and also need to consider differences in species at different seasons

After the discussion of the above elements, it was recommended that the Scientific Committee to prepare Standard Operating Procedures (SOP) for the full range of activities as part of the sampling and analysis activities.

8.5 Sampling frequency

- Pilot study: 2 months in 2017, Training, purchase of instrumentations, and actual sampling to start in mid-2017 (dusty season, April-June)
- Baseline 2018: full year, to cover the dust and non-dust seasons

8.6 Samples banking

It was agreed that ROPME shall archive the samples under the required condition. Sub-samples will be sent and analysed in ROPME designated labs.

8.7 Data management and reporting

The committee agreed that data should be archived in ROPME and GEOMAR data library and made available to all partners, pending data agreement; ROPME will lead on data validation (part of training and capacity building). Data will be organized into technical reports.

8.8 Training needs

A series of training activities was proposed, all to be conducted in the ROPME region:

- Sampling, preservation and analysis: training in the region (4 days before the start of the Pilot Study)
- Aerosol and water analysis for organic compounds (4 days during or just after the Pilot Study)
- Aerosol and water analysis for inorganic compounds (4 days during or just after the Pilot Study)
- 4 day training workshop in a regional institute (after the Pilot Study) on data modelling and management (different atmospheric and oceanographic biogeochemical models)

Dr. Awad emphasized the need to do the proficiency tests in order:

- To find the gaps and training needs
- To find out who and which lab can do the proposed analyses

8.9 Linkages with other ROPME activities

It was recommended that linkage/harmonisation should be established for the baseline 2018 with the following activities:

- Oceanographic cruises; set up a scientific programme for the planned upcoming cruises
- ROPME Mussel Watch programme; every three years (25 sites for sampling oysters); harmonise the time of sampling for dust and oysters; could potentially see the impact of dust which represent added value
- Survey of radionuclides in sediment and biota

Dr. Mohammadi added that ROPME satellite images receiving station can help in the programme and produced data can be stored in the ROPME integrated information system (RIIS). In this regard, access protocol to be developed, for the time being, access is limited but can be arranged if Member States want to do some work on the specific areas.

Dr. Awad Hassan insisted on the importance that all relevant regional and national activities should be integrated to have a more representative regional picture; linkage of science, social and economic benefits.

Mr. Salim, UAE representative highlighted that it is a need to link the programme to other activities in national institutions (Department of Transport , research centres, regulators,…..). He added that voluntary sharing of responsibilities in the aerosol dust sampling programme is one important step.

Some participants urged ROPME should explore the possibility of integration with regional and international programmes of UNEP.

Some members of the committee proposed to include in the programme the study of mineral dust impacts on rain events on the Indian sub-continent, and the effects of west Asian pollution aerosols on the health of the RSA.

KISR representatives expressed strong willingness to contribute in the programme. KISR will also order dust samplers. They advised other Member States to order the samplers themselves as well; this is capital investment so should be purchased by member states.

AGENDA ITEM 9: IMPLEMENTATION PLAN AND TIME- FRAME

Dr. Awad proposed the Time Plan for the implementation of the three phases of the Programme. The proposal was discussed and the Committee Members agreed on the following Time Plan:

1) Mid-Oct: send the updated questionnaire to members states including the type of dust collectors (type and specification of the samplers and whether the members states have the samplers)
2) Mid-Nov 2016: to obtain the questionnaires of three countries which have not yet been able to submit, with additional information from other member states
3) End of Nov 2016: The completed questionnaires will be sent to consultants; the questionnaire report will be updated; consultants will list the existing laboratories in the region to be invited to participate in the pilot study
   a. Consultants and ROPME to contact respective labs; Consultants recommend what to analyse, budget and timeframe and then Member States will respond and then we can finalize
   b. We know what countries can do sampling
   c. We need to find out what countries and labs can do the analysis
4) End of 2016: circulate the list of labs that are willing to participate in the sampling and analysis for the pilot study
5) Jan 2017: Reference samples to be sent to the willing labs for proficiency tests by the consultants
   a. Contact participating labs in member states whether the samplers can be purchased and funding available? Order placed? When they will be delivered and ready for use?
6) Jan to Feb 2017: sample analysis by participating laboratories in the region
7) Mid-march 2017: Data to be sent to ROPME and Consultants
8) End of March 2017: Consultants will identify the gaps and training needs
9) April 2017: Dust and water sampling training (2 persons from each Member State)
10) Sep to Oct 2017: Pilot study sampling period
11) May 2018: Completion of sample analyses and reporting for pilot study data to consultants: six months after the sampling
12) June 2018: meeting in the region to discuss the outcome of the pilot study; we expect that *participants from pilot study will present* their results

13) Aug 2018: Reports of the pilot study to the ROPME Council (one for decision makers and one scientific report)

14) Jan-Dec 2019: baseline (abbreviation to change to 2019)
    a. Mid report for the baseline in 2019

15) June 2020: completion of analyses of samples and reporting for baseline study 2018

AGENDA ITEM 10: DISTRIBUTION OF TASKS AND ORGANISATION OF WORK

According to the above accorded implementation plan by the Committee Members, the following points were deeply discussed and agreed on:

- Questionnaire has to be updated with additional section for the used types of aerosols collectors and frequency of sampling and re-circulated for completion and updating.

- It is necessary to unify the type of used aerosols collectors among the participating countries in the programme. Consultants will look for and propose a model of suitable collector.

  Dr. Mohammadi mentioned that Member States are to purchase their own samplers as their own property

- Towards widening the participation of Member States in the programme, ROPME Secretariat will circulate a call for participation among national institutions for conducting the analyses

- ROPME will organise a Proficiency Test among the willing laboratories for the selection of competent laboratories to participate in the analyses

- Certified reference materials to be used for training, Proficiency Test and analyses of samples during the whole programme.

- ROPME has to share all data/reports; anyone engaged in the study will be acknowledged in relevant reports/publication; all participants should have access to relevant information within the programme

Dr. Awad mentioned that if there are countries, for some reasons cannot participate in the pilot phase of the programme, ROPME Secretariat will make every efforts to ensure their participation in the baseline study.

AGENDA ITEM 11: OTHER MATTERS

No other matter was raised.

AGENDA ITEM 12: CONCLUSIONS AND RECOMMENDATIONS

The Meeting of the Scientific Committee adopted the following recommendations:

1. Implementation of the work plan of the programme within the agreed time frame

2. Consultants to update the questionnaire including types of used collectors and frequency of sampling

3. Circulation of the updated questionnaire for compiling and updating by all Member States

4. Unifying the aerosols collectors be used during the whole programme. States should purchase their own collectors as their own property

5. Scientific Committee will prepare Standard Operating Procedures (SOP) for the full range of activities as part of the sampling and analysis activities

6. Representatives of Kuwait to send to ROPME Secretariat the list of instruments needed for seawater analysis using the standard procedure and the consultants to send the recommended procedure for the biological impact assessment.

7. ROPME Secretariat to organize a Proficiency Test (PT) among the willing national laboratory in the region for participation in the analyses of collected samples. Consultants will provide the necessary Reference Materials for the Test. The PT be carried out during the baseline or later experiments

8. Consultants to update the Concept Paper highlighting the potential of Climate Change on Sand-dust Storms and its impacts on the marine environment in RSA

9. ROPME to establish a module in the ROPME Integrated Information System (RIIS) for uploading activities and data relevant to the whole programme for sharing within the region and world-wide in future.

AGENDA ITEM 13: CLOSURE OF THE MEETING

Dr. Hassan, Coordinator of ROPME concluded the meeting after the exchange of courtesies at 17:00 hours on Wednesday, 28 September 2016.

ANNEX I

LIST OF PARTICIPANTS

( )

ANNEX II

PROVISIONAL AGENDA

UNITED ARAB EMIRATES
MINISTRY OF CLIMATE CHANGE
& ENVIRONMENT

الإمارات العربية المتحدة
وزارة التغير المناخي
والبيئة

Scientific Committee Meeting on Monitoring and Assessment of Sand and Dust Storms in ROPME Sea Area

Dubai, UAE, 26-28 September 2016

PROVISIONAL AGENDA

1) **Registration**

2) **Opening of the Meeting**

3) **Organization of the Work:**
- Statement of Ministry of Climate Change and Environment
- Statement of ROPME

4) **Adoption of the Agenda**

5) **Experience from Outside the Region (Japanese Case Study)**

6) **Current Monitoring and Research Activities in the Region**

7) **Status of Existing Capacity for Sand and Dust Storms Monitoring in the RSA**

8) **Elements of the Monitoring Programme of Fallen Dust Impacts on the Marine Environment of the ROPME Sea Area**
- Overall and Specific Objectives
- Coverage Area (Sub regional / Regional)
- Scientific Programme design (duration, sampling sites and frequency, analytes….etc.)
- Needed training

9) **Implementation Plan and Time- Frame**

10) **Distribution of Tasks and Organisation of Work**

11) **Other Matters**

12) **Conclusions and Recommendations**

13) **Closure of the Meeting**

ANNEX III

QUESTIONNAIRE EVALUATION REPORT

Scientific Programme for Baseline Assessment and Long-term Monitoring of Impacts of Sand and Dust Storms on the Marine Environment in the ROPME Sea Area

The ROPME technical workshop in Dubai on 11-12 October 2015 agreed on conducting a long-term monitoring programme to assess the effects of dust and sand storms on the marine environment in the ROPME region. The first step of this process is to undertake an evaluation of existing capabilities in the region, and the second step is to undertake a pilot study. Subsequently, a baseline study of a full year and long-term monitoring programme can be undertaken.

This document reports on the evaluation of the existing capacity in the region, and provides an outline plan for the pilot study.

Existing capacity

The return on the evaluation form send out by us in late 2015 was excellent. We received returns from 5 countries (Iraq, Iran, Kuwait, UEA, Bahrain) with details on existing atmospheric and water column sampling and analysis. The amount of monitoring undertaken is extensive and very useful to our proposed scientific programme. We have summarized the finding, and this is provided in appendix 1.

There is a significant amount of particulate matter and gas sampling undertaken at a good number of sampling sites in the region. Furthermore, a number of countries have substantial satellite observation and ground based remote sensing activities. A limited amount of aerosol modelling is undertaken; it will be important to engage the modellers in our programme.

There is a good amount of water sampling undertaken, and in particular sampling for nutrients is common. The sampling stations are well distributed around the region. This is all very useful to our scientific programme.

There is a substantial amount of air quality data available from member states, which should be mined for analysis of the spatial distribution of air pollutants and dust as well as providing information on the sources of PM.

Overall, the return on the evaluations were of great importance and provide us with excellent information to design the pilot study, baseline study and long-term monitoring programme.

The scheduled meeting in August 2016 will allow us to make decisions on where to site the samplers for the pilkot and baseline study, with the aid of the information from the evaluation.

ROPME Pilot Project design

A number of important questions need to be addressed in order to improve our understanding of the effects of dust and sand storms on the marine environment in the ROPME area:

- What are the supplies of nutrients, trace elements and organic contaminants to the RSA by total and soluble aerosol deposition?
- What are the contributions of anthropogenic and natural sources to aerosol loadings in the RSA?
- What are the chemical and biological impacts of aerosol inputs to the waters of the RSA?
- How can future decisions be made on reduction of anthropogenic aerosol emissions in the ROPME region to mitigate their impact on RSA ecosystems?

These questions require us to understand and assess the impact of aerosol inputs to the RSA upon agreed baseline parameters.

The first step in the process of obtaining baseline parameters and undertaking a long term monitoringprogramme, will be the setting up of a pilot study of a limited scope and duration.

The Pilot Study will form a limited study involving 3 to 5 sampling sites in different parts of the RSA. The Pilot Study will ensure that the overall programme gets underway swiftly, and will also allowidentification of gaps and needs for the follow up larger programmes.

The pilot study is thus the predecessor of the Baseline Assessment. The “Baseline Assessment of Impact of Sand and Dust Storms (BAISDS) in the ROPME Sea Area” is a collective task of assessing Aerosol inputs and their biological impact for a full year in 2018-2019, to be used in references, comparisons and decision making. The BAISDS-2018 is expected to become a reference status to mineral dust and other aerosols for future times to come.The Long-term monitoring programme will follow the baseline assessment andprovide a temporal perspective to regional dust and anthropogenic aerosol concentration changes, and subsequent impacts on the health of the RSA.

Basic approach for the development of Pilot Study and BAISDS-2018

In developing the Pilot study and BAISDS-2018, complete harmonization of related initiatives and sharing of responsibilities will occur. The major milestones to be achieved are:

- Meeting of a Scientific Group to finalize the details of Scientific Programme of Pilot Study and BAISDS-2018.This meeting will identify sampling sites and institutes responsible for sampling
- Practical activity of developing the Pilot Study and BAISDS-2018 by way of completing sampling, analyses, interpretation and reporting

- Development of Regional capacity to contribute to and continue the efforts over a long time period by way of strengthening expertise and designating Regional Reference Laboratories

The overall aim of this small Pilot scale study is to provide initial data for developing a one year monitoring programme of BAISDS-2018.

Objectives of Pilot Study

- Set-up capacity to undertake aerosol sampling with high volume aerosol collectors, purchase aerosol collectors and sampling equipment for water column sampling
- Train staff in aerosol collection and water sampling
- Collection of aerosols and seawater samples over a 2 months period in the year 2017 at 3-5 locations in the ROPME Sea Area
- Identification of gaps and needs for larger monitoring programme
- Measurement of total and soluble elements and compounds in the collected aerosol samples at GEOMAR, Germany
- Measurement of trace elements, nutrients, organic compounds, carbonate chemistry, chlorophyll a and indicators of ecosystem structure in the collected water samples at GEOMAR, Germany
- Determination of the biological impact of aerosols in selected samples at GEOMAR, Germany
- Identification of the potential sources and transport pathways of mineral and anthropogenic aerosols in the Region at Birmingham

Expected outcome from Pilot Study

- Small and limited dataset on aerosol deposition and impacts on surface water biogeochemistry and biology for parts of the RSA
- Substantial and high quality dataset
- Gaps and Risks assessment for BAISDS-2018
- Actions plan to deal with gaps and risks for BAISDS-2018 implementation

Requirements to undertake Pilot Study

- High volume aerosol collectors for 3-5 sampling sites (2 collectors at each site)
- Funds for consumables and transport of samples to GEOMAR

- Researcher and technician at GEOMAR to prepare pilot study, train collectors, undertake sample analyses and reporting
- Researcher at Birmingham to undertake data analysis on existing and pilot study data

Indicative Programme Time-frame

- Meeting of the Ad-hoc Committee to finalize a detailed Scientific Programme with the identification of sampling team, players and Protocol of sampling – August 2016
- Designation of responsible Laboratories for conducting Aeolian mineral dust and seawater pilot study sampling – August 2016
- 1 week Training on sampling and sample preparations: January 2017
- Start of sampling for pilot study: June 2017 for a period of 2 months
- Completion of sample analyses of samples and reporting for pilot study: January 2018
- Start of BAISDS-2018: June 2018 for a 12 months period
- Completion of analyses of samples and reporting for BAISDS-2018: June 2019

Appendix 1

ROPME Evaluation outcomes

Iraq, Basra Environmental
Mr. Ahmed Hanoon

<u>Section 1</u>: <u>Dust monitoring, analysis, and modelling</u>

Section 1.1: Dust, air quality, and meteorology monitoring stations

A range of PM_{10} and $PM_{2.5}$samplers are available, and placed in the south of the country and also Bagdad. Optical and beta-attenuation measurements are also available. These are all very useful to our ROPME programme.

In addition, SO_2, O_3, NO_x-NO_2, CO, VOC data are available.

Section 1.2: Chemical and mineralogical analysis of airborne dust or dustfall

Elemental data is available for particulate matter and dust fall since 2006 for the Basra region, which is very useful.

Section 1.3: Ground-based remote sensing observations

No detail provided.

Section 1.4: Satellite observations

No detail provided.

Section 1.5: Analytical capacity of airborne dust and dust fall

Trace metals using AAS

Section 1.6: Modelling capacity of airborne dust and dust fall

none

Section 1.7: Additional Information

<u>Section 2</u>: <u>Ocean biogeochemical and biological parameter monitoring, analysis, and modelling</u>

Section 2.1: Ocean nutrient, trace metal and biological monitoring

Measurements of pH, temperature, phosphate, nitrate, chla and trace metals are made in the sea waters near Basra.

Section 2.2: Analytical capacity of marine biogeochemical variables

Spectrophotometer for nutrients and AAS for trace metals.Microscope with camera for phytoplankton.

Section 2.3: Remote sensing

No detail provided

Section 2.4: Modelling capacity of ocean biogeochemistry

No detail provided

Section 2.6 Additional information

No detail provided

Iran, Department of Environment
Dr Shina Ansari

<u>Section 1</u>: <u>Dust monitoring, analysis, and modelling</u>

Section 1.1: Dust, air quality, and meteorology monitoring stations

A range of PM_{10} and $PM_{2.5}$samplers are available, and placed around the country with also units along the coast, but it is difficult to assess what the locations are. There are optical, beta-attenuation, TEOM and filter systems available for online PM mass monitoring. This is all very useful to our ROPME programme.

In addition, SO_2, O_3, NO_x-NO_2, CO, VOC data is available

Section 1.2: Chemical and mineralogical analysis of airborne dust or dustfall

Elemental data and organic is available for particulate matter and dust fall, which is very useful.

Used analytical methods include GC-MS, IC, ICP-MS, ICP-OES, AAS, XRD, SEM, XRF, ToT,

Section 1.3: Ground-based remote sensing observations

Handheld and automatic sunphotometer measurements

Lidar observations and ceilometer (vertical backscattering) measurements

Section 1.4: Satellite observations

A whole range of satellite observations are used for collection of atmospheric and oceanographic products

Section 1.5: Analytical capacity of airborne dust and dust fall

A full suite of analytical techniques are available to measure trace metals, organic compounds, nutrients, particle characteristics.

Section 1.6: Modelling capacity of airborne dust and dust fall

Model	Center
BSC-DREAM8b	**BSC-CNS**
MACC-ECMWF	**ECMWF**
NGAC	**NCEP**
NMMB/BSCDust	**BSC-CNS**
Others: hysplit, aeromod, pmf, cmb, cmaq, wrf	

A range of models are used in Iraq. It is not clear at what institute the models are run, and who runs them.

Iran Meteorological Research Centre (ASMERC) is running aerosol/dust models, in particular the CasHKIand WRF-Chemmodels.

Section 1.7: Additional Information

Section 2: Ocean biogeochemical and biological parameter monitoring, analysis, and modelling

Section 2.1: Ocean nutrient, trace metal and biological monitoring

Measurements of pH, temperature, salinity, phosphate and trace metals are made in the sea waters off Khuzestan and Hormozgan, since 2013, and also in river waters and marshes.

Section 2.2: Analytical capacity of marine biogeochemical variables

Spectrophotometer for nutrients and ICPMS, ICPOES and AAS for trace metals.Microscope and PCR for phytoplankton and zooplankton.Also particle characteristics using XRF.

Section 2.3: Remote sensing

Not reported

Section 2.4: Modelling capacity of ocean biogeochemistry

ASMERC runs WRF-chem model for dust

Section 2.6 Additional information

none

United Arab Emirates, National Centre of Meteorology and Seismology (NCMS)
Majed Nasser Al Shekaili

<u>Section 1</u>: <u>Dust monitoring, analysis, and modelling</u>

Section 1.1: Dust, air quality, and meteorology monitoring stations

Air quality monitoring at Al Jeer –RAK,Al Burairat–RAK,Al Qasimiyah–RAK, Ghalilah–RAK, Al Humaidiyah–Ajman, Mushririf–Ajman, Hamriyah FZ-Sharjah, Kalba- Sharjah stations

PM_{10}beta-attenuation and SO_2, NO_x-NO_2, CO monitors are operational. This is useful to our ROPME programme.

Kuwait, KISR
Dr. T Al-Said and Dr. A Dousari

<u>Section 1</u>: <u>Dust monitoring, analysis, and modelling</u>

Section 1.1: Dust, air quality, and meteorology monitoring stations

TSP (gravimetric) and PM_{10} (gravimetric) and PM_{10} beta attenuation systems are operational at various sites since 2010. It seems that TEOM data are also available.

Section 1.2: Chemical and mineralogical analysis of airborne dust or dustfall

SEM, ICP-MS, Radionuclide, Pollen, Particle Size and amount fallen dust, and TPH are determined on dustfall for the period 2009-2011.

In addition, SO_2, NO_x-NO_2, O_3, CO data is available, so do meteorological data.

All these are at a range of sites.

Section 1.3: Ground-based remote sensing observations

No detail reported

Section 1.4: Satellite observations

MODIS Aqua Terra work is undertaken for 2009-2011

Section 1.5: Analytical capacity of airborne dust and dust fall

No detail provided but SEM, ICP-MS, Radionuclide, Pollen, Particle Size

Section 1.6: Modelling capacity of airborne dust and dust fall

Section 1.7: Additional Information

<u>Section 2</u>: <u>Ocean biogeochemical and biological parameter monitoring, analysis, and modelling</u>

Section 2.1: Ocean nutrient, trace metal and biological monitoring

Measurements of pH, temperature, salinity, nitrate, silicate, phosphate and metals are made in the sea waters off Kuwait.

Section 2.2: Analytical capacity of marine biogeochemical variables

CTD, Colorimetric techniques for nutrients, GFAAS, CSV, FeFIA for metals.Fluorimeter for chlorophyll, microscopy for phytoplankton and zooplankton.

Section 2.3: Remote sensing

Section 2.4: Modelling capacity of ocean biogeochemistry

Section 2.6 Additional information

none

Bahrain, Supreme Council for Environment (SCE)

Ms. Sara YousifTaqi
Eng. Hassan Abdulla AlMarzooq

Section 1: **Dust monitoring, analysis, and modelling**

Section 1.1: Dust, air quality, and meteorology monitoring stations

PM_{10} beta attenuation system operational at site in period 20061-2012.

In addition, SO_2, NO_x-NO_2, CO, VOC, and meteorological data data are available at Bahrain Fort, Tubli, Hidd, Ma'ameer and Askar Stations

Section 1.2: Chemical and mineralogical analysis of airborne dust or dustfall

No detail reported

Section 1.3: Ground-based remote sensing observations

No detail reported

Section 1.4: Satellite observations

No detail reported

Section 1.5: Analytical capacity of airborne dust and dust fall

No detail provided

Section 1.6: Modelling capacity of airborne dust and dust fall

No detail reported

Section 1.7: Additional Information

No detail reported

Section 2: **Ocean biogeochemical and biological parameter monitoring, analysis, and modelling**

Section 2.1: Ocean nutrient, trace metal and biological monitoring

Measurements of pH, temperature, salinity, nitrate, phosphate and chlorophyll are made in the sea waters off Bahrain since 2007, in particular at Qassar Noon, Mashtan, Jabbari, FashtTighalib, Ghumais, Askar, Msoor, Petroleum refinery, Al Gaha, Suhain, Fa#ash, Al Gazara, Dam, Qita'at>Jaradah, Marina club, Al JarimKhorfasht, Murwada, Bartafi, Qassar, Umm Al na'assan, JaziratYa#suf, Al Jasara, Shtaya, Abu Ithama, Najwat Abu Ithama, BpOmana, and Al Jarim West.

Section 2.2: Analytical capacity of marine biogeochemical variables

CTD, Colorimetric techniques for nutrients, GFAAS, CSV, FeFIA for metals.Fluorimeter for chlorophyll, microscopy for phytoplankton and zooplankton.

Section 2.3: Remote sensing

No detail reported

Section 2.4: Modelling capacity of ocean biogeochemistry

No detail reported

Section 2.6 Additional information

No detail reported

ANNEX IV

CONCEPT PAPER

BASELINE ASSESSMENT AND MONITORING OF IMPACTS OF DUST ON THE MARINE ENVIRONMENT OF THE ROPME SEA AREA

Concept Paper

Baseline Assessment and Monitoring of Impacts of Dust on the Marine Environment of the ROPME Sea Area

Introduction

Background

Decision CM16/7 of the ROPME Ministerial Council directed that in view of the high significance of the matter, information on the impact of sand and dust storms on the marine environment in the ROPME Sea Area (RSA) be obtained. It mandated that a Concept Paper be prepared to elaborate the issues of the impact of sand and dust storms on the health of the ocean in the RSA, to be followed immediately by a pilot scale project and subsequently by a baseline assessment and long-term monitoring programme. Pursuing these Decisions, a Regional Meeting for the Review of the Concept Paper Elaborating the Issues of Sand and Dust Storms and their impact on Ocean Health in the RSA is conducted during 11-12 October 2015. This forum provides an opportunity to review the general aspects relevant to mineral dust production, transport and deposition in the ocean and consequent biogeochemical and physical impacts in the Region, consider the capacities and resources of the Member States and prioritize the areas of future activities of high significance to RSA. The Meeting will develop a small scale pilot study which will cover part of the region and will allow the identification of gaps and needs that are required to be addressed for a successful implementation of the subsequent larger scale programme. The Meeting will also develop the rationale for the baseline assessment and long-term monitoring "to generate the first synoptic data on sand and dust storms and their impacts on the marine environment in the RSA, collate existing data, assess and mobilise the core expertise of the Member States on the subject and prepare technical capacity grounds for a comprehensive Regional monitoring programme and Regional network of facilities". The present Draft Concept Paper is prepared in this context and is submitted to the First Meeting of the Regional Scientific Group to deliberate upon and finalize.

Need for Baseline Assessment and Long-term Monitoring Programme

Millions of tons of dust, usually from arid and semi-arid areas, are emitted annually to the atmospheric boundary layer (Shi et al., 2012). The large quantities of dust result in severe air pollution, reduced visibility, adverse human health effects and impaired soil fertility. Importantly, mineral dust is a dominant atmospheric aerosol on a global scale and plays an important role in the Earth's climate system. Mineral dust directly affects the climate by reflecting solar radiation and absorbing solar and terrestrial radiation, and indirectly by influencing cloud properties. The radiative effects therefore have important implications for global climate, but form an important uncertainty in climate model predictions (Patey et al., 2015). Dust can indirectly affect the climate by stimulating primary productivity and di-nitrogen fixation in the surface ocean through addition of nutrients such as iron and phosphorus (Zender et al., 2003). For example, variations in iron supply to the Southern Ocean associated with mineral dust are considered to influence atmospheric CO_2 levels on geological timescales through iron fertilisation of primary productivity (Martin, 1991).

The African and Asian low-latitude deserts are the major global sources of dust (Zender et al., 2003). The dust belt includes the Sahara and Sahel, arid and semi-arid regions in Arabia and Central Asia, and the Taklamakan and Gobi deserts in East Asia. The Arabian Plateau and the Tigris-Euphrates Basin in the Middle East are areas of active wind erosion. The most important dust sources in the region include the Tigris-Euphrates River alluvial plain in Iraq and Kuwait, the low-lying flat lands in the east of the Arabian peninsula along the Gulf, and the Ad Dahna and the Rubal Khali deserts (Ginoux et al., 2001). The alluvial plains have the highest frequency of dust storms in the Middle East (Ito, 2013), and the fine sediments from the Tigris and Euphrate rivers allow long distance dust transport. Another dust source area is along the Oman coast, with a low frequency of dust storms (Ito, 2013).

Dust emission estimates for the Middle East range from 221 to 496 Tg y^{-1} (Ginoux et al., 2001; Tanaka and Chiba, 2006; Zender et al., 2003) representing between ca. 12 to 28% of global dust emissions. In recent years dust activities have intensified in the region, and this has been attributed to anthropogenic activities such as damming of the Tigris and Euphrates rivers, retreat of Caspian and Aral Seas, land use changes and land degradation (Al-Awadhi et al., 2014; Ginoux et al., 2012). Enhanced atmospheric dust loadings occur throughout the year in the region, but decrease in winter months. A typical annual cycle shows increases in dust loadings in March and April, a maximum in June and July and a decrease in September (Ginoux et al., 2001).

The RSA receives one of the largest aerosol loadings of any of the world's ocean regions due to its proximity to the Middle Eastern deserts and prevailing wind patterns. The situation in the RSA is comparable to the tropical and subtropical North Atlantic Ocean, which is subjected to large dust inputs from North African deserts (Patey et al., 2015). Dust and anthropogenic aerosols form an important source of nutrients (nitrogen, phosphorus and silicon) and biologically important (e.g. iron, zinc) and toxic (e.g. copper) trace elements to the global surface ocean (Baker et al., 2007; Duce and Tindale, 1991; Jickells et al., 2005), and therefore have an important influence on marine biogeochemical processes and ecosystems. It has been reported that transport of dust from the Sahara and Sahel regions of northern Africa results in increased dissolved Fe concentrations in the North Atlantic Ocean (Measures et al., 2008; Rijkenberg et al., 2008; Rijkenberg et al., 2012; Sarthou et al., 2007; Ussher et al., 2013), which influences di-nitrogen fixation (Mills et al., 2004; Moore et al., 2009; Rijkenberg et al., 2011; Schlosser et al., 2014) and the structure and functioning of microbial communities (Hill et al., 2010). Aerosol inputs into the Northern Red Sea have been reported to have detrimental effects on phytoplankton communities, which has been attributed to enhanced dust-derived copper inputs (Paytan et al., 2009). However, very little is known about aerosol inputs to the RSA and their impacts of ocean chemistry and biology.

Recent studies have shown that anthropogenic emissions have become an important contributor to aerosol deposition to the oceans (Duce et al., 2008; Fomba et al., 2013; Patey et al., 2015). Studies in the tropical North Atlantic Ocean have shown that pollutant aerosols originating from west Africa, Europe and North America become mixed with Saharan and Sahelian mineral dust (Fomba et al., 2013; Patey et al., 2015). The anthropogenic aerosols are derived from agriculture, biomass burning, fossil fuel burning in power plants, domestic heating, automobiles and ships (Ito, 2013; Ito and Shi, 2015; Luo et al., 2008; Mahowald et al., 2009; Myriokefalitakis et al., 2015), and industrial processes including smelting and petrochemical activities. Anthropogenic aerosol particles are typically smaller than mineral dust, and hence can be transported further afield. In addition, a higher proportion of the elements and compounds associated with anthropogenic aerosols dissolve upon deposition in the surface ocean, compared with mineral dust. The following compounds are enriched in anthropogenic aerosols: V, Ni, Cu, Cr, Zn, Cd, Hg, Pb, N, sulphate, organic carbon and black carbon, polyaromatic hydrocarbons (PAHs).

Furthermore, acidic gases emitted from fossil fuel combustion can also interact with mineral dust, leading to dust acidification. This will help to convert insoluble nutrients such as iron and phosphorus into bioavailable forms (Ito, 2013; Ito and Shi, 2015; Myriokefalitakis et al., 2015; Nenes et al., 2011; Shi et al., 2012). The net effect would be an increase in the delivery of bioavailable nutrients and trace elements to the ocean (Ito and Shi, 2015).

The ROPME region has seen pronounced population growth and industrialisation over the last decades (ROPME, 2013), resulting in enhanced environmental pressures on the RSA. Pressures identified by ROPME include oil pollution, radioactive discharges, discharges of household and industrial sewage which provide enhanced metal, nutrient and organic matter loadings, and environmental degradation of coastal zones and overexploitation of living marine resources (ROPME, 2013). The increased frequency of nuisance phytoplankton blooms (red tides) has been considered a major threat to human health and marine ecosystem services in the RSA (ROPME, 2013).

The impacts of mineral dust deposition to the RSA has however not yet been considered, despite reported increased dust activity over recent years (Solmon et al., 2015) and likely a higher contribution to the dust loading of anthropogenic aerosols (both from fossil fuel combustion and anthropogenic dust emission) from increased urbanisation and industrialisation. Anthropogenic aerosols will likely also be transported to the RSA from outside the ROPME region; in particular atmospheric pollution from Pakistan and India will be delivered during the NE monsoon period. The anthropogenic and biomass burning aerosols from the Indian subcontinent can be observed during the NE monsoon period over the North Indian Ocean (December to May), including the Sea of Oman (Myriokefalitakis et al., 2015); the impacts on the health of the ocean are unknown. Furthermore, the RSA is an important shipping region, with annually nearly 50,000 vessels passing through the Strait of Hormuz. Ship´s emissions contain elevated levels of toxic trace elements and compounds (Cr, V, Ni, PAHs, S) which tend to be highly soluble (Ito, 2013; Schroth et al., 2009) and are therefore likely to make a significant but unknown contribution to aerosol inputs in the RSA.

The importance of mineral dust and other aerosols as a source of trace elements, nutrients and other compounds to the ocean has stimulated research into its production, transport, deposition and subsequent dissolution in surface waters. Over the last two decades, satellite measurements have proved indispensable in the evaluation of dust sources and the provision of transport pathways. While they provide unparalleled spatial and temporal coverage of dust transport, it is however hard to extract quantitative information on aerosol concentration, composition and its dissolution in seawater from satellite observations. In-situ aerosol measurements and dust dissolution studies are therefore essential to obtain accurate data (Mahowald et al., 2005). Due to the sporadic nature of dust transport, long-term measurements of aerosols, such as those made at Bermuda, Miami and in the

Canary Islands (Gelado-Caballero et al., 2012; Prospero and Lamb, 2003; Trapp et al., 2010) and Cape Verde (Patey et al., 2015) are essential in order to build up a picture of dust fluxes and composition. Analyses of the total quantity of elements and compounds in aerosols provide information on the total fluxes to the surface ocean. Dissolution experiments with collected aerosols provides data on the fraction of elements and compounds released upon entry of aerosols in seawater (Buck et al., 2006), which is directly relevant to assess biological impacts. Collected aerosols can also be used to assess their effects on surface water microbial communities through short term bottle incubation experiments involving aerosol additions to microbial populations (Hill et al., 2010; Mills et al., 2005; Paytan et al., 2009).

In situ oceanographic observations of the impacts of aerosol deposition on biogeochemical processes and ecosystem functioning and structure in the surface ocean are of great value. A multitude of studies have provided important information about aerosol impacts on surface ocean chemistry, di-nitrogen fixation, heterotrophy and community structure (Achterberg et al., 2013; Guieu et al., 2014; Moore et al., 2009; Schlosser et al., 2014).

The chemical composition and mineralogy of transported dust can be used to identify the original source of the dust (Patey et al., 2015). This will be important for tracing anthropogenic atmospheric pollution sources in view of potential targeted emission reduction legislation. Recent research indicated the importance of dust composition and mineralogy for trace metal solubility (Aguilar-Islas et al., 2010; Sholkovitz et al., 2012), which highlights the need to link aerosol samples to specific sources.

In the light of all these, a number of important questions arise:

- What are the supplies of nutrients, trace elements and organic contaminants to the RSA by total and soluble aerosol deposition?
- What are the contributions of anthropogenic and natural sources to aerosol loadings in the RSA?
- What are the chemical and biological impacts of aerosol inputs to the waters of the RSA?
- How can future decisions be made on reduction of anthropogenic aerosol emissions in the ROPME region to mitigate their impact on RSA ecosystems?

These questions require us to understand and assess the impact of aerosol inputs to the RSA upon agreed baseline parameters.

Definitions and mechanism

Generic definition of Pilot Study, Baseline Assessment and Long-term monitoring programme

The Pilot Study will form a limited study involving up to 3 sampling sites in different parts of the RSA. The Pilot Study will ensure that the overall programme gets underway swiftly, and will also allow identification of gaps and needs for the follow up larger programmes.

The Baseline Assessment will be described in detail in the course of this documentation. However, a generic definition is to be established at the start, in order to delineate the scope of the work and focus the efforts within a framework of feasibility. The generic definition is as follows:

The "Baseline Assessment of Impact of Sand and Dust Storms (BAISDS) in the ROPME Sea Area" is a collective task of assessing Aerosol inputs and their biological impact for a full year in 2017-2018, to be used in references, comparisons and decision making.

The BAISDS-2017 is expected to become a reference status to mineral dust and other aerosols for future times to come.

The Long-term monitoring programme will provide a temporal perspective to regional dust and anthropogenic aerosol concentration changes, and subsequent impacts on the health of the RSA.

Basic approach for the development of Pilot Study and BAISDS-2017, and subsequent Long-term monitoring Programme

In developing the Pilot study and BAISDS-2017, complete harmonization of related initiatives and sharing of responsibilities will occur. The major milestones to be achieved are:

- Meeting of a Scientific Group to finalize the details of Scientific Programme of Pilot Study and BAISDS-2017
- Practical activity of developing the Pilot Study and BAISDS-2017 by way of completing sampling, analyses, interpretation and reporting
- Development of Regional capacity to contribute to and continue the efforts over a long time period by way of strengthening expertise and designating Regional Reference Laboratories

While this is the broader picture, the details will emerge further on in this document.

Objectives and outcomes

The overall aim of this small Pilot scale study is to provide initial data for developing a one year monitoring programme of BAISDS-2017.

Objectives of Pilot Study

- Set-up capacity to undertake aerosol sampling with high volume aerosol collectors
- Collection of aerosols and seawater samples over a 2 months period in the year 2016 at 3 locations in the ROPME Sea Area
- Identification of gaps and needs for larger monitoring programme
- Measurement of total and soluble elements and compounds in the collected aerosol samples
- Measurement of trace elements, nutrients, organic compounds, carbonate chemistry, chlorophyll a and indicators of ecosystem structure in the collected water samples
- Determination of the biological impact of aerosols in selected samples
- Identification of the potential sources and transport pathways of mineral and anthropogenic aerosols in the Region

Objectives of Study of Dust Inputs to RSA during 4 seasonal Cruises in 2016

- Contribute to the 2016 cruise programme through aerosol collection and surface water analysis for assessment of impacts of aerosols on RSA
- Undertake aerosol sampling on cruises using high volume aerosol samplers
- Measurement of total and soluble elements and compounds in the collected aerosol samples
- Determination of the biological impact of aerosols in selected samples
- Identification of the sources and transport pathways of aerosols collected on cruises

Objectives of BAISDS-2017

The overall aim is to provide essential baseline data for developing an international flagship monitoring programme of aerosol impact on the RSA

- Collection of aerosols over a full seasonal cycle in the year 2017 at locations in the ROPME Sea Area
- Measurement of total and soluble elements and compounds in the collected aerosol samples

- Collection of surface water samples over a full seasonal cycle in the year 2017 at locations in the ROPME Sea Area for chemical and biological measurements
- Determination of the biological impact of aerosols over a full seasonal cycle in 2017-2018 in the ROPME Sea Area
- Determination of the impact of aerosols on the water column carbonate system (ocean acidification) over a full seasonal cycle in 2017-2018 in the ROPME Sea Area
- Quantification of the sources and fluxes of mineral and anthropogenic aerosols in the Region
- Determination of the main processes regulating the distribution, transport and the deposition of mineral and anthropogenic aerosols in the RSA
- Chemical transport modelling to integrate the mineral and anthropogenic aerosol data from observations with information on dispersion, transport and biological uptake processes
- Modelling of trace element and nutrient deposition, constrained by remote sensing of total aerosol deposition rates in combination with ground measurements
- Further development of local physical-biogeochemical model with improved aerosol supply fluxes and biological impact quantification
- Use outcomes of the monitoring programme to assess impact of aerosol deposition on health of the RSA and lobby regional governments to reduce anthropogenic atmospheric emissions in the region
- Promotion and strengthening of the capabilities and readiness of the Member States in the domain aerosol mineral dust monitoring and establishment of biological effects
- Archival and integration of relevant atmospheric and oceanographic information to the BAISDS-2017
- Establishment of Regional and international collaborations on the platform of BAISDS-2017 as a networked capacity for future endeavors
- Designation of Regional Reference Laboratories for the continuation of work emanating from the BAISDS-2017
- Establishment of a regular long-term Regional Monitoring Programme including the networking of National Monitoring Programmes on aerosols

Objectives of Long-term monitoring programme

The overall aim is to provide long-term trends on aerosol deposition and the impacts on the health of the RSA

- Quantification of temporal and spatial distribution of deposition fluxes of soluble and total trace elements, atmospheric nutrients and organic pollutants to the ROPME Sea Area from both natural and anthropogenic sources

- Quantification of temporal and spatial impacts of aerosol deposition on water column biogeochemistry, carbonate chemistry (ocean acidification) and ecosystems
- Quantification of anthropogenic sources (dust and fossil fuel combustion aerosol) to the aerosol deposition fluxes
- Refinement of the chemical transport model with the outcomes of the monitoring programme
- Assessment of temporal changes in aerosol deposition and biogeochemical and ecosystem impacts in the RSA
- Development and refinement of RSA biogeochemical model
- Development of effective atmospheric pollutant emission control measures in the region
- Assessment of the effectiveness of atmospheric pollutant emissions in the RSA and benefits to RSA

Expected outcome from Pilot Study

- Small and limited dataset on aerosol deposition and impacts on surface water biogeochemistry and biology for parts of the RSA
- Substantial and high quality dataset from collaborative 2016 cruise campaigns in RSA region
- Gaps and Risks assessment for BAISDS-2017
- Action plan to deal with gaps and risks for BAISDS-2017 implementation

Expected outcome from the BAISDS-2017

- Establishment of a comprehensive geospatial database of previous relevant studies in the Region and experiences gained elsewhere on aerosol impacts, with provision for updating of data from the monitoring stations and networking with other data facilities

- Establishment of a joint information center with dedicated website for collection of required international standards, international guidelines, standard software, data analysis models, standards concerning aerosols as related to marine biogeochemical and ecosystem impacts and decision support tools

- Designation of Regional aerosol dust monitoring facilities and measurement laboratories, and including a cross calibration exercise to guarantee harmonization of the measurements made by each laboratory (capacity building)

- Development of a Regional Monitoring programme for Aeolian mineral dust and its impacts on the ocean through the participation of Member States, including designated stations and standardized operating procedures and equipment

- Establishment/suitable upgrading of aerosol dust analysis stations in the ROPME Sea Area. These stations serve both as a network for Aeolian mineral dust concentration information as well as Aerosol Monitoring System through standardized methodology

- Provision of scientist exchange programme and Regional seminars/ workshops on studies dedicated to marine environment and Aeolian mineral dust and their impacts on ocean health

- Establishment of aerosol dust monitoring and analysis stations, biological impact assessment activities for dust deposition to the ocean, training and collaboration programmes by the Member States

The above outcomes can be targeted in a phased manner on completion of the BAISDS-2017 and presentation of results to the Member States by the Regional Scientific Group.

Expected outcome from Long-term Study

- High quality temporal and spatial data set of Aeolian mineral dust measurements, with their impact on the ocean in the RSA
- Data for policy makers and scientists to establish impacts of Aeolian mineral dust inputs on health of the ocean, including nuisance algal blooms
- Data and evaluation tools for regional policy makers to undertake emission reduction measures with respect to atmospheric pollution
- Strengthened long-term scientific collaborations in the ROPME region

Technical description

Elements of BAISDS-2017

Following are the elements of the technical programme to develop BAISDS-2017, each of which is described in detail below:

1. Geographic coverage
2. Prioritization of monitoring and research issues
3. Target elements and compounds
4. Criteria and selection of suitable sampling sites
5. Sampling Protocol and sample types
6. Sampling Frequency

7. Sampling management
8. Database design and operation
9. Sample analyses issues and Identification of responsible laboratories
10. Inter-calibration and QA/QC procedures
11. Data Management and Reporting
12. Training needs
13. Linkage with other ROPME Activities
14. Integration with other National and Regional Programmes
15. Programme Time-frame

Description of the elements of the technical programme of BAISDS-2017

1. **Geographic coverage**

   BAISDS-2017 is envisaged to cover the ROPME Sea Area. Aerosol sources from both the Middle East and India and Pakistan are expected to be transported to the RSA, and consequently sampling stations will need to be situated at various strategic sites in the ROPME region

2. **Prioritization of monitoring and research issues**

   The basic research issue linked to the BAISDS-2017 is:
   - Background survey

3. **Target elements, compounds, and biological impact assays**

   The priority set of target elements and compounds to be analyzed in collected aerosol samples in BAISDS-2017 are listed below. The elements include essential elements for microbial organisms (e.g. Fe, Co, N, P), but also toxic elements and compounds (Cu, PAHs) and elements that may be involved in nuisance bloom development (N, P). We will also determine the impacts of dust inputs on water column carbonate chemistry, in order to assess ocean acidification effects. On selected samples, we will determine mineralogy using XRD and electron microscope (EM) techniques, in order to contribute to the determination of the source of the aerosol. A comprehensive quantitative source apportionment of airborne particles and soluble trace elements and nutrients therein will be carried out using receptor models. We will undertake atmospheric modelling of trace element and nutrient deposition, constrained by remote sensing of total aerosol deposition rates in combination with ground measurements

   We will undertake water sampling to assess the impact of aerosol inputs on chemistry (including ocean acidification) and biology. We will further develop a local physical-biogeochemical model with improved aerosol supply fluxes and biological impact quantification. Typical anthropogenic gases, such as ozone, NOx and SO_2 are to be determined at selected stations to identify origin of the collected air masses. Multispectral (UV to PIR) atmospheric aerosol optical depth (AOD) will be performed using manual photometers in the frame of the Maritime Aerosol Network (MAN) component of AERONET. Data will be provided to the AEROSOL/MAN data base of aerosol measurements over marine areas (http://aeronet.gsfc.nasa.gov/new_web/maritime_aerosol_network.html).

Elements, compounds, gases and physical measurements	**Matrix**
Na, Mg, Al, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ag, Cd, Sn, Hg, Pb, U, P, OC/EC, PAHs, molecular tracers	Collected aerosols (total fraction)
Na, Mg, Al, K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ag, Cd, Sn, Hg, Pb, U, Cl^-, sulphate, ammonium, nitrate, phosphate, silicic acid, sulphate, DOC	Water soluble aerosol fraction
Al, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ag, Cd, Hg, Pb, U, ammonium, nitrate, phosphate, silicic acid, DOC, dissolved inorganic carbon and total alkalinity	Seawater samples
Ozone, VOCs, NOx and SO_2 at selected stations	Gas phase

Aerosol optical depth (AOD, using manual photometer)	Atmosphere
XRD-EM mineral analysis	Particulate aerosol samples

Biological Impact	**Matrix**
Effects of dust deposition on surface water ecosystems (chlorophyll a , photosynthetic efficiency and microbial composition of waters)	Surface seawaters
Dust additions from selected samples to phytoplankton cultures	Seawater phytoplankton culture

4. Criteria and selection of suitable sampling sites

Criteria are required to select the optimum sampling sites, for which the following aspects are to be considered:

- Sampling must be cost and effort effective
- Process of selection of sampling sites should consider the wind patterns of the Region and represent locations of importance for the various air masses reaching the RSA, and anthropogenic activities (industry, urban areas, shipping). Air mass trajectory modeling experiments and regional air quality data analysis will be conducted to aid with site selection.
- Existing ROPME Reference sites are to be carefully considered in order to benefit from historical data
- Existing and planned Regional initiatives including surveys should be utilized to undertake Aeolian mineral dust sampling at sea in combination with water column sampling to assess impact of dust deposition. This harmonization will optimize sampling effort and provide important added value to the programme

- Adaptive extension of national efforts should be ensured to cover some sites on the coast as well as in the near-shore environment through national activities as contribution to BAISDS-2017

With these criteria, xx sites as explained below are considered as BAISDS-2017 reference stations.

5. Sampling Protocol and sample types

The standard operating procedure of sampling for aerosols will be to collect total suspended particles (TSP) using high volume aerosol collectors, employing W41 (Whatmann 41) filters and also Quartz (Whatmann QMA) filters. Full digestion will be undertaken on the W41 filters for subsequent elemental analyses by inductively coupled plasma mass spectrometry (ICP-MS). The digestion will involve a mixture of HCl, HNO_3 and HF to obtain complete digestion. A rapid deionized water (e.g. MQ water, Millipore) leach will be undertaken on W41 and QMA filters for subsequent elemental analyses by ICP-MS, and anion analyses by ion chromatography and nutrient analyses by autoanalyser. Dissolved organic carbon analyses will be undertaken using high temperature combustion techniques and PAHs using liquid chromatography. Mineralogical composition will be conducted on selected samples through X-Ray Diffraction (XRD)/EM analyses. A punch of QMA will be used for organic carbon (OC) and elemental carbon (EC) using a carbon analyser. Half of the QMA filters will be extracted with organic solvent for molecular marker analysis by GC-MS.

Water column sampling will be undertaken for nutrients with subsequent analysis using an nutrient autoanalyser. Samples will be collected for organic carbon, organic pollutants, microbial community structure and chlorophyll a analysis. In addition samples will be undertaken for trace elements using specialized trace metal clean techniques. Analysis will be undertaken by ICP-MS following preconcentration and matrix removal. Samples will be collected for carbonate chemistry analysis (dissolved inorganic carbon and total alkalinity). Temperature and salinity will be determined on-site using calibrated probes.

Biological impact assessment of aerosols will be conducted by addition of aerosol sample to phytoplankton cultures during short-term (48 h) incubation experiments, and assessment of changes in biomass (chlorophyll a) and physiological health (Fv/Fm) (Hoffmann et al., 2012).

For BAISDS-2017, we will adopt the aerosol sampling and elemental analysis protocol from the International GEOTRACES programme (Morton et al., 2013). For nutrient and organic analyses we will use standard methods. The Scientific Group will prepare clear standard operating procedures for the full range of activities as part of the sampling and analyses activities.

6. Sampling Frequency

The BAISDS-2017 is an exercise of establishing a reference for the year 2017-2018 over a period of 12 months. As such, a full seasonal cycle will be sampled continuously at the various sampling sites. Filters on the high volume pumps will be changed every 2 days. Filters will be frozen to -20C for subsequent analyses. Water samples will be collected every month.
Daily AOD measurements will be undertaken. At selected sites continuous gas measurements will be undertaken.

7. Sampling management

The sampling process management will be a coordinated operation, requiring cooperation and support of the Member States. The schema is as follows:

- ROPME will be BAISDS-2017 Coordinator and will receive guidance from the Scientific Group.
- BAISDS-2017 Coordinator will establish a sampling schedule, provide necessary technical support and prepare a Sampling Protocol in cooperation with the Regional Scientific Group and GEOMAR to be made available to the members of the sampling management team

8. Sample banking

ROPME shall archive the samples in ROPME-Sample Bank (RSB) under required conditions, pending the dispatch of sub-samples to the central laboratory for analyses.

9. Sample analyses issues and identification of responsible laboratories

One laboratory is designated for the analyses of samples, especially since this is a baseline assessment. For the follow-up monitoring however, further laboratories can be selected and involved by conducting proficiency tests. In case of force majeure, it may be decided to split the samples for analyses amongst different laboratories in the Region.

10. Inter-calibration and QA/QC procedures

This will be carried out as per the relevant Guidelines of GEOMAR

11. Data Management and Reporting

All data generated from the BAISDS-2017, both concerning Aeolian mineral dust and the ancillary environmental information, will be secured under ROPME copyright as they are produced. BAISDS-2017 Coordinator, in consultation with the Scientific Group will validate all the data. The validated data will be managed as per the following schema:

- Data will be archived in ROPME and GEOMAR Data Library
- Data will be organized into technical report with necessary interpretations, with the help of expert consultants
- Technical report will be published by ROPME for circulation
- Data will be hosted on ROPME Integrated Information System (RIIS)

12. Training needs

There is a distinct opportunity for capacity development in the Region for both the participation in BAISDS-2017 and to carry out the follow-up activities, such as a regular monitoring programme. As such, the training needs are for:

- Effective sampling , sample preservation and analyses
    - A training course demonstrating the relevant procedures for sampling and aerosol analyses is planned with the cooperation of GEOMAR for National experts expected to participate in BAISDS-2017. This can be treated as an exercise to 'train the trainers', expecting a cascading effect in the Member States. GEOMAR is to provide the training programme along with the needs and requirements for the training course, so as to help in preparations
- Successful sampling and analyses of samples
    - The designated Regional Reference Laboratory will have the responsibility to train the scientists of the Region periodically to carry out the sampling and analyses of aerosols
- Data management
    - ROPME in cooperation with IOC and GEOMAR and on the platform of RIIS will conduct training programmes on general marine data management as applicable to the Region, from time to time

13. Linkage with other ROPME Activities

Effective linkages/harmonization will be established for BAISDS-2017 with the following ROPME activities, as cited earlier:

- Oceanographic cruises
- Preparation of the State of the Marine Environment Report (SOMER)
- RIIS

14. Integration with other National and Regional Programmes

It is expected that the Member States will offer an opportunity to integrate with their existing and planned national programmes of relevance in order to make BAISDS-2017 cost and effort effective. Voluntary sharing of responsibilities in the aerosol dust sampling programme is one important primary step.

Further, ROPME shall explore the possibility of involving Regional and International programmes of UNEP. In particular, a link to UNEP-ROWA will be important in order to link aeolian mineral dust impacts on rain events on the Indian sub-continent, and the effects of west Asian pollution aerosols on the health of the RSA.

15. Indicative Programme Time-frame

- Finalization of Draft Scientific Programme: January 2016
- Meeting of the Ad-hoc Committee to finalize a detailed Scientific Programme with the identification of sampling team, players and Protocol of sampling – March 2016
- Designation of responsible Laboratories for conducting Aeolian mineral dust and seawater pilot study sampling – April 2016
- 2 weeks Training on sampling and sample preparations: May 2016
- Contribution to 2016 ROPME cruise programme
- Start of sampling for pilot study: Nov 2016 for a period of 2 months
- Completion of sample analyses and reporting for pilot study: July 2017
- Start of BAISDS-2017: Nov 2017 for a 12 months period
- Completion of analyses of samples and reporting for BAISDS-2017: November 2019

Conclusion

BAISDS-2017 is an essential and timely exercise. As structured in the descriptions above, it is feasible to conduct it successfully and establish a reference for future use. Cooperation and establishment of a mechanism for sharing the responsibilities by the Member States is the key to success. Once completed, BAISDS-2017 will stand as a key milestone in the collective efforts of monitoring the Region and rendering our ecosystems protected.

Achterberg, E.P. et al., 2013. Natural iron fertilization by the Eyjafjallajökull volcanic eruption. Geophysical Research Letters, 40(5): 921-926.

Aguilar-Islas, A.M., Wu, J., Rember, R., Johansen, A.M. and Shank, L.M., 2010. Dissolution of aerosol-derived iron in seawater: Leach solution chemistry, aerosol type, and colloidal iron fraction. Marine Chemistry, 120(1-4): 25-33.

Al-Awadhi, J.M., Al-Dousari, A.M. and Khalaf, F.I., 2014. Influence of Land Degradation on the Local Rate of Dust Fallout in Kuwait. Atmospheric and Climate Sciences, Vol.04No.03: 10.

Baker, A.R. et al., 2007. Dry and wet deposition of nutrients from the tropical Atlantic atmosphere: Links to primary productivity and nitrogen fixation. Deep Sea Research Part I: Oceanographic Research Papers, 54(10): 1704-1720.

Buck, C.S., Landing, W.M., Resing, J.A. and Lebon, G.T., 2006. Aerosol iron and aluminum solubility in the northwest Pacific Ocean: Results from the 2002 IOC cruise. Geochemistry Geophysics Geosystems, 7.

Duce, R.A. et al., 2008. Impacts of atmospheric anthropogenic nitrogen on the open ocean. Science, 320(5878): 893-897.

Duce, R.A. and Tindale, N.W., 1991. Atmospheric transport of iron and its deposition in the ocean. Limnology and Oceanography, 36(8): 1715-1726.

Fomba, K.W., Müller, K., van Pinxteren, D. and Herrmann, H., 2013. Aerosol size-resolved trace metal composition in remote northern tropical Atlantic marine environment: case study Cape Verde islands. Atmos. Chem. Phys., 13(9): 4801-4814.

Gelado-Caballero, M.D. et al., 2012. Long-term aerosol measurements in Gran Canaria, Canary Islands: Particle concentration, sources and elemental composition. Journal of Geophysical Research: Atmospheres, 117(D3).

Ginoux, P. et al., 2001. Sources and distributions of dust aerosols simulated with the GOCART model. Journal of Geophysical Research: Atmospheres, 106(D17): 20255-20273.

Ginoux, P., Prospero, J.M., Gill, T.E., Hsu, N.C. and Zhao, M., 2012. Global-scale attribution of anthropogenic and natural dust sources and their emission rates based on MODIS Deep Blue aerosol products. Rev. Geophys, 50.

Guieu, C. et al., 2014. Does the pulsed nature of atmospheric deposition in Low Nitrate Low Chlorophyll regions matters? Global Biogeochemical Cycles.

Hill, P.G., Zubkov, M.V. and Purdie, D.A., 2010. Differential responses of Prochlorococcus and SAR11-dominated bacterioplankton groups to atmospheric dust inputs in the tropical Northeast Atlantic Ocean. FEMS Microbiology Letters, 306(1): 82-89.

Hoffmann, L.J. et al., 2012. Influence of trace metal release from volcanic ash on growth of Thalassiosira pseudonana and Emiliania huxleyi. Marine Chemistry, 132-133(0): 28-33.

Ito, A., 2013. Global modeling study of potentially bioavailable iron input from shipboard aerosol sources to the ocean. Global Biogeochemical Cycles, 27(1): 1-10.

Ito, A. and Shi, Z., 2015. Delivery of anthropogenic bioavailable iron from mineral dust and combustion aerosols to the ocean. Atmos. Chem. Phys. Discuss., 15(16): 23051-23088.

Jickells, T.D. et al., 2005. Global Iron Connections Between Desert Dust, Ocean Biogeochemistry, and Climate. Science, 308(5718): 67-71.

Luo, C. et al., 2008. Combustion iron distribution and deposition. Global Biogeochemical Cycles , 22(1).

Mahowald, N.M. et al., 2005. Atmospheric global dust cycle and iron inputs to the ocean. Global Biogeochemical Cycles, 19(4).

Mahowald, N.M. et al., 2009. Atmospheric Iron Deposition: Global Distribution, Variability, and Human Perturbations. Annual Review of Marine Science, 1(1): 245-278.

Martin, J.H., 1991. Iron, Liebig's Law, and the Greenhouse. Oceanography, 4(2): 53-55.

Measures, C.I., Landing, W.M., Brown, M.T. and Buck, C.S., 2008. High-resolution Al and Fe data from the Atlantic Ocean CLIVAR-CO2 Repeat Hydrography A16N transect: Extensive linkages between atmospheric dust and upper ocean geochemistry. Global Biogeochemical Cycles, 22(1).

Mills, M.M., Ridame, C., Davey, M., La Roche, J. and Geider, R.J., 2004. Iron and phosphorus co-limit nitrogen fixation in the eastern tropical North Atlantic. Nature, 429(6989): 292-294.
Mills, M.M., Ridame, C., Davey, M., La Roche, J. and Geider, R.J., 2005. Iron and phosphorus co-limit nitrogen fixation in the eastern tropical North Atlantic (vol 429, pg 292, 2004). Nature, 435(7039): 232-232.
Moore, C.M. et al., 2009. Large-scale distribution of Atlantic nitrogen fixation controlled by iron availability. Nature Geoscience, 2(12): 867-871.
Morton, P.L. et al., 2013. Methods for the sampling and analysis of marine aerosols: results from the 2008 GEOTRACES aerosol intercalibration experiment. Limnology and Oceanography: Methods, 11(2): 62-78.
Myriokefalitakis, S. et al., 2015. Changes in dissolved iron deposition to the oceans driven by human activity: a 3-D global modelling study. Biogeosciences, 12(13): 3973-3992.
Nenes, A. et al., 2011. Atmospheric acidification of mineral aerosols: a source of bioavailable phosphorus for the oceans. Atmos. Chem. Phys., 11(13): 6265-6272.
Patey, M.D., Achterberg, E.P., Rijkenberg, M.J. and Pearce, R., 2015. Aerosol time-series measurements over the tropical Northeast Atlantic Ocean: Dust sources, elemental composition and mineralogy. Marine Chemistry, 174: 103-119.
Paytan, A. et al., 2009. Toxicity of atmospheric aerosols on marine phytoplankton. Proceedings of the National Academy of Sciences, 106(12): 4601-4605.
Prospero, J.M. and Lamb, P.J., 2003. African Droughts and Dust Transport to the Caribbean: Climate Change Implications. Science, 302(5647): 1024-1027.
Rijkenberg, M.J.A. et al., 2011. Environmental Forcing of Nitrogen Fixation in the Eastern Tropical and Sub-Tropical North Atlantic Ocean. PLoS ONE, 6(12).
Rijkenberg, M.J.A. et al., 2008. Changes in iron speciation following a Saharan dust event in the tropical North Atlantic Ocean. Marine Chemistry, 110(1–2): 56-67.
Rijkenberg, M.J.A. et al., 2012. Fluxes and distribution of dissolved iron in the eastern (sub-) tropical North Atlantic Ocean. Global Biogeochemical Cycles, 26(3).
ROPME, 2013. Summary of the State of the Marine Environment Report-2013.
Sarthou, G. et al., 2007. Influence of atmospheric inputs on the iron distribution in the subtropical North-East Atlantic Ocean. Marine Chemistry, 104(3-4): 186-202.
Schlosser, C. et al., 2014. Seasonal ITCZ migration dynamically controls the location of the (sub)tropical Atlantic biogeochemical divide. Proceedings of the National Academy of Sciences, 111(4): 1438-1442.
Schroth, A.W., Crusius, J., Sholkovitz, E.R. and Bostick, B.C., 2009. Iron solubility driven by speciation in dust sources to the ocean. Nature Geoscience, 2(5): 337-340.
Shi, Z. et al., 2012. Impacts on iron solubility in the mineral dust by processes in the source region and the atmosphere: A review. Aeolian Research, 5: 21-42.
Sholkovitz, E.R., Sedwick, P.N., Church, T.M., Baker, A.R. and Powell, C.F., 2012. Fractional solubility of aerosol iron: Synthesis of a global-scale data set. Geochimica et Cosmochimica Acta, 89: 173-189.
Solmon, F., Nair, V.S. and Mallet, M., 2015. Increasing Arabian dust activity and the Indian summer monsoon. Atmos. Chem. Phys., 15(14): 8051-8064.
Tanaka, T.Y. and Chiba, M., 2006. A numerical study of the contributions of dust source regions to the global dust budget. Global and Planetary Change, 52(1–4): 88-104.
Trapp, J.M., Millero, F.J. and Prospero, J.M., 2010. Temporal variability of the elemental composition of African dust measured in trade wind aerosols at Barbados and Miami. Marine Chemistry, 120(1-4): 71-82.
Ussher, S.J. et al., 2013. Impact of atmospheric deposition on the contrasting iron biogeochemistry of the North and South Atlantic Ocean. Global Biogeochemical Cycles, 27(4): 1096-1107.
Zender, C.S., Bian, H. and Newman, D., 2003. Mineral Dust Entrainment and Deposition (DEAD) model: Description and 1990s dust climatology. Journal of Geophysical Research: Atmospheres, 108(D14): n/a-n/a.

10 ROPME = ∂ √ █

= █ Ң ǂ ♠ ⁱ ◦ ˥ ǂ

ROPME/WG-174/1.1

Provisional Programme

Meeting of the Regional Task Force on Marine Climate Change Dimensions in ROPME Sea Area

Kuwait, 10-12 April 2017

Introduction:

ROPME is holding a meeting of the Regional Task Force on Marine Climate Change Dimensions to prepare a Concept Note for a Regional Action Plan to develop a Regional Marine Climate Change Risk Assessment and Adaptation and Mitigation Strategy. The meeting will:

- review existing marine and coastal-related policies with regards to marine dimensions of climate change, and climate change adaptation and mitigation mechanisms at the national and regional level in the ROPME Sea Area;

- review international understanding of marine climate change issues, and particularly marine aspects of the in-country declaration of intent following the United Nations Framework Convention on Climate Change (UNFCCC) held in Paris in December 2015;

- review and develop a common understanding of the potential ecological, physical and chemical dimensions of marine climate change in the ROPME Sea Area;

- review and develop a common understanding of how climate change may affect societies and economies in the ROPME Region in terms of:
    - biodiversity
    - water resources (desalinisation)
    - human health
    - fisheries and aquaculture
    - tourism and recreation
    - transport and shipping
    - coastal development
    - energy industry, including both fossil fuels and renewable;

- explore common objectives across sectors for the development of a Regional Climate Change Risk Assessment, and Adaptation and Mitigation Strategy;

- learn lessons from other regions with established strategies/ programmes on regional seas based on climate change risk assessment (for example the UK CCRA);

- review and discuss the development of ROPME Regional Marine Climate Change Risk Assessment, and Adaptation and Mitigation Strategy Concept Note.

Expected Outcome:

Agreed Concept Note for a Regional Action Plan to develop a Regional Marine Climate Change Risk Assessment, and Adaptation and Mitigation Strategy for the ROPME Sea Area.

Centre for Environment Fisheries & Aquaculture Science

Provisional Programme of the Meeting:

DAY 1: 10 April 2017 – Marine Climate Change Background and Impacts	
08:30 - 09:00	**Registration**
09:00 - 09:30	**Opening of the Meeting:** - Welcome address - Introduction and Background to the Meeting - Objectives of the Meeting
09:30 - 09:45	**Organization of the Work:** - Designation of Chairman and Minutes Taker - Introduction of Participants - Adoption of the Programme
09:45 - 10:45	**Plenary Session I: Future Scenarios and physical and chemical impacts of marine climate change** *Dr. John Pinnegar, Cefas* - Sea level rise - Temperature - Current circulation - Ocean acidification - Oxygen depletion - Salinity - Storms / hurricanes / monsoons - Upwelling **Qs&As**
10:45 - 11:15	Coffee Break
11:15 – 12:15	**Plenary Session II: Ecological impacts of marine climate change** *Dr. Susana Lincoln, Cefas* - Changes in primary production, chlorophyll a - Harmful algal blooms - Jellyfish outbreaks - Coral reefs - Mangroves - Seagrass beds - Fisheries - Aquaculture - Species of biodiversity concern **Qs&As**
12:15 - 13:45	Lunch Break

13:45–14:45	**Plenary Session III: Social and economic impacts of marine climate change** *Dr. Will Le Quesne, Cefas* Overview of current and future impacts of marine climate change on the following sectors in the ROPME Sea Area: - biodiversity - water resources (desalinisation) - human health - fisheries and aquaculture - tourism and recreation - transport and shipping - coastal development - energy industry, including both fossil fuels and renewables - Other marine social and economic goods and services **Qs&As**
14:45 - 15:15	Coffee Break
15:15 - 16:00	**Plenary Session IV: Introduction to climate change policy drivers and objectives** *Prof. Andrew Watkinson, University of East Anglia & Dr. Susana Lincoln, Cefas* Overview of international policy drivers, commitments and action plans related to marine climate change and climate change risk assessments, and adaptation and mitigation plans **Qs&As**
16:00 - 17:00	**Plenary Session V: International examples of climate change risk assessments, and adaptation and mitigation strategies 1** North Sea Regional Climate Change Assessment *Prof. Dr. Markus Quante, Institute of Coastal Research* UK National Climate Change Risk Assessment *Dr. John Pinnegar, Cefas* Lessons learnt. **Qs&As**
End of Day 1	

Centre for Environment Fisheries & Aquaculture Science

DAY 2: 11 April 2017 – Climate Change Policy and Activities	
09:00 - 09:15	**Welcome back and outlook for Day 2**
09:15 –10:00	**Plenary Session VI: International examples of climate change risk assessments, and adaptation and mitigation strategies 2** Japanese activity for climate change adaptation in coastal region *Dr.Yoichi Ishikawa, JICA* Development of the UK National Climate Change Adaptation Plan *Dr. John Pinnegar, Cefas* **Qs&As**
10:00 -10:30	**Plenary Session VII: Regional examples of climate change risk assessments, and adaptation and mitigation strategies 1** Climate change marine and coastal vulnerability in the Region *Jane Glavan, AGEDI* **Qs&As**
10:30 - 11:00	Coffee Break
11:00 - 12:00	**Plenary Session VIII: Regional examples of climate change risk assessments, and adaptation and mitigation strategies 2** Blue Carbon as part of policy setting: local, national and regional opportunities *Jane Glavan, AGEDI* Use of time-series ocean color satellite data for assessment of climate change trends Dr. Wahid Moufaddal, *ROPME* **Qs&As**
12:00- 12:30	**Plenary Session IX: National marine climate change action overviews** National Presentations on national UNFCCC commitments, policy drivers, objectives and activities related to marine and coastal climate change (10-15 minutes per country) **Qs&As**
12:30- 14:00	Lunch Break
14:00 -15:00	**Plenary Session X: National marine climate change action overviews(continuation)** National Presentations on national UNFCCC commitments, policy drivers, objectives and activities related to marine and coastal climate change (10-15 minutes per country) **Qs&As**
15:00 - 15:30	Coffee Break
15:30 - 16:15	**Plenary Session XI: Overview of draft Regional Action Plan** Overview of the proposed ROPME Regional Action Plan to develop a Marine Climate Change Risk Assessment and Adaptation and Mitigation Strategy for the ROPME Sea Area *Dr. Will Le Quesne, Cefas*

16:15 - 17:00	**Plenary Discussion XII: Potential ROPME activities to enable a regional marine climate change risk assessment** Summary of the main features of the proposed marine climate change risk assessment *Dr. John Pinnegar, Cefas* **Discussion**
End of Day 2	

DAY 3: 12 April 2017 – Preparing a ROPME Marine Climate Change Strategy	
09:00 - 09:15	**Welcome back and outlook for Day 3**
09:15 –10:00	**Plenary Discussion XIII: Potential ROPME activities to enable a regional marine climate change adaptation strategy** Summary of the main features of the proposed marine climate change adaptation strategy *Dr. John Pinnegar, Cefas* **Discussion**
10:00-10:45	**Plenary Discussion XIV: Potential ROPME activities to support a regional marine climate change mitigation strategy** Summary of the main features of the proposed marine climate change mitigation strategy *Dr. Susana Lincoln, Cefas* **Discussion**
10:45 - 11:15	Coffee Break
11:15– 12:15	**Plenary Discussion XV: Review of the draft Concept Note for the Regional Action Plan** Review of the proposed Regional Action Plan to develop a Marine Climate Change Risk Assessment and Adaptation and Mitigation Strategy for the ROPME Sea Area
12:15 - 13:45	Lunch Break
13:45 - 14:30	**Plenary Discussion XVI: Next steps** Future course of action and time frame Requirements for the Regional Task Force on Marine Climate Change to implement the Regional Action Plan
14:30 – 15:30	**Conclusion of the meeting and Recommendations** Discussion
End of Day 3 and Closure of the Meeting	

Concept Note on Regional Marine Climate Change - Risk Assessment, Adaptation and Mitigation Strategy for the ROPME Sea Area

1. Introduction

Climate change is a major threat for the 21st century and beyond, as recognised by many of the world's governments. The United Nations Framework Convention on Climate Change (UNFCCC) entered into force on 21 March 1994 and have been ratified by 197 countries including all countries in the ROPME Sea Area (RSA). The COP21 Paris Agreement established further agreement to undertake ambitious efforts to combat climate change and adapt to its effects. The Paris Agreement requires all Parties to put forward their best efforts through "nationally determined contributions" (NDCs) and to strengthen these efforts in the years ahead.

Climate change can impact marine and coastal environments in a number of ways. The direct impact of climate change is to change the physical and chemical environment in the sea. Increased warming directly increase sea temperature, but this can also affect ocean currents and weather patterns that drive the physical environment of the seas. An example of this is sea level rise due to melting at the polar ice caps. Rising levels of carbon dioxide in the atmosphere causes chemical changes in the ocean, which in turn is causing the sea to become more acidic, an effect known as ocean acidification. The ecology of marine ecosystems is affected by the physical and chemical conditions in the sea, and as the physical and chemical environment changes due to climate change this will have wider effects on marine ecosystems.

The biodiversity and productivity of the seas may be impacted by climate change. The distribution and productivity of phytoplankton can be impacted by changes in ocean currents and local weather conditions. Sea temperature rise can also lead to changes in the depth and latitudinal distribution of marine species of biodiversity, commercial or recreational importance.

The changes in the distribution and productivity of the environment can have impacts on the productivity of fisheries and biodiversity conservation as well as other human activities dependent on the seas. For example, this may lead to a decline in the production of food and income from fisheries, or a reduction in tourism due to the decline or loss of coral reefs. Adapting to these changes may require changes in fisheries and environmental management to adjust to the changing ecological conditions.

The changing distribution of species does not just affect species of fisheries and biodiversity importance, but can also affect the distribution of harmful marine species such as harmful algal bloom forming species and marine pathogens that directly affect human health.

For example, the viruses *Vibrio cholerae*, *V. parahaemolyticus* and *V. vulnificus* exist in seawater and can cause major wound infections, gastroenteritis and occasionally human fatalities. The incidence of these species is known to be closely linked to warm seawater temperatures and they have all been found in seawater samples from the RSA, in particular off the coast of Saudi Arabia. Changes in water temperature can also affect growth rates of farmed finfish and shellfish, increase the presence of parasites and affect the general suitability of areas for aquaculture.

Sea level rise can cause significant adverse impacts on coastal communities and ecosystems. Cities, towns and key national infrastructure are often located along the coast and if actions are not taken to protect or move these structures, long-term sea level rise could lead to massive impacts on these coastal communities and facilities. Furthermore, in addition to direct impacts on human structures, sea level rise can have adverse impacts on coastal ecosystems such as the loss of mangrove and inter-tidal wetlands if these habitats cannot adjust to the change in sea level.

Climate change in the marine and coastal environment can therefore cause a number of adverse impacts that will affect the social and economic benefits that people derive from the sea. These changes are also occurring alongside an increase in other human activities impacting the seas, such as coastal development and fishing, and the combination of these impacts occurring together may lead to cumulative impacts on the seas and reduce the resilience of marine ecosystems to cope with climate change.

There are two main actions that can be taken to address climate change, these are 'mitigation' and 'adaptation'. 'Mitigation' refers to limiting climate change by reducing the emissions of greenhouse gases and by enhancing the uptake of greenhouse gasses by promoting or protecting natural 'sinks', and 'adaptation' refers to reducing the adverse impacts of climate change by taking actions to prepare for the changes that will be caused by climate change.

While it will not be possible to completely avoid the impacts of climate change, taking steps to mitigate the extent of climate change, and to adapt to the changes that will be caused by climate change reduce the impacts that climate change has on marine environment and on the human activities that depend on the seas.

ROPME Sea Area

ROPME was established in 1979 and acts as the Secretariat for the Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment from Pollution (1978). The ROPME Sea Area (RSA) is bordered by eight countries namely the Kingdom of Bahrain, Islamic Republic of Iran, Republic of Iraq, State of Kuwait, Sultanate of Oman, State of Qatar, Kingdom of Saudi Arabia and the United Arab Emirates. The RSA has a total surface area of around 240,000 km^2 and is characterised by shallow waters of high temperature, marked differences in salinity (ranging from near-freshwater at the entrance to the Tigris-Euphrates-Karun river system to above 70 in some shallow semi-enclosed embayments) and strong seasonal upwelling, driven by monsoon winds. In 1994 ROPME and UNEP published an overview of "*Implications of Climate Change in the ROPME region*"(UNEP 1994)but this topic has received relatively limited attention in the intervening period.

The RSA region has been recognised as one of the warmest sea areas in the world, with both extreme positive and negative temperature variation (annual temperature range of 12–35°C). Like other semi-enclosed seas, the inner RSA area is particularly vulnerable to changing environmental conditions. Localized analyses (e.g. of Kuwait Bay) have shown strong and significant warming trends in excess of 0.6°C per decade. Recent projections from the IPCC suggest that sea temperatures are very likely to increase significantly with increases of 3.5–4.4°C predicted over the period 2010–2099.The increase in temperature, leading to increased evaporation, coupled with reduced freshwater inputs and desalination plants is leading to an increase of salinity within the RSA. Salinity of surface waters in the Arabian Sea increased by 0.5-1.0% over the past 60 years and further rises expected across the whole RSA.

Despite coral ecosystems in this region being pre-adapted to some of the highest temperatures experienced anywhere on earth, anthropogenic climate change is now driving higher frequencies and intensities of mass coral bleaching and mortality. The mass coral bleaching events that occurred in 1996 and 1998 were a direct result of sensitivity to temporarily elevated sea temperatures. These changes to coral reefs have resulted in reductions of some fish species, which can combine with fishing to cause increased pressure on key commercial fish stocks.

Long-term measurements of surface waters in the RSA demonstrate that RSA is becoming increasingly acidic at a faster rate than in many of the world's oceans and this trend is projected to continue into the future. One of the effects of ocean acidification is to affect the 'aragonite saturation horizon. This is the depth below which certain carbonate compounds naturally dissolve in seawater. The aragonite saturation horizon in the Arabian Sea is now 100–200 m shallower than in pre-industrial times as a result of ocean acidification. 'Shoaling' of the aragonite saturation horizon may affect a range of organisms and processes, such as the depth distribution and persistence of reef-forming corals or other shell-forming species present throughout the RSA.

As a result of long-term climate change, regions of the ocean with low oxygen concentrations are expected to increase in the future. Low levels of oxygen concentration can effect the growth, feeding and reproduction of marine species, and extreme cases can cause mortality events such as fish kills. The Arabian Sea oxygen minimum zone is the second-most intense oxygen minimum zone in the world, with near-total depletion of oxygen at depths from 200 to 1000 m. Within the inner RSA low oxygen levels in water have been detected in the coastal waters of several countries. Low oxygen levels can be caused by several factors, such as sewage pollution, in addition to increased temperature but temperature increases will lead to further reductions in oxygen concentrations.

According to a World Bank study, Qatar, UAE and Kuwait are among the most vulnerable countries in the world in terms of sea level rise, whereby 1% to 3% of land in these countries could be affected by only a 1m rise in sea level. This extent of sea level rise may threaten up to 15 km of coastline in Bahrain. Furthermore sea level rise is leading to salt water intrusions in to the Shatt Al-Arab and coastal freshwater aquifers.

Based on a consideration of these factors and wider potential impacts of climate change, the 2013 ROPME 'State of the Marine Environment Report' recognised climate change as an emerging issue of particular concern, for which it is necessary "to raise public awareness and flag the consequences of inactions or lack of clear policies, legislation and enforcement towards alleviating possible risks".

The marine and coastal environment can play a role in reducing the extent of climate change, through the uptake and sequestration of carbon in marine and coastal ecosystems, as well as being affected by climate change. 'Blue carbon' is the term used to refer to carbon stored in coastal and marine ecosystems. Coastal ecosystems are some of the most productive on Earth and in addition to providing important ecosystem services, such as coastal protection and nursery grounds for fish, they also sequester and store carbon and hence can play a role in climate change 'mitigation'.

Mangroves, tidal marshes and sea grass in particular can sequester and store huge quantities of carbon in both the plants themselves and the sediment below. When degraded or destroyed, these coastal ecosystems emit the carbon they have stored for centuries into the atmosphere and oceans and become 'sources' of greenhouse gases. It has been estimated that as much as 1.02 billion tons of carbon dioxide are being released annually from degraded coastal ecosystems.

The International Blue Carbon Initiative is a coordinated, global program focused on mitigating climate change through the conservation and restoration of coastal and marine ecosystems. The Blue Carbon Initiative currently focuses on mangroves, tidal marshes and seagrasses.

2. ROPME Regional Marine Climate Change Risk Assessment, Adaptation and Mitigation Strategy

As part of the UNFCCC, the ROPME Member States have made commitments to tackle climate change and adapt to its effects. Furthermore, a key recommendation in the 2013 ROPME 'State of the Marine Environment Report' was that "Member States, agree on plans and actions commensurate with the efforts of the international community to mitigate possible impacts of global climate change on the Region's marine ecosystems and coastal areas, according to the IPCC best agreed scenarios for the Region".

A ROPME Regional Marine Climate Change Risk Assessment, Adaptation and Mitigation Strategy is proposed to address the challenges of marine climate change for the RSA. The primary focus of the strategy will be on identifying adaptation strategies; however, some consideration will be given to mitigation through building and conserving 'blue carbon'.

The ROPME Marine Climate Change Strategy will act to help member countries meet their national commitments to marine and coastal climate change adaptation, as specified by international and regional commitments, in a regionally coordinated manner. The proposed ROPME Marine Climate Change Strategy is based on examples of the development of climate change risk assessments, adaptation plans and mitigation plans that have been conducted internationally. The strategy is based around two parallel strands of activity that separately address adaptation and mitigation.

The first step to preparing the adaptation strategy is to conduct a risk assessment that will identify the main impacts associated with climate change in the marine and coastal environment. Once these priority impacts have been identified, the key adaptation actions will be identified to reduce the adverse impacts. A novel element to the work plan is the potential application of 'decision support tools' to identify key threats and potential adaptation strategies.

The mitigation strategy will proceed by identifying the ecosystem components in the RSA that store and sequester blue carbon, and will then proceed to identify how these ecosystem components can be managed to gain the benefits of blue carbon storage and sequestration.

The strategy includes a plan to report on success of implementation ahead of the next IPCC AR6 assessment to be finalized in 2021.

<u>International policies, strategies and targets relevant to the ROPME Marine Climate Change Strategy</u>

The ROPME Member States have committed to act to develop national mitigation and adaptation plans through a series of international commitments and frameworks. This includes the UNFCCC, the UN Sustainable Development Goals and the Convention on Biological Diversity.

The COP21 Paris Agreement aimed to strengthen the global response to the threat of climate change by keeping the observed global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius if possible. Additionally, the agreement aims to strengthen the ability of countries to deal with the impacts of climate change, and it notes the importance of ensuring the integrity of all ecosystems, including oceans.

Under the UNFCCC countries have agreed to develop plans to combat the effects of climate change and to develop plans to adapt to the adverse impacts of climate change, and to report on actions that have been taken.

The UN Sustainable Development Goal 13 is to 'Take urgent action to combat climate change and its impacts". This SDG recognises that "climate change presents the single biggest threat to development … [and] …Urgent action to combat climate change and minimize its disruptions is integral to the successful implementation of the Sustainable Development Goals".

Under the UN Convention on Biological Diversity, Aichi biodiversity target 10 states: "By 2015, the multiple anthropogenic pressures on coral reefs, and other vulnerable ecosystems impacted by climate change or ocean acidification are minimized, so as to maintain their integrity and functioning". This recognises the impact of climate change on marine and coastal ecosystems and seeks additional management to support the resilience of these ecosystems as part of the adaptations to the impacts of climate change.

The 34th session of the UNFCCC Subsidiary Body for Scientific and Technological Advice (SBSTA) called for the sustainable management, conservation, and enhancement of "sinks and reservoirs of all greenhouse gases not controlled by the Montreal Protocol including … oceans as well as … other coastal and marine ecosystems."

The implementation of the ROPME Strategy for Marine Climate Change is designed to be both supported by fulfilment of existing national commitments for the development and implementation of climate change adaptation and mitigation strategies, and also designed to support the fulfilment of existing national commitments for the development and implementation of climate change adaptation and mitigation strategies.

<u>Objective of the Strategy</u>

The objective is to develop a Regional Marine Climate Change - Risk Assessment, Adaptation and Mitigation Strategy. This region-wide Strategy will provide a common vision and catalyse policy coherence across sectors and countries in the ROPME Sea Area.

3. Preliminary draft Work Plan

Phases	Activities
Phase I: Review (12 months)	- Establish Regional Task Force to conduct the Regional Strategy. - Identification and analysis of key stakeholders, individuals, organizations and agencies across sectors. - Identify common goals, interests and objectives.

	- Draft report on current and potential impacts of climate change on physical, chemical and ecological components of marine and coastal ecosystems and associated social and economic goods and services. - Draft report on current availability of IPCC climate model outputs for the region (from IPCC AR5 report and CMIP 5 model ensemble), also down-scaled regional marine climate change projections. - Draft regional marine climate change 'evidence report'. - Organization of a regional multi-stakeholder workshop on Marine Climate Change (MCC) to agree on approaches for the development of a Regional MCC Strategy.
Phase II: Projection and Evaluation (12 months)	- Develop marine climate change projections using models for the ROPME Region (sea level rise, marine temperature, pH, plankton productivity, surface winds, etc). Draft technical report and summary report card, and archive data outputs. - Conduct modelling studies of present and future distribution of key marine species and habitats focusing on species and habitats of specific commercial, biodiversity, or human health relevance. Draft technical report and summary report card, and archive data outputs. - Conduct sectoral based risk and vulnerability assessment at the regional or national level, taking into account: (1) exposure, (2) sensitivity, (3) scale of potential consequences, (4) proximity in time, (5) scientific confidence/consensus, (6) adaptive capacity. Draft technical report and sectoral summary report cards. - Draft outline of the framework for the marine climate change adaptation and mitigation strategy. - Organization of multi-stakeholder meeting(s) to agree on a strategic framework.

Phase III: Prepare Adaptation and Mitigation Strategy (12 months)	- Draft report on potential adaptation actions to address predominant impacts identified in Phase II. Draft technical report and sectoral summary report cards. - Apply decision support tools to identify key threats and potential adaptation strategies including identifying potential 'adaptation pathways'. - Hold stakeholder workshop(s) to review and prioritise potential adaptation actions. - Draft report on prioritised options for marine mitigation actions to reduce climate change through 'blue carbon'. Draft technical report and summary report card. - Prepare Strategy document based on the strategic framework agreed in Phase II and prioritised adaptation and mitigation actions. - Develop Strategy implementation plan. - Develop Strategy monitoring plan. - Organization of a High-level Regional Workshop to adopt the Regional Strategy.
Phase IV: Implement Adaptation and Mitigation Strategy (duration)	- Implement Regional Marine Climate Change Adaptation and Mitigation Strategy. - Monitor implementation of Regional MCC Strategy. - Regional Workshop to report on success of the implementation of the Regional Marine Climate Change Strategy and to identify next steps. - Provide inputs for the next IPCC AR6 assessment to be finalized in 2021

4. Expected Outcomes/Outputs

Outcomes

Increased regional resilience to the adverse impacts of climate change, sea level rise and ocean acidification on marine and coastal environments.

Increased capacity of national stakeholders to conduct climate change risk assessments and to develop adaptation strategies in the face of adverse impacts of marine and coastal climate change.

In-depth characterisation of potential threats in the ROPME Sea Area, making use of new high-resolution model outputs.

An assessment of potential economic consequences (on goods and services) that can be used in an evaluation of costs and benefits, with regard to future adaptation/mitigation measures.

Identification of potential barriers and difficulties in the implementation of marine climate change adaptation strategies in the ROPME Sea Area

Support for national implementation of marine climate change risk assessment, adaptation and mitigation strategies.

Develop common understanding of marine and coastal climate change drivers and impacts in the RSA.

Outputs

- A scoping study analysing existing marine climate change policies and adaptation activities and strategies in the ROPME Sea Area.
- A regional marine climate change 'evidence report', including an assessment of past changes in the ROPME Region and the availability of relevant regional climate model outputs.
- Summary report cards covering:
  - historic, current and future marine climate change impacts in the ROPME Sea Area
  - marine climate change risk assessment for the ROPME Sea Area
  - potential adaptation strategies for the ROPME Sea Area
- A strategic framework for Regional Climate Change Risk Assessment, Adaptation and Mitigation Strategy
- Final Regional Marine Climate Change Risk Assessment document
- Final Regional Marine Climate Change Adaptation and Mitigation Strategy document
- Final workshop reports

ROPME/WG-174/3

Meeting of the Regional Task Force on Marine Climate Change Dimensions

April 10th-12, Kuwait

Regional Marine Climate Change Risk Assessment, Adaptation and Mitigation Strategy for the ROPME Sea Area

Authors: Dr John Pinnegar, Dr Will Le Quesne, Dr Susana Lincoln

Centre for Environment Fisheries & Aquaculture Science

Contents

1. Brief introduction - why ROPME countries should be interested

The Regional Organization for the Protection of the Marine Environment (ROPME) was established in 1979 and acts as the Secretariat for the Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment from Pollution (1978). The ROPME Sea Area (RSA) has a total surface area of ~240,000 km2 and is characterised by shallow waters of high temperature, marked differences in salinity and strong seasonal upwelling driven by monsoon winds. The RSA is bordered by eight countries, namely the Kingdom of Bahrain,Islamic Republic of Iran, Republic of Iraq, State of Kuwait, Sultanate of Oman, State of Qatar, Kingdom of Saudi Arabia, andthe United Arab Emirates. In 1994, ROPME together with UNEP, published an overview of *'Implications of Climate Change in the ROPME region'* (UNEP 1994) but this topic has since received relatively limited attention.

In 1994 the United Nations Framework Convention on Climate Change (UNFCCC) came into force and in October 2015 Countries, including most ROPME Member States submitted 'Intended Nationally Determined Contributions' (INDCs) outlining what they each plan to do about climate change, including commitments to reduce carbon emissions as well as providing a description of how countries plan to enhance resilience and adapt to future threats.

The RSA region has been recognised as one of the warmest sea areas globally. In common with other semi-enclosed basins, the northern RSA is particularly vulnerable to changing environmental conditions as a result of its landlocked nature. Localized analyses (e.g. of Kuwait Bay) have shown strong and significant warming trends in excess of 0.6°C per decade since 1985(Al-Rashidi, et al. 2009). In the Arabian Sea, sea surface temperature increased by 0.18°C from 1982–2006 (Rayner et al., 2003; Belkin, 2009). Recent projections suggest that sea temperatures are likely to continue to increase markedly under future carbon emission scenarios (IPCC 2013; AGEDI 2015a). Increases of 3.45–4.37°C are projected over the period 2010–2099, with the greatest increases projected for surface waters of the northern part of Inner RSA (4.26°C). In the 2013 ROPME 'State of the Marine Environment' report, climate change was recognised as an 'emerging issue' of particular concern, for which it is necessary *"to raise public awareness and flag the consequences of inactions or lack of clear policies, legislation and enforcement towards alleviating possible risks".*

There is a developing body of evidence to suggest that marine ecosystems, including coral reefs, seagrass beds and mangrove forests are vulnerable to changes in regional climate caused predominately by warming of air and sea surface waters and to a lesser extent by modification of precipitation regimes and wind patterns. Added to this rising levels of carbon dioxide have been found to cause chemical changes in the ocean, which in turn have led to the oceans becoming more acidic, imposing further stresses on already degraded habitats and ecosystems.

This briefing document provides an overview of existing evidence for maritime climate change in the RSA, it describes model outputs showing projections for the future and it considers what ROPME countries can do to mitigate or cope with the challenges ahead.

2. What is happening now - existing evidence for climate change in the RSA

Changes in temperature, salinity and ocean chemistry

The ROPME Sea Area can be divided into three distinct zones, each with differing responses to climate change. These areas are: the Inner ROPME Sea Area (I-RSA), that covers the marine area west of 56°E longitude, extending from Strait of Hormuz to the northern coast of Iran; the Middle ROPME Sea Area (M-RSA), that covers the Sea of Oman; and the Outer ROPME Sea Area (O-RSA) that covers the entire southern area of the RSA across the Arabian Sea.

The Outer ROPME Sea Area (O-RSA) is the northernmost part of the Indian Ocean with a typically monsoonal climate. The summer monsoon (April to September) results in strong winds from the southwest, high rainfall and produces strong upwelling. Sea surface temperatures in the O-RSA reflect the region's monsoonal nature. During the winter monsoon period sea surface temperature (SST) reduces from 26°C in November to 22-23°C in February. By contrast, with the onset of the summer monsoon, the temperature rises to ~ 28°C in May -until upwelling dominates and temperatures in the upwelled areas drop to below 22°C near the coast in August. The lower temperatures near the coast persist until the upwelling weakens in November.

The Middle ROPME Sea Area (M-RSA) is a deep 'arm' of the Indian Ocean that extends northwards and westwards for ~400km to connect with the Inner ROPME Sea Areathrough the shallow (maximum depth 100m) and narrow (narrowest width 56km) Strait of Hormuz. It is affected by the Arabian Sea monsoons to varying degrees, but the effect diminishes with increasing distance from the Indian Ocean.In the Middle RSA, sea surface temperatures are not affected by the seasonal monsoons to the same extent as in the Outer RSA. Minimum winter SST of around 22°C occurs in February and maximum SST of 32°C occurs in August with water along the Arabian coast being generally warmer than along the Iranian coast (UNEP, 1994).

The Inner ROPME Sea Area (I-RSA) is a shallow shelf area (mean depth 35m) with the maximum depth occurring near the Strait of Hormuz. The bottom profile across the I-RSA is asymmetrical, with shallower slopes on the Arabian side and steeper slopes on the Iranian side. Thus, the channel with maximum depth lies on the Iranian side.In the I-RSA the shallowness of the area accentuates seasonal differences in SST with temperatures ≤13°C occurring off Kuwait and Iraq in the north in February and nearing 35°C at the height of the long summer. The temperature difference between summer and winter is greatest (>20°C) in the north-western part and lowest (<11°C) at Hormuz (UNEP, 1994).

Since 1985, seawater temperature in the Kuwait Bay part ofthe I-RSA, has increased on average by 0.6°C per decade(Al-Rashidi, et al. 2009). This is about three times faster than the global average rate reported by the Intergovernmental Panel on Climate Change (IPCC). Differences are due to regional and local effects. Increased temperatures are having profound effects on key habitats and on power generation in the Inner RSA (Al-Rashidi, et al. 2009). The increase has been greatest in the early summer and least during winter months. In 1998 and 2003, the monthly measurements of sea surface temperature showed unusually high peaks in summer, coincident with El Niño events - periodic warming of the atmosphere and ocean affecting weather in many parts of the world. It has been estimated that about a third (0.2°C) of the observed increase in seawater temperature in Kuwait Bay can be attributed to global climate change, while around 13 per cent of the increase (0.08°C) is due to human activity along the coast of the bay, especially the direct impacts of power and desalination plants(Al-Rashidi, et al. 2009). The remaining 0.3°C (50 per cent) of decadal warming appears to have been due to changes in circulation and mixing of seawater in the Inner RSA, the influence of the dominant north-westerly wind (Shamal), freshwater discharge from the Euphrates and Tigris rivers, and sand storms (Al-Rashidi, et al. 2009). Sea surface temperature increased by 0.18°C and 0.26°C in the Arabian Sea (O-RSA) and Somali Current, respectively, from 1982–2006 (Rayner et al., 2003; Belkin, 2009), which is consistent with the overall warming of the Western Indian Ocean (IPCC 2014).

The salinity of the I-RSAranges widely, from 36.5 at the Strait of Hormuz to above 70 in shallow semi- enclosed embayments, e.g. Salwa Bay. There is an area near the mouth of Shatt Al-Arab i.e. the outflow of the Tigris-Euphrates-Karun river system where salinity notably decreases, the extent of which depends on the level of freshwater discharge, although low salinity regions remain very localised. The high salinity results from high levels of evaporation, estimated at 1.4 m/yr (Meshal and Hassan,1986).Salinity of surface waters in the Arabian Sea increased by 0.5–1.0% over the past 60 years, due to increased evaporation. Further rises in salinity are anticipated for the I-RSA as a result of more frequent droughts and large-scale irrigation projects in the surrounding countries reducing freshwater input.

When carbon dioxide (CO_2) is absorbed by seawater, chemical reactions occur that reduce seawater pH, carbonate ion concentration, and saturation states of biologically important calcium carbonate minerals. These chemical reactions are termed "ocean acidification" or "OA" for short. Since the beginning of the Industrial Revolution, the average pH of surface ocean waters has fallen by 0.1 pH units globally. Since the pH scale is logarithmic, this change represents approximately a 30 percent increase in acidity (although seawater remains alkaline overall). Few pH measurements exist for the ROPME Sea Area; however, the Inner RSA is known to be a major sink for atmospheric CO_2. Biweekly pH concentration measurements in surface waters over a four-year period (Uddin et al., 2012) suggest that waters of the Inner RSA are becoming increasingly acidic (figure 1). Large data gaps exist in our understanding of the Inner RSAenvironment and especially with regard to temporal and spatial patterns of pH variability, CO_2 sequestration and carbonate chemistry.

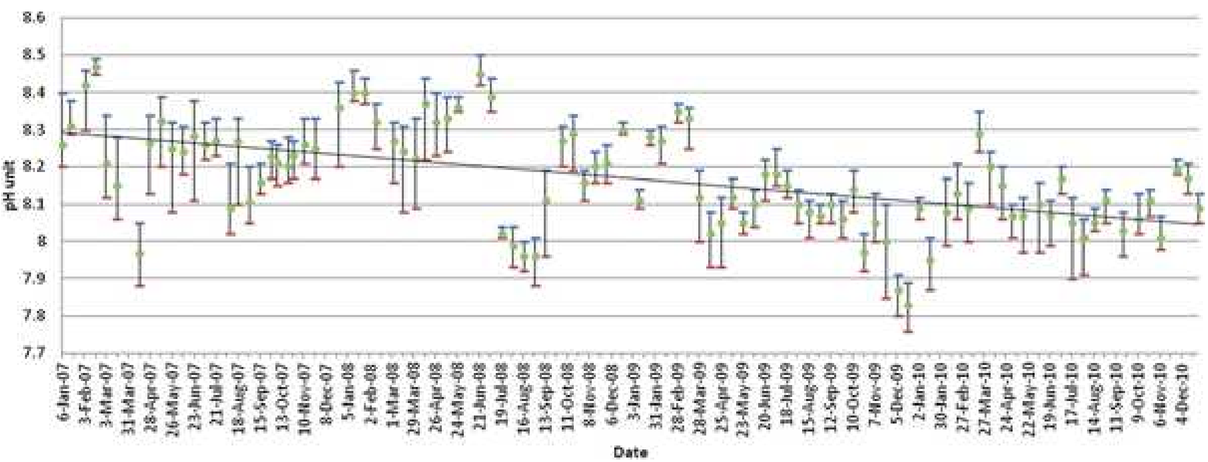


Figure 1. pH measurements between January 2007 and December 2010 in Kuwait territorial waters (red dashes correspond to minima, blue to maxima andgreen is average value)(from Uddin et al., 2012).

Calcium carbonate minerals are the building blocks for the skeletons and shells of many marine organisms. In areas where most life now congregates in the ocean, the seawater is supersaturated with respect to calcium carbonate minerals. This means there are abundant building blocks for calcifying organisms to build their skeletons and shells. However, continued ocean acidification is causing many parts of the ocean to become under-saturated with these minerals, which is likely to affect the ability of some organisms to produce and maintain their shells. A comprehensive review of the status of the Inner RSA(Sheppard et al. 2010) highlighted temperature and pH as major stressors contributing to the decline in biodiversity and ecology in this region.

The aragonite saturation horizon in the Arabian Sea is now 100–200 m shallower than in pre-industrial times as a result of ocean acidification. 'Shoaling' (shallowing) of the aragonite saturation horizon is likely to affect the depth distribution and persistence of reef-forming corals or other shell-forming species present throughout the RSA (Feely et al., 2004).

As a result of long-term climate change, regions of the ocean with low oxygen concentrations are expected to increase in frequency and extent in the future. More than 50% of the area of oxygen minimum zones (OMZs) in the world's oceans occur in the Arabian Sea and Bay of Bengal and long-term measurements reveal that oxygen concentrations are declining in this region (Helly and Levin, 2004; Stramma et al., 2010). The ArabianSea oxygen minimum zone (OMZ) in the O-RSA is the second-most intense OMZ in the world, with near-total depletion of oxygen at depths from 200 to 1000 m (McCreary et al., 2013). Within the I-RSA a hypoxic water layer has also been detected in the marine Exclusive Economic Zone (EEZ) of Qatar caused by the interaction between temperature differences in the water column that acts as a barrier to oxygen replenishment, and respiration by marine organisms resulting in drawdown of oxygen (Al-Ansari et al. 2015).

Sea level rise

Increasesin global atmospheric temperature result in a direct effect on the ocean by causing a rise in ocean temperature and melting of glaciers. Both these processes ultimately lead to a rise in sea level. Studies on regional sea-level rise in the north Indian Ocean have been few, and have mostly been based on tide-gauge data from India. Unnikrishnan and Shankar (2007) considered a wider range of tide-gauge data including stations in Aden (Yemen) and Karachi (Pakistan) at the edge of the RSA. For Aden, the trend in relative sea level rise was 1.21 mm per year throughout the 20th Century, and 0.61 mm per year in Karachi. Overall northern Indian Ocean records longer than 40 years yielded a range of sea level- rise estimates between 1.06–1.75 mm per year, with an average of 1.29 mm per year for the region as a whole.

Alothman et al. (2015) examined relative sea level variations in the north-western part of theInner RSA using 28 years of observations from seven coastal tide gauge stations in Saudi Arabia, Bahrain, Kuwait and Iran, covering the period 1979–2007.A relative sea level rise estimate of 2.2 mm/year was suggested for the northern Inner RSA.

Impacts on habitats, fisheries and marine ecosystems

Several ecosystems, including seagrass beds, coral reefs, mangroves, and mudflats contribute to the productivity and biodiversity of marine resources in the RSA. Most of these habitats are rich in varieties of fish, which are in-turn a major source of food for people. Ecosystem benefits in the RSA are not limited to the provision of food, and extends to other services ranging from primary production and nutrient cycling to erosion and sedimentation control (Naser, 2014).

Seagrass beds are highly productive ecosystems that provide important ecological functions and economic services. Ecologically, seagrass ecosystems provide food sources and feeding grounds for several threatened species in the Inner RSA such as turtles and dugongs. They can also improve water quality by stabilizing loose sediment and by removing some water-borne pollutants. Economically, seagrasses serve as important nursery grounds for penaeid shrimps, pearl oysters and other organisms of importance to the Inner RSA's commercial fisheries (Naser 2014). Three species of seagrass occur in the Inner RSA, these are generally tolerant to the extremes of salinity and temperature experienced in the region. For instance, seagrasses are thriving in the extreme thermosaline conditions of Salwa Bay, south of

Bahrain, where sea temperature exceeds 31 °C and salinity may reach 70 in summer.The largest areas of seagrass beds occur off the coasts of United Arab Emirates and between Bahrain and Qatar with estimated areas of 5500 and 1000 km_2, respectively (Erftemeijer and Shuail, 2012). These seagrass habitats are of critical importance as they support the largest population of dugongs known outside Australia (Naser, 2014).

Although Seagrasses seem to be able to survive short exposures to elevated temperatures, observations in Florida suggest that prolonged departures exposure to extreme conditions (35-40°C) can result in leaf loss, inhibition of root growth and eventually plant death. In general, it appears that sustained elevations of sea temperatures of 4-5°C above summer ambient maxima will cause extensive mortality (Edwards 1995).

Coral reefs ecosystems provide a variety of ecological services such as sources of seafood, maintenance of genetic, biological and habitat diversity, recreational values, and economic benefits such as protecting coasts and infrastructure from waves and storm surges. Coral growth occurs in most of the RSAwith best development on offshore shoals. Additionally, fringing corals occur along the coastlines of United Arab Emirates, Qatar, Saudi Arabia and Bahrain (Riegl and Purkis, 2012). Extremes in temperature, salinity and other physical factors in the Inner RSA restrict the growth and development of corals to patchy forms (Sheppard et al., 2010). However, despite these harsh environmental conditions, corals in the Inner RSA exhibit remarkable resilience and vitality (Naser, 2014).

Recently, corals in the RSA region have been exposed to severe temperature anomalies at a recurrence interval more frequent than in any other coral regions in the world. Therefore, it is argued that corals in the Inner RSA already exist in a thermal environment that is equal to the 2099 projections of the Intergovernmental Panel on Climate Change (IPPC) in tropical oceans (Riegl and Purkis, 2012). Coral reefs in the Inner RSA have been severely affected by recent bleaching events as well as human impacts such as sediment runoff from dredging and reclamation activities and pollution from land-based sources (Naser, 2014). Large-scale decline in coral reef has been observed. It is estimated that almost 70% of original reef cover in the Inner RSA may be considered lost and a further 27% threatened or at critical stages of degradation (Wilkinson, 2008).

The mass coral bleaching and mortality that occurred in 1996 and 1998 were a direct result of the sensitivity of reef-building corals to elevated sea temperatures (Riegl, 2003). These changes to coral reefs have resulted in a loss of fish species that feed on coral-associated invertebrates while herbivores and planktivorous fish abundances have increased (Riegl, 2002).

Mangrove habitats of the Inner RSA support a variety of important species of fish, shrimps, turtles, and birds, and significantly contribute to the coastal productivity (Al-Maslamani et al., 2013). The Inner RSA coastlines are dominated by only one species of mangrove, *Avicennia marina*. Mangroves are largely distributed along the southern shores of the Inner RSA (Naser, 2014). Dense growth of mangroves is particularly confined to low-energy and sheltered coastal areas along the coastlines of United Arab Emirates, Saudi Arabia and Qatar. Overall, according to the IUCN Red List of threatened species, mangroves in the RSA are classified as ‘Least Concern’, however mangrove stands in Bahrain are subject to human impacts that might affect their persistence in the long-term. The marine area of Tubli Bay, which hosts the last remaining mangroves in Bahrain, has been reduced from 25 to 12 km2 in 2008 due to intensive reclamation activities (Naser 2014).

Climate change is likely to have a substantial impact on mangrove ecosystems (Ellison 2015), through processes including sea level rise (SLR), changing ocean currents, increased storminess, increased temperature, and changes in precipitation (Ward et al. 2016). Mangroves are sensitive to changes in inundation duration and frequency as well as salinity levels that exceed a species-specific physiological threshold of tolerance. Storms can significantly influence mangrove productivity and health and globally extreme weather events have been predicted to increase in frequency and severity (IPCC 2013). In comparison to other regions of the world, there have been far fewer studies on the impacts of climate change on mangroves within the RSA (see Ward et al. 2016).

The contribution of marine fisheries sector to RSA economies may appear to be of low importance compared to the oil industry (RECOFI, 2010). However, fish and shellfish are among the most important natural renewable resources, contributing to local food supply and exports. In addition, the fisheries sector (including aquaculture) directly provides employment to ~250,000 people in RSA countries and assures livelihood for more than one million people (RECOFI, 2010).Ecological responses to climate change are varied and many. Observations related to abundance and distribution (including depth shifts) of marine species have been widely reported. Evidence suggests that sensitivities of fish and other ectotherms to temperature are generally increased when exposed to additional climate-change stressors such as reduced oxygen or ocean acidification and vice versa (Pörtner and Peck, 2010; Deutsch et al., 2015).

The negative impact of climate change on fisheries resources is already evident in declining catches throughout the ROPME Sea Area. Fisheries of the RSA are make use of over 1000 finfish and 15 shellfish species (ROPME 2013). However, the over-exploitation of fish, crustaceans and mollusc species is starting to become a serious concern. Shrimps, and species such as silvery pomfret, hilsa shad, rock lobster and abalone are all considered over-exploited (Al-Husaini et al. 2012). Furthermore habitat loss, in part caused by climate change is exacerbating these losses.

Zobaidy (or silver pomfret) is a prime, valuable and shared fish stock in the northern I-RSA between Kuwait and Iran. Its catches constitute from 30 to 40 percent of the total value of Kuwait’s capture fin-fish fisheries, but Kuwait catches have declined from 1100 tonnes in 1994 to 120 tonnes in 2000. The catches and catch rates of by Iranian fleet have also decreased substantially from 1142 tonnes in 1996 to only 114 tonnes in 2000. Now it is believed that the northern part of Inner RSA fishery stocks are under environmental stress due to high fishing capacity of fleet, and to ecological changes, increasing elevated temperatures and a decrease in the Tigris-Euphrates-Karun rivers discharges.

Impacts on human health, industries and infrastructure

As sea temperatures change and raise, so the biogeographical ranges of species change in response, and this includes the distribution of harmful marine species such as bloom forming algae and marine pathogens that directly affect human health. For example the viruses *Vibrio cholerae, V. parahaemolyticus* and *V. vulnificus* exist in seawater and can cause major wound infections, gastroenteritis and occasionally human fatalities. The incidence of these species is known to be closely linked to warm seawater temperatures and they have all been found in seawater samples from the RSA, in particular off the coast of Saudi Arabia (Elhadi 2012).

Biological changes (e.g., harmful algal blooms and fish kills) have been associated with the increasing sea temperatures of the Inner RSA, although attribution to increasing temperatures as opposed to other factors (e.g., water quality) is often very difficult (Bauman et al., 2010).

A very intensive and prolonged harmful algal bloom event occurred in the southern reaches of the RSA in 2008 (Sale et al., 2011). Starting in the autumn of 2008, the bloom initiated in the Sea of Oman expanded north along the Musandam coast and into the Inner RSA as far as the shores of Dubai and the Iranian Coastal areas by the end of 2008, eventually dissipating by August 2009. The dominant species was *Cochlodinium polykrikoides*, a fish-killing species common in other areas throughout the world. This was the first confirmed report of this species in the RSA (Richlen et al., 2010). While the fish-killing attributes of *C. polykrikoides* are well known, this particular bloom also damaged other marine fauna, particularly hard coral communities and the associated fish fauna (ROPME 2013).

Ciguatoxins are produced by microscopic plant-like forms that grow in reefs of warm tropical waters. They are unicellular algae called dinoflagellates. Small fish that eat the algae become contaminated. If larger fish eat many smaller, contaminated fish, the poison can bio-accumulate to dangerous levels. Dinoflagellates are present in the whole of the Inner RSA and have been reported to be present all along Kuwait's shores when large numbers of dead fish have previously been observed, although human ciguatera fish poisoning may be underreported or not diagnosed yet in the RSA (Hajar Albinali 2011). Ciguatoxins are present in the Inner RSAand the dinoflagellates commonly form red tides in the summer causing the death of large numbers of fish due to the toxins and depletion of dissolved oxygen.

When beaches and other habitats undergo negative changes as a result of climate and meteorological events, this can affect the appeal of a destination. Widespread resource degradation challenges, such as beach erosion and coral bleaching, as well as harmful algal blooms, impact negatively the perception of destination attractiveness in various locations.

Given that the development of recreational and tourism facilities is an important priority for the diversification of national economies, ROPME Member States are developing tourism facilities on the coast at a rapid rate especially in Bahrain, Oman and UAE. For example, considerable stretches of the intertidal areas along the Kuwait City coast and some sections along the southern coast of Kuwait have been landfilled. In addition to the destruction of coastal habitats caused by landfilling, the disturbance of the natural hydrodynamic conditions of the coastal water and local beach processes have intensified erosion problems significantly along most of the fill edge of the landfilled areas. The effect of these landfilling activities is not only the partial or total loss of the upper intertidal areas but also the modification of the physical nature of the adjacent tidal flat (Al-Bakri et al., 1985). Landfilling has been extensively practised by all countries of the Region with tremendous impacts on the marine environment of RSA during the past four decades. Siltation increases due to the release of fine material during seafilling and dredging and results in an increase in water turbidity. This has the potential to intensify erosion impacts caused by climate change with adverse environmental effects on the coastal ecosystem and negative consequences for their appeal to tourists and visitors.

Important coastal infrastructure is already facing pressure from natural forces such as a wind, waves, tides and currents, which are exacerbated by the impacts of climate change and in particular sea-level rise. Climate change is having a direct, as well as indirect, impact on energy generation, distribution and transmission infrastructure. Cyclones damage superstructures such as lines and poles. Power generation stations located on or near the coast are highly vulnerable to coastal flooding from sea-level rise.Sand and dust storms in the Region have negative socio-economic impacts as they cause an increase in traffic accident rates, and oil export losses due to temporary closures of marine terminals.

Cities, towns and key national infrastructure are often located along the coast and if actions are not taken to protect or move these structures, long-term sea level rise could lead to massive impacts on these coastal communities and facilities.

3. What do we expect to happen in the future?

Physics and chemistry

The Intergovernmental Panel on Climate Change's Fifth Assessment Reports (AR5) in 2013 and 2014 involved a collaborative effort by scientists from institutes around the world. In particular, these scientists provided outputs from a total of 1145 computer model simulations and these have been archived and made available to users. Subsets of the marine data can be extracted and are presented here for the ROPME Sea Area specifically.

These comprise an average of across all the models available from the IPCC, out to the year 2090, assuming a 'business as usual' future CO_2 emission scenario (RCP8.5).

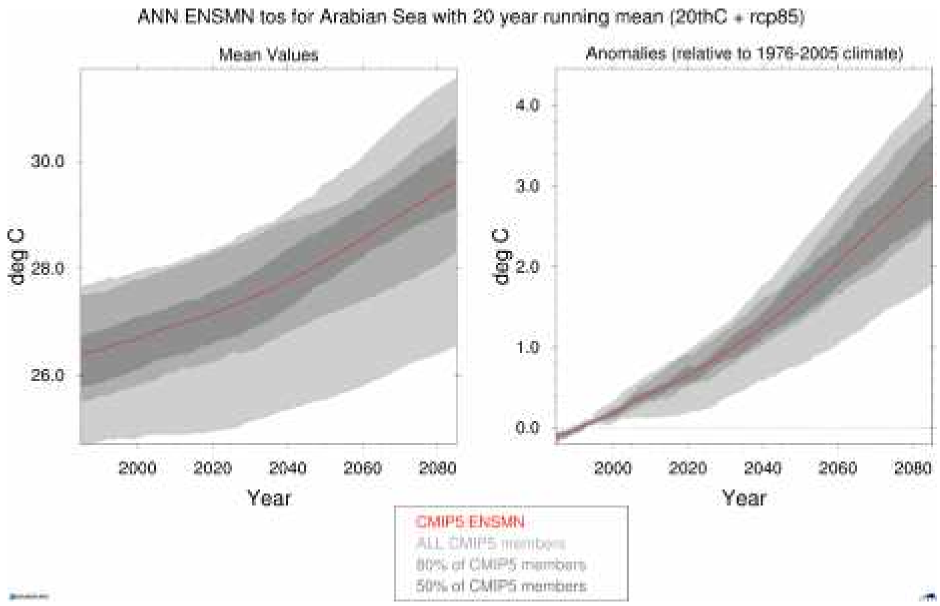


Figure 2. Sea surface temperature (SST) projections for the Arabian Sea region, based on the CMIP5 IPCC climate model ensemble.

The IPCC CMIP5 model scenarios suggest that average sea surface temperatures (SST) for the Arabian Sea region will rise throughout the 21st Century from around 26.5°C in 2000 to almost 30°C by 2090 (figure 2). This is an increase (relative to the 1976-2005 baseline) of around 3°C.

Figure 3 shows maps of future SST, salinity, surface pH and Chlorophyll for the ROPME Sea Area, comparing the second half of the 21st Century (2050-2099) to the historic baseline (1956-2005). These plots show that temperature rises will be larger inside the inner ROPME Sea Area compared to outside (a rise of around 2.8°C in the I-RSAcompared to 2.5 °C in the M-RSA and O-RSA). Similarly, salinity is expected to increase in the I-RSA but changes are expected to be negligible outside. pH will continue to decline throughout the ROPME Sea Area by around 0.2 pH units and Chlorophyll concentrations (populations of microscopic plants) will decline, especially off the southern coast of Oman (and neighbouring Yemen).These global outputs offer relatively crude spatial resolution and may not capture fine-scale dynamics of the RSA region, hence a downscaled model is needed (see below), but they do give a broad indication of anticipated future climate change in the region.

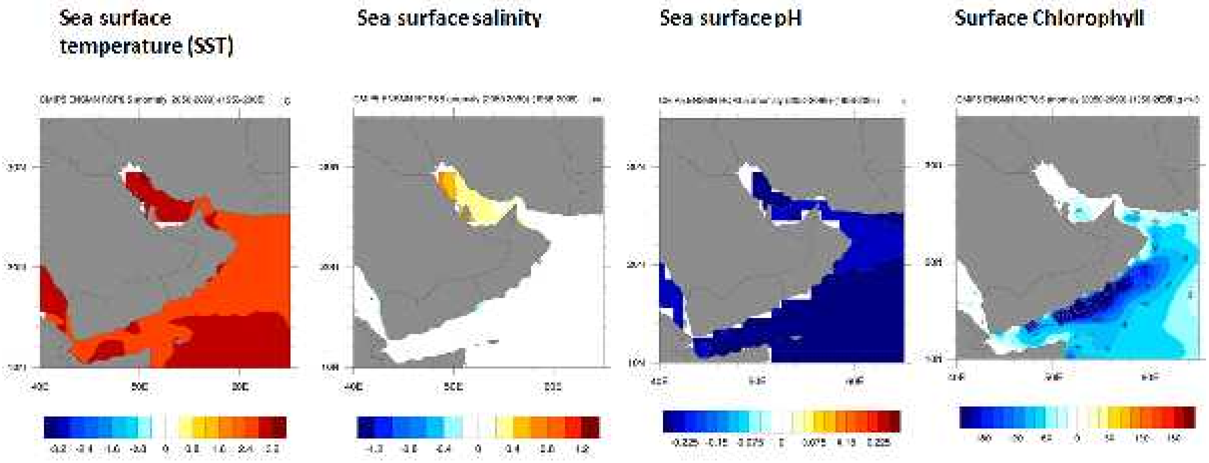


Figure 3. Change in sea surface temperature (SST), salinity, pH and Chlorophyll projections for the Arabian Sea region, based on the CMIP5 IPCC climate model ensemble.

In October 2013, the Abu Dhabi Global Environmental Data Initiative (AGEDI) launched the "Local, National, and Regional Climate Change (LNRCC) Programme to build upon, expand, and deepen understanding of vulnerability to the impacts of climate change as well as to identify practical adaptive responses at local (Abu Dhabi), national (UAE), and regional (Arabian Peninsula) levels. A Regional Ocean Model System (ROMS) was deployed to provide fine-scale outputs for the Inner RSA sea surface temperature, salinity, sea level height, and currents were projected up to the year 2100, assuming a “business as usual” IPCC’s scenario (RCP8.5). The authors (AGEDI 2015a) present two time slices periods from 2000 till 2020 and from 2080 till 2100, hereafter called early 21st and late 21st Century.

Sea surface temperature increases throughout the region(figure 4) but particularly on the western, northern and southern coasts (Kuwait, Saudi Arabia, Bahrain, Qatar, UAE) and in the Strait of Hormuz. Salinity primarily increases on the western side of the Inner RSA , with decreases indicated in the late 21st century along the deep channel on the eastern (Iranian) side. Sea level height increases throughout the Inner RSA(figure 4)but particularly in the Strait of Hormuz and southern shore, for example around Bahrain and eastern Qatar (where also salinity increases the most).

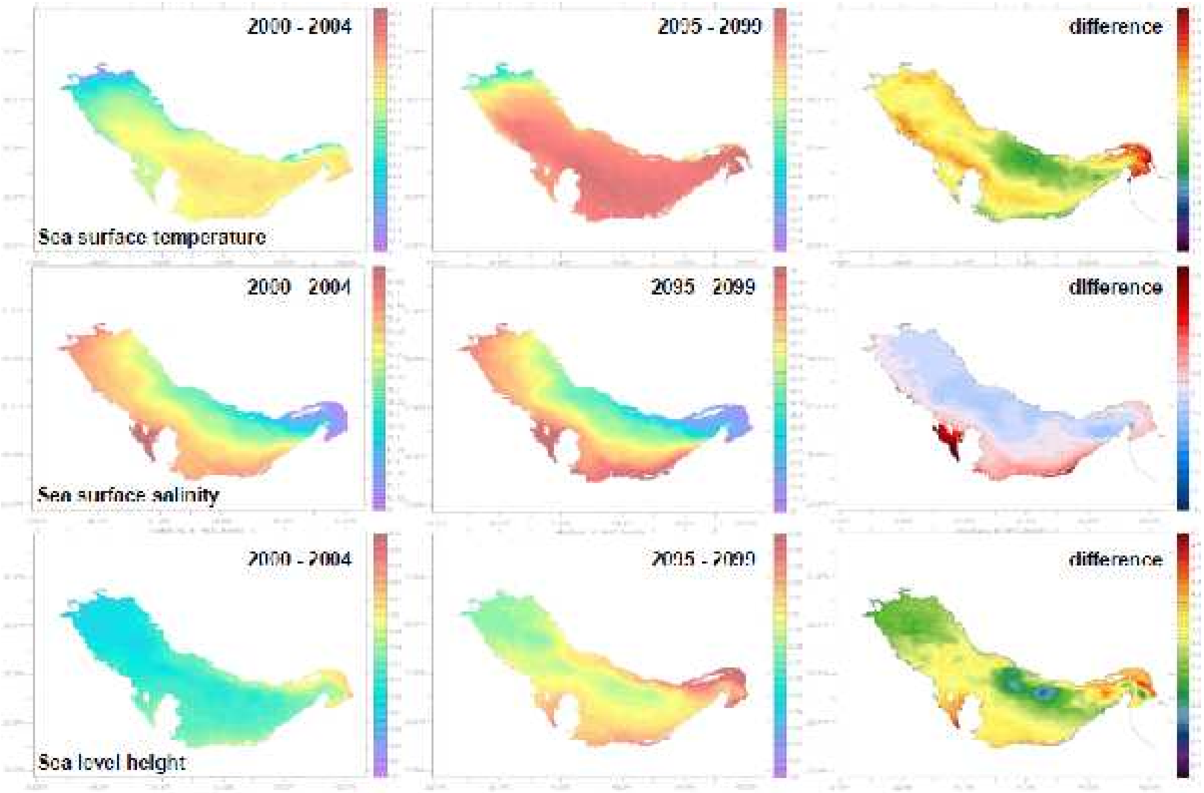


Figure 4: Sea surface temperature (upper row); surface salinity (centre row); and sea surface height (lower row). The first column is the average results for the early 21st Century (2000-2005); the second column is the average for the late 21st Century (2095-2099); and the third column is the difference between these two'experiments' (Late 21st - Early 21st) (from AGEDI 2015a).

Marine ecosystems and biodiversity

Climate change can impact the pattern of marine biodiversity through changes in species' distributions. Cheung et al. (2009) set out to investigate the global consequences of such impacts by projecting the distributional ranges of a sample of 1066 exploited marine fish and invertebrates into the future (for 2050) using a newly developed dynamic bioclimate envelope model. These authors found that climate change may lead to local extinction in the sub-polar regions, the tropics and particularly semi-enclosed seas. Notably, local extinctions were predicted for the Inner RSA. In semi enclosed seas, the dispersal of species is limited by land boundaries. In addition, sea bottom temperature and SST of semi-enclosed seas are projected to increase at a faster rate than temperatures in the adjacent open seas, causing more local extinctions and range-shifting in these semi-enclosed water bodies.

Cheung et al. (2010) attempted to estimate global catch potential for the same 1066 species of exploited marine fish and invertebrates from 2005 to 2055 under climate change scenarios. These authors show that climate change may lead to large-scale redistribution of catch potential, with an average of 30–70% increase in high-latitude regions and a drop of up to 40% in the tropics. Moreover, maximum catch potential declines considerably in the southward margins of semi-enclosed seas while it increases in poleward tips of continental shelf margins. For the ROPME sea region Cheung et al. (2010) suggested a decline of around 0.5 tonnes/km2 per year in fish yield by 2050, within the inner RSA, but conversely a slight increase in fishery yield in the Sea of Oman and northern Arabian Sea (the M-RSA and O-RSA respectively) (figure 5). The negative impact of climate change on fisheries resources is already evident in the declining catches from capture fisheries throughout the ROPME Sea Area.

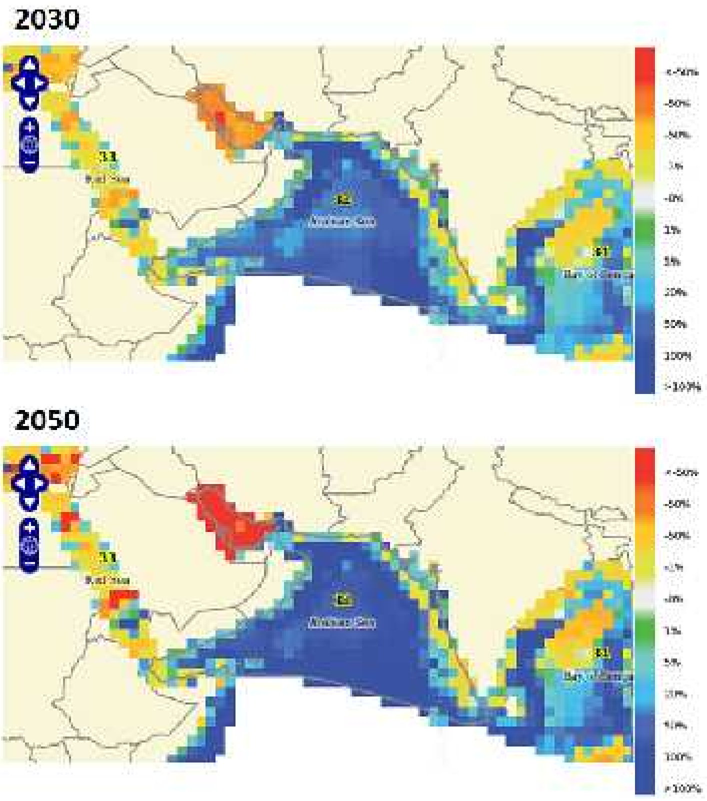


Figure 5. Proportion of catch potential change in 2030 and 2050, compared to 2000 (based on Cheung et al. 2010).

The "Marine Biodiversity and Climate Change" study within the AGEDI Programme (AGEDI 2015b) aimed to assess the potential impacts and the vulnerability of marine biodiversity and fisheries in the Inner RSA to climate change, this included a regional downscaling of the fisheries modelling work of Cheung et al (2009, 2010). The authors predicted the current and future distributions of the 56 focal fishery species for the period 2000-2020 and 2080-2099.

Projections of changes in distributions of marine species (AGEDI 2015b) suggest that climate change is expected to have severe impacts on marine biodiversity and fisheries in the Inner RSA region. The authors found a high rate of local extinction (up to 35% of initial species richness) by 2090 relative to 2010 under the RCP 8.5 scenario. Species invasion is low (up to 5% of the initial species richness). As a result, many areas in the Inner RSA are projected to experience a net loss in biodiversity. Spatially, local extinction is highest in the southwestern part of the Inner RSA, off the coast of Saudi Arabia, Qatar and the UAE. In contrast, species invasion is only limited to small areas in the northern part of the Inner RSA, off the coast of Kuwait and northern Iran. Most parts of the Inner RSA, and in particular areas in the south and southwestern part of the Inner RSA, are projected to experience a decline in the sum of habitat suitability for all species.

As part of the AGEDI "Marine Biodiversity and Climate Change" the authors also focused on modelling several charismatic species: the dugong (*Dugong dugon*), Indo-Pacific humped-back dolphin (Sousa chinensis), Indo-Pacific bottlenose dolphin (*Tursiops aduncus*), green sea turtle (*Chelonia mydas*), and hawksbill sea turtle (*Eretmochelys imbricata*). Current and future habitat suitability of these species in the Inner RSA were projected using the modelling methods as described above. The predicted changes in habitat suitability for charismatic species were used as indicators of sensitivity, and thus vulnerability, of these species to climate change impacts.

Overall, total habitat suitability of all charismatic species was projected to decline most in the waters of countries on the western side of the Inner RSAby 2050 and 2090 under RCP 8.5. Habitat, as defined by changes in temperature and salinity, in waters of Oman, Bahrain and Qatar was projected to be particularly affected, with a 36% drop in future habitat suitability, followed by the UAE and Saudi Arabia. Waters of countries in the northern part of Inner RSA were projected to be less vulnerable. There was generally high agreement of results among the three environmental niche models tested (AGEDI 2015b).

4. Key International policy drivers

A number of international conventions and agreements are relevant to, or specifically mention climate change in the marine environment. Most ROPME Member States are signatories to these conventions and hence countries need to consider what these commitments might entail in practice and put in place measures to ensure compliance. The following section provides a brief overview of the most important policy commitments that ROPME members should be aware of.

United Nations Framework Convention on Climate Change (UNFCCC)

The UNFCCC entered into force on 21 March 1994. The ultimate objective of the Convention is to stabilize greenhouse gas concentrations "at a level that would prevent dangerous anthropogenic (human induced) interference with the climate system." The convention states that "such a level should be achieved within a time-frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened, and to enable economic development to proceed in a sustainable manner." As they are the source of most past and current greenhouse gas emissions, industrialized countries are expected to do the most to cut emissions. Developing countries (Non-Annex I Parties) report in more general terms on their actions both to address climate change and to adapt to its impacts, their reporting is contingent on their getting funding for the preparation of the reports, particularly in the case of the Least Developed Countries. All ROPME Member States are Non-Annex I Parties to the UNFCCC Convention.

The COP21 Paris Agreement (signed on 12 December 2015) builds upon the Convention and brings all nations into a common framework to undertake ambitious efforts to combat climate change and adapt to its effects. The central aim of the COP21 Agreement is keep the global temperature rise this century well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5°C. Parties to the UNFCCC are responsible for providing a range of national reports on their efforts to implement the agreement. As of 4 April 2016, 161 “intended nationally determined contributions”, from 189 of the 197 Parties to the Framework Convention had been recorded by the secretariat (including contributions from ROPME countries), providing insights into the efforts countries are taking to integrate climate change measures into national policies, strategies and planning.

As Parties scale up climate change action, enhanced cooperation, capacity-building and access to financial and technical support will be needed to help many countries realize their priorities, including those identified in intended nationally determined contributions and national adaptation plans. Developed countries have committed to mobilizing, by 2020, $100 billion a year in climate financing from a wide variety of sources to help address the needs of developing countries. By 2025, Parties to the UNFCCC will set a new collective goal of at least $100 billion per year. The Green Climate Fund, a mechanism within the Framework Convention created to assist developing countries in adaptation and mitigation practices, is an important delivery vehicle for this financing.

United Nations Sustainable Development Goals (SDGs)

On 19 July 2014, the United Nations Open Working Group (OWG) on Sustainable Development Goals (SDGs) forwarded a proposal for 17 "Global Goals" with 169 targets to the UN General Assembly. These included ending poverty and hunger, improving health and education, making cities more sustainable, combating climate change, and protecting oceans. Following negotiations, a final document was adopted at the UN Sustainable Development Summit, September 25–27 2015, in New York.

Sustainable Development Goal number 13 specifically refers to the need to take urgent action to combat climate change and its impacts. It recognises that climate change presents the single biggest threat to development, and its widespread, unprecedented impacts disproportionately burden the poorest and most vulnerable. Urgent action to combat climate change and minimize its disruptions is integral to the successful implementation of the Sustainable Development Goals. Countries are encouraged to "take urgent action to combat climate change and its impacts by regulating emissions and promoting developments in renewable energy".

Sustainable Development Goal number 14 encourages countries to "Conserve and sustainably use the oceans, seas and marine resources". Specific targets include:

- By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans.
- Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels.
- By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics
- By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information.

CBD Aichi Biodiversity Target Number 10

All ROPME countries are signatories (Parties) to the UN Convention on Biological Diversity (CBD). From 6–17 October 2014, Parties discussed the implementation of the Strategic Plan for Biodiversity 2011-2020 and its Aichi Biodiversity Targets, which are to be achieved by the end of this decade.

The Aichi Biodiversity target number 10 (strategic goal B) requires that"By 2015, the multiple anthropogenic pressures on coral reefs, and other vulnerable ecosystems impacted by climate change or ocean acidification are to be minimized, so as to maintain their integrity and functioning". The associated actions are:

- Sustainably managing fisheries on coral reefs and closely associated ecosystems (such as mangroves and seagrass systems), by empowering local and indigenous communities and individuals involved in local fisheries.
- Managing coastal zones and inland watersheds in an integrated manner in order to reduce pollution and other land-based activities that threaten coral reefs.

- Increasing the spatial coverage and effectiveness of marine and coastal protected and managed areas in coral reefs and closely associated ecosystems.
- Managing coastal development to ensure that the health and resilience of coral reef ecosystems are not adversely impacted and promoting sustainable coral reef tourism, including through the use of guidelines for tourists and tour operators.
- Maintaining sustainable livelihoods and food security in reef-dependent coastal communities and provide for viable alternative livelihoods, where appropriate.
- At a national level, identifying other ecosystems that are vulnerable to climate change and related impacts, implementing measures to improve their resilience, and monitoring their effectiveness.

5. Adaptation measures - what can ROPME countries do?

There are two main actions that can be taken to address climate change, these are 'mitigation' and 'adaptation'. 'Mitigation' refers to limiting climate change by reducing the emissions of greenhouse gases and by enhancing the uptake of greenhouse gasses by promoting or protecting natural 'sinks', and 'adaptation' refers to reducing the adverse impacts of climate change by taking actions to prepare for the changes that will be caused by climate change.

Even if carbon emissions are stabilized relatively soon, global warming and its effects will last many years, and adaptation will be necessary in the short to medium term. Adaptation can be defined as adjustments to reduce vulnerability and to increase the resilience to change. The ability to adapt is referred to as 'adaptive capacity'. Those societies that can respond to change quickly and successfully have a high adaptive capacity. In the ROPME Sea Area a number of actions are underway to enhance resilience, and these are detailed in the "Intended Nationally Determined Contributions"(reports submitted to the UNFCCC secretariat) of each country.

6. Mitigation- reducing carbon emissions and blue carbon

The marine and coastal environment can play a role in reducing the extent of climate change, through the uptake and sequestration of carbon in marine and coastal ecosystems, as well as being affected by climate change. 'Blue carbon' is the term used to refer to carbon stored in coastal and marine ecosystems. Coastal ecosystems are some of the most productive on Earth and in addition to providing important ecosystem services, such as coastal protection and nursery grounds for fish, they also sequester and store carbon and hence can play a role in climate change 'mitigation'.

Mangroves, tidal marshes and sea grass in particular can sequester and store huge quantities of carbon in both the plants themselves and the sediment below. When degraded or destroyed, these coastal ecosystems emit the carbon they have stored for centuries into the atmosphere and oceans and become 'sources' of greenhouse gases. It has been estimated that as much as 1.02 billion tons of carbon dioxide are being released annually from degraded coastal ecosystems.

The International Blue Carbon Initiative is a coordinated, global program focused on mitigating climate change through the conservation and restoration of coastal and marine ecosystems. The Blue Carbon Initiative currently focuses on mangroves, tidal marshes and seagrasses.These coastal ecosystems are found on every continent except Antarctica and combined they cover approximately 49 Mha.

The Blue Carbon Initiative works to protect and restore coastal ecosystems for their role in reducing impacts of global climate change. To support this work, the Initiative is coordinating the International Blue Carbon Scientific Working Group and International Blue Carbon Policy Working Group, which provide guidance for needed research, project implementation and policy priorities. Projects are being developed at sites globally to protect and restore coastal ecosystems for their "blue" carbon value, and research into the sequestration, storage and loss of carbon from blue carbon systems is ongoing.

Noted examples of 'blue carbon' projects in the ROPME Sea Area, include:

- Bahrain - amangrove transplantation project to rehabilitate degraded coastal areas, which began in 2013. The project succeeded in the cultivation of mangroves in Tubli Bay and Doha Arad.The Kingdom is planning to further engage with the International Union for Conservation of Nature to better understand the role of mangroves and seagrass beds on carbon sequestration
- Saudi Arabia is investing heavily in activities that help protect the Kingdom's natural environment including the protection of marine and coastal biodiversity. Some adaptation strategies with mitigation co-benefits involve planting mangrove seedlings along the coasts.
- In 2013, the United Arab Emirates initiated the Blue Carbon Demonstration Project, which provided decision-makers with a stronger understanding of the carbon sequestration potential in the Emirate of Abu Dhabi. In 2014, the project's scope was expanded to cover the entire country, and is known as the UAE's National Blue Carbon Project.
- Oman and I.R.Iran have had a large number of mangrove transplantation projects successfully implemented in the past few decades.

7. Why ROPME needs an action plan and what it might look like

As part of the UNFCCC, the ROPME Member States have made commitments to tackle climate change and adapt to its effects. Furthermore, a key recommendation in the 2013 ROPME 'State of the Marine Environment Report' was that "Member States, agree on plans and actions commensurate with the efforts of the international community to mitigate possible impacts of global climate change on the Region's marine ecosystems and coastal areas, according to the IPCC best agreed scenarios for the Region".

A ROPME Regional Marine Climate Change Risk Assessment, Adaptation and Mitigation Strategy is proposed to address the challenges of marine climate change for the RSA in a regionally coordinated manner. The primary focus of the strategy will be on identifying key risks and associated adaptation strategies; however, some consideration will be given to mitigation particularly through building and conserving 'blue carbon'. The ROPME Marine Climate Change Strategy will act to help member countries meet their national commitments to marine and coastal climate change adaptation, as specified by international and regional commitments, in a regionally coordinated manner. The proposed ROPME Marine Climate Change Strategy is based on examples of the development of climate change risk assessments, adaptation plans and mitigation plans that have been conducted internationally. The strategy is based around two parallel strands of activity that separately address adaptation and mitigation.

The first step to preparing the adaptation strategy is to conduct a risk assessment that will identify the main impacts associated with climate change in the marine and coastal environment. Once these priority impacts have been identified, the key adaptation actions will be identified to reduce the adverse impacts. A novel element to the work plan is the potential application of 'decision support tools' to identify key threats and potential adaptation strategies.

A similar approach to risk assessment and adaptation planning has been successfully implemented in the United Kingdom. The UK Climate Change Act (2008) requires a Climate Change Risk Assessment (CCRA) to be carried out every five years, to assess the major risks and opportunities from climate change to the UK. Two versions of the CCRA have now been completed (in 2012 and 2017) and the 2012 report included a separate, sector report on 'marine and fisheries' (Pinnegar et al. 2012). Immediately following the publication of each CCRA report, the Government is required to publish a National Adaptation Programme (NAP) that sets out the UK Government's long term strategy to address the main risks and opportunities identified in the risk assessment. The first National Adaptation Programme was published in July 2013. The programme focuses on: raising awareness of the need for climate change adaptation, increasing resilience to current climate extremes, taking timely action for long-lead interventions, and addressing major evidence gaps.

One suggestion included in the 'concept note' accompanying this briefing note is for the 'ROPME Regional Marine Climate Change Risk Assessment' to include an element of sectoral-based risk and vulnerability assessment at the regional or national level, taking into account: (1) exposure, (2) sensitivity, (3) scale of potential consequences, (4) proximity in time, (5) scientific confidence/consensus, (6) adaptive capacity. Some work along these lines has already been carried out within the RSA as part of the AGEDI (2015b) "Marine Biodiversity and Climate Change" study.

The ROPME Marine Climate Change Strategy would identify the key risks associated with climate change on a sectoral basis and identify the potential adaptation actions that can be taken to respond to these challenges in an informed and timely manner to reduce the impacts of climate change on the societies and economies of the ROPME Sea Area.

References

AGEDI (2015a) Regional Ocean Modelling for the Arabian Gulf Region- Future Scenarios and Capacity Building. LNRCCP. CCRG/USP. Abu Dhabi Global Environmental Data Initiative (AGEDI), 63pp.

AGEDI (2015b) Technical report: Regional marine biodiversity vulnerability and climate change. LNRCCP. CCRG/UBC/Changing Ocean Research Unit/Sea Around Us. Abu Dhabi Global Environmental Data Initiative (AGEDI), 62pp.

Al-Ansari E.M.A.S., Rowe G., Abdel-Moati M.A.R., Yigiterhan O., Al-Maslamani I., Al-Yafei M. A., Al-Shaikh I., Upstill-Goddard R.(2015) Hypoxia in the central Arabian Gulf Exclusive Economic Zone (EEZ) of Qatar during summer season. Estuarine, Coastal and Shelf Science, 159:60-68.

Al-Bakri D., Fouda M., Behbehani M., Khalaf F., Shublaq W., Al-Sayed M., Al-Sheikh Z., Kihaneh W., Khuraibit A., Al-Kaid A. (1985) The Environmental Assessment of the intertidal zone of Kuwait. Kuwait Institute for Scientific Research, Report No. KISR 1687, Kuwait.

Al-Husaini M., Al-Baz A., Rajab S., Al-Alawi A., Chen W., Dashti T., Al-Jazzaf S., Husain H., Almatar S., Al-Ramadhan A., Al-Radhi A., Al-Binali A., Al-Yafee E., Al-Maamari J. (2012) Survey of the Demersal Fish Stocks of the Arabian Gulf and Sea of Oman, Volume 1: Main Text. Kuwait Institute for Scientific Research, Report No. KISR, (Final Report, FM045C), Safat, Kuwait.

Al-Maslamani I., Walton M., Kennedy H., Al-Mohannadi M., Le Vay L. (2013) Are mangroves in arid environments isolated systems? Life-history evidence of dietary contribution from inwelling in a mangrove-resident shrimp species. Estuarine, Coastal and Shelf Science, 124: 56-63.

Alothman A.O., Bos M.S., Fernandes R.M.S., Ayhan M.E.(2014) Sea level rise in the north-western part of the Arabian Gulf.Journal of Geodynamics 81: 105–110.

Al-Rashidi T.B., El-GamilyH.I., AmosC.L., Rakha K.A. (2009) Sea surface temperature trends in Kuwait Bay, Arabian Gulf, Natural Hazards, 50(1), 73-82.

Bauman A., Burt J., Feary D., Marquis E., Usseglio P. (2010). Tropical harmful algal blooms: An emerging threat to coral reef communities? Marine Pollution Bulletin. 60: 2117–2122.

Belkin I. M. (2009), Rapid warming of large marine ecosystems, Progress in Oceanography, 81(1-4), 207-213.

Cheung W.W., Lam V.W., Sarmiento J.L., Kearney K., Watson R., Pauly D. (2009) Projecting global marine biodiversity impacts under climate change scenarios. Fish and Fisheries 10: 235-251.

Cheung W.W.L., Lam V.W.Y. Sarmiento J.L., Kelly K., Watson R., Zeller D., Pauly, D. (2010) Large-scale redistribution of maximum fisheries catch potential in the global ocean under climate change. Global Change Biology 16: 24-35.

Deutsch C., Ferrel A., Seibel B., Pörtner H.-O., Huey R. B. (2015) Climate change tightens a metabolic constraint on marine habitats. Science 348: 1132–1135.

Edwards A.J. (1995) Impact of climatic change on coral reefs, mangroves, and tropical seagrass ecosystems. In Eisma, D. (ed). Climate change: impact on coastal habitation. Lewis Publishers, Amsterdam p209-234.

Elhadi N. (2012) Occurrence of potentially human pathogenic Vibrio species in the coastal water of the eastern province of Saudi Arabia. Research Journal of Microbiology, 8(1):1-12

Ellison J. (2015) Vulnerability assessment of mangroves to climate change and sea-level rise impacts. Wetlands Ecology and Management 23:115–137.

Erftemeijer P., Shuail D. (2012) Seagrass habitats in the Arabian Gulf: distribution, tolerance thresholds and threats. Aquatic Ecosystem Health and Management. 15(S1): 73-83.

Feely R.A., SabineC.L., LeeK., BerelsonW., KleypasJ., FabryV.J., Millero F.J. (2004) Impact of anthropogenic CO_2 on the CaCO system in the oceans, Science, 305(5682):362-366.

Hajar Albinali H.A. (2011) Ciguatera fish poisoning, Heart Views, 12: 165.

Helly J.J., Levin L.A. (2004), Global distribution of naturally occurring marine hypoxia on continental margins, Deep-Sea Research Part I-Oceanographic Research Papers, 51(9):1159-1168.

IPCC (2013)Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

IPCC (2014) Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1132 pp.

McCreary Jr. J.P., Yu Z., Hood R.R., Vinaychandran P.N., Furue R., Ishida, A., Richards K.J.(2013) Dynamics of the Indian-Ocean oxygen minimum zones. Progress in Oceanography, 112–113: 15–37.

Meshal A.H., Hassan H.M. (1986) Evaporation from the coastal water of the central part of the Gulf.Arab Gulf Journal of Scientific Research. Math., Phys. Sc. A7(1) 93-109.

Naser H.A. (2014) Marine Ecosystem Diversity in the Arabian Gulf: Threats and Conservation. Chapter 12. In: Biodiversity - The Dynamic Balance of the Planet", Oscar Grillo (Ed.), Publisher: InTech, pp 297-328.

Pinnegar J., Watt T., Kennedy K. (2012) Climate Change Risk Assessment for the Marine and Fisheries Sector. UK Climate Change Risk Assessment (CCRA), Department for Environment, Food and Rural Affairs (Defra), London. 204pp.

Pörtner H. O., Peck M. A. (2010). Climate change effects on fishes and fisheries: towards a cause-and-effect understanding. Journal of Fish Biology, 77: 1745–1779.

Rayner N.A., ParkerD.E., HortonE.B., FollandC.K., AlexanderL.V., RowellD.P., KentE.C., Kaplan A. (2003) Global analyses of sea surface temperature, sea ice, and night marine air temperature since the late nineteenth century, Journal of Geophysical Research, 108(D14):4407.

RECOFI (2010) Trends and Emerging Issues of the Gulf Fisheries: A Regional Perspective. Regional Commission for Fisheries (RECOFI), Fourth meeting of the Working Group on Fisheries Management, Muscat, Oman, 35-October, 2010.

Richlen M., Morton S., Jamali E., Rajan A., Anderon D. (2010). The catastrophic 2008–2009 red tide in the Arabian Gulf region, with observations on the identification and phylogeny of the fish-killing dinoflagellate *Cochlodinium polykrikoides*. Harmful Algae, 9: 163–172.

Riegl B. (2002) Effects of the 1996 and 1998 sea surface temperature anomalies on corals, fish and coral diseases in the Arabian Gulf (Dubai, UAE). Marine Biology, 140: 29–40,

Riegl B. (2003). Climate change and coral reefs: different effects in two high-latitude areas Arabian Gulf, South Africa. Coral reefs, 22: 433–446.

Riegl B., Purkis S. (2012) Coral reefs of the Gulf: adaptation to climatic extremes. Springer, Dordrecht Heidelberg. Volume 3 of the series Coral Reefs of the World pp 1-4

ROPME (2013) State of the Marine Environment Report- 2013. ROPME/GC-16 /1-ii Regional Organization for the Protection of the Marine Environment, Kuwait, 225 pp.

Sale P., Feary D., Burt J., Bauman A., Cavalcante G., Drouillard K., Kjerfve B., Marquis E., Trick S., Usseglio P., Van Lavieren H. (2011) The growing need for sustainableecological management of marine communities of the Persian Gulf. Ambio. 40(1): 4–17.

Sheppard C., Al-Husiani M., Al-Jamali F., Al-Yamani F., Baldwin R., Bishop J., Benzoni F., Dutrieux E., Dulvy N., Durvasula S., Jones D., Loughland R., Medio, D., Nithyanandan M., Pilling G., Polikarpov I., Price A., Purkis S., Riegl B., Saburova M., Namin K., Taylor O., Wilson S., Zainal K. (2010) The Gulf: A young sea in decline. Marine Pollution Bulletin, 60(1):13–38.

Stramma L., SchmidtkoS., LevinL.A., Johnson G.C. (2010), Ocean oxygen minima expansions and their biological impacts, Deep-Sea Research Part I-Oceanographic Research Papers, 57(4):587-595.

Uddin S., Geyao B., Al-Ghadban A.N., Nithyanandan M., Al-Shamroukh D. (2012) Acidification in Arabian Gulf--insights from pH and temperature measurements.Journal of Environmental Monitoring, 14(5):1479-82.

UNEP (1994) Implications of climate change in the ROPME region: An overview. UNEP Regional Seas Reports and Studies Number 155. United Nations Environment Programme (UNEP), 25pp.

Unnikrishnan A.S., Shankar D.(2007) Are sea-level-rise trends along the coasts of the north Indian Ocean consistent with global estimates? Global and Planetary Change 57: 301–307.

Ward R.D., FriessD.A., DayR.H., MacKenzieR.A.(2016) Impacts of climate change on mangrove ecosystems: a region by region overview. Ecosystem Health and Sustainability 2(4):e01211.

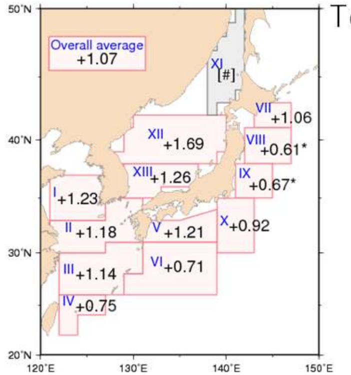
Wilkinson, C. (2008) Status of Coral Reefs of the World. Australian Institute of Marine Science, Townsville.298pp.

Japanese activity for climate change adaptation in coastal region

Yoichi Ishikawa
(Japan Agency for Marine-Earth Science and Technology)

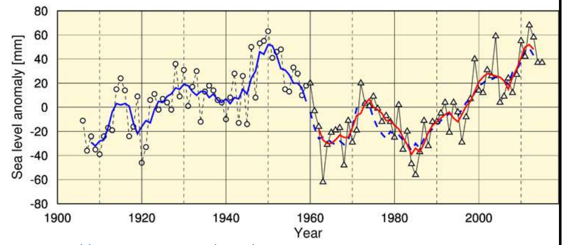
1

Climate change around JAPAN



Temperature increase /100 year

No significant signal in Sea level rise in 100 years



http://www.jma.go.jp/jma/indexe.html

2

Introduction

- Adaptation
- Prevent/reduce the negative impact of global warming
- Local scale, some impacts are already evident
- Various sectors: agriculture, fisheries, disaster prevention, natural ecosystem, etc……

- Mitigation
- limit emissions of greenhouse gases
- Global and middle-long term
- Go ahead of adaptation

3

National Plan for Adaptation to the Impacts of Climate Change

- Cabinet Decision on 27 November 2015
- By promoting adaptation measures to climate change impacts, to build a secure, safe and sustainable society that is able to minimizing and avoiding damage for life of citizens, properties, economics, and natural environment due to its impacts, and to be resilient against damage.
- Period: Considered with long-term perspective till the end of 21st century, showing the basic direction in about coming 10 years.

4

Basic strategy for adaptation

1. Mainstreaming adaptation into government policy
2. Enhancement of scientific findings
3. Promotion of understanding and cooperation through sharing and providing information about climate-related risks
4. Promotion of adaptation in region
5. Promotion of international cooperation and contribution

- An assessment of climate change impacts is to be implemented and formulated approximately every five years, and the Plan is to be revised as required.

5

Sectoral measures

Basic adaptation measures associated with marine environments

- (1-3)for Fisheries
  - Significance Very High, Urgency High, Confidence Medium
- (1-3)for Aquaculture
  - Significance Very High, Urgency High, Confidence Low
- (3-3)for Coastal Ecosystems
  - Significance Very High, Urgency High, Confidence Medium
  - Services cannot assessed currently
- (3-4)for Marine Ecosystems
  - Significance Very High, Urgency Medium, Confidence Low
- (4-2)for Storm Surges and High Waves
  - Significance Very High, Urgency High, Confidence High

6

Sample description for aquaculture

- [Impacts]
- Regarding the current status, the following phenomena, which are believed to be affected by an increase in seawater temperature, have been reported in many places: mass mortality of scallops and an increase in mortality rates of oysters, ……
- Regarding the projected impacts, in yellowtail aquaculture, while there is a concern about increases in mortality rate in the summer due to high water temperature, enhanced growth is projected in fall and winter.
- [Basic Measure]
- Continue research and studies concerning the relationship between the occurrence of red tide plankton, which causes significant impacts on the aquaculture industry, and climate change.
- Based on a concern for decreasing growth in the aquaculture areas, continuously work on developing breeds including high-water-temperature-tolerant culture breeds. As for seaweed in particular, further work will be done as follows: ……

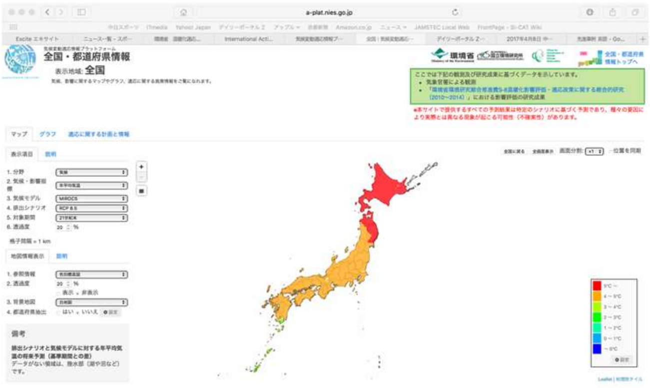
7

Information platform: A-PLAT

- http://www.adaptation-platform.nies.go.jp/en/index.html
- Portal site for climate adaptation
  - funded by the Ministry of Environment
  - operated by National Institute for Environmental Studies
- Can download some papers
  - National plan, advances cases
  - International action
- GIS based viewer
  - User: Local government

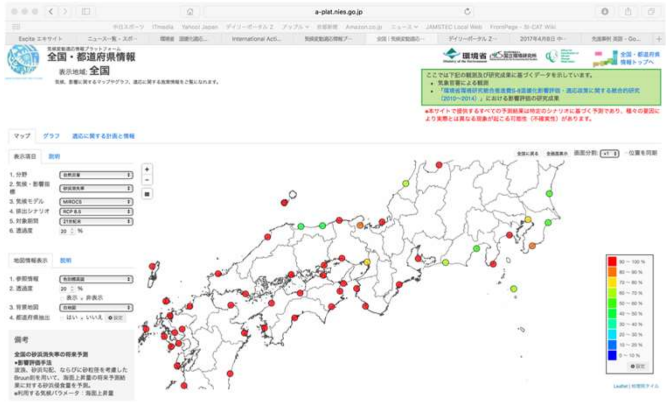
8

GIS platform



9

GIS platform



10

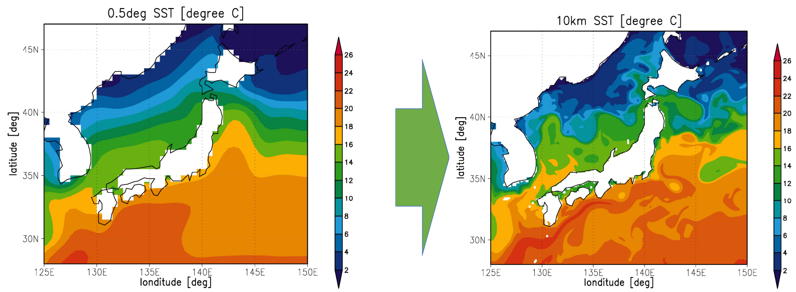
SI-CAT: national project for adaptation

- Social Implementation program for Climate change Adaptation Technology see https://si-cat.jp/en/
- Nationwide assessments with high resolution for local governments
- Make advanced case with selected area and target sector

Near future projection → downscaling → Assessing impacts → Social implementation

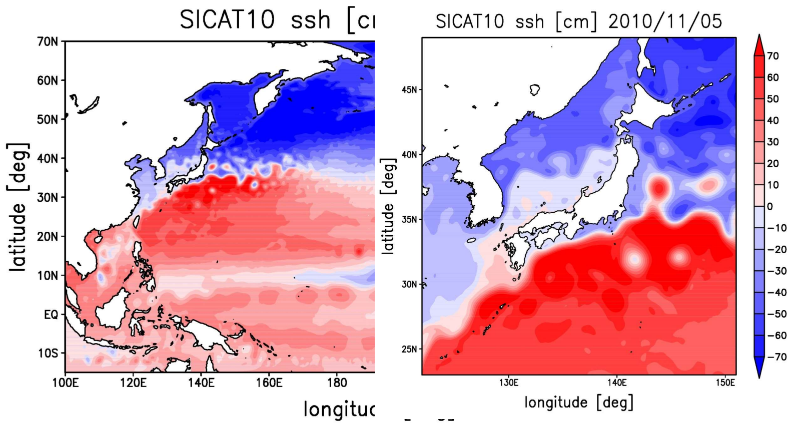
11

Downscaling of marine Environments



12

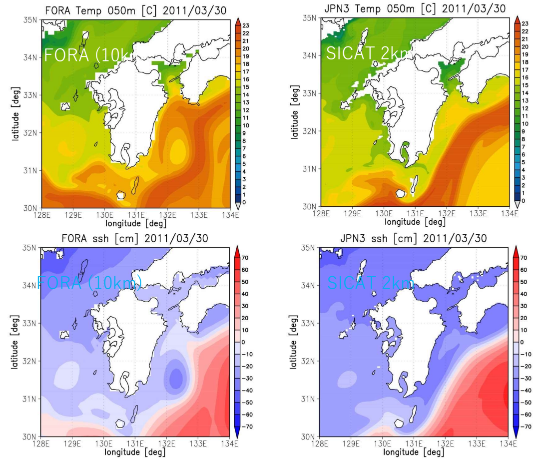
Downscaling for marine environments



13

Developments of Further downscaling model 10km -> 2km

Mar.30,2011



Temp.

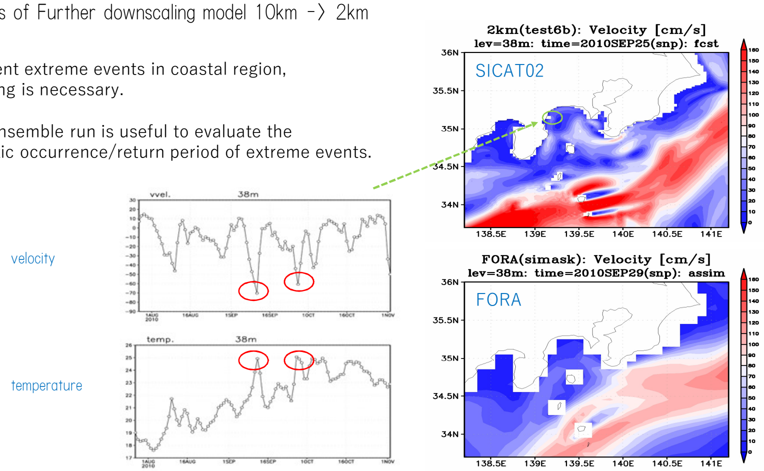
Sea level

14

Developments of Further downscaling model 10km -> 2km

To represent extreme events in coastal region, downscaling is necessary.

Massive ensemble run is useful to evaluate the probabilistic occurrence/return period of extreme events.



15

Application of impact assessments

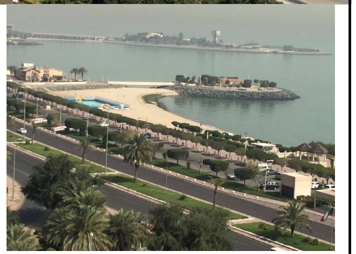
- Fisheries:
- Fishing from coastal to open ocean: temperature, primary production
- Aquaculture: Temperature rise, water quality, evaluation of extreme events is necessary as well as an mean state.

- Coastal protection
- Disaster prevention from High tide, High wave: mean sea level rise and extreme events of currents and waves
- Sand beach: mean sea level rise and extreme events of currents and waves

16

Mainstreaming

- There are many plans associated with adaptation, but they are unrecognized.
- The impacts of global warming are including intentionally.
- Making advanced case successfully and bottom-up penetration.
- Use mass media, policy maker for top-down spread.



17

Future plan

- Re-evaluate adaptation plan, every 5years
  - State-of-the-art model/downscaling and assessments
  - Reduce items/sectors of “cannot be assessed”
- Monitoring and simulation will continue
  - Discussing national scenarios for climate change as well as socioeconomics, land usage, and ……
- Mainstreaming Effort
  - Take into accounts of global warming impacts for existence/planning projects
  - Making advanced cases in local governments, and spread over
- International activity
  - A-PLAT -> APLAT-AP
  - Industrial sector requires world-wide assessment due to the global supply chain

18

2017 年 4 月 14 日

ROPME ワークショップ参加報告

１．概要

・タイトル：Meeting of the Regional Task Force on Marine Climate Change Dimensions in ROPME Sea Area

・期間：2017 年 4 月 10 日（月）～12 日（水）

・場所：ROPME 本部、クウェート

・プログラム、コンセプトノート、参考資料：別添参照

・参加者：イラク、クウェート、オマーン、バーレーン、サウジアラビアから気候変動担当者各 1 名～2 名
クウェートは EPA と KISR から数名
AGEDI
CEFAS 3 名
ROPME 事務局数名
（詳細は後日 ROPME から名簿を配布予定）

２．バックグラウンド

英国の機関である Center for Environment Fisheries and Aquaculture Science: Cefas が ROPME 海域での海洋での気候変動に係る緩和と適応のためのコンセプトつくりを目的に開催したもの。

リーダーへのヒアリングでは、現段階（コンセプトつくりで約 30 ヶ月）では 100％英国政府の資金で行っているが、その後はコストシェアを考えていくとのことである。

Cefas は在クウェート　イギリス大使館に事務所を置き、またリーダー自身は 2 年前からクウェートに移り住み、EPA に事務所を借りて協力を行っているとのこと。

３．議論とアウトプット

今回のワークショップでは、以下のことが討議された。

第一日目：ROPME 海域での生態系の確認と気候変動による脅威の認識

温暖化は進んであろうことが、さまざまな観測事例から紹介された。

第二日目：世界的な海洋での気候変動にかかる緩和と適応に関する取り組み、ROPME 海域への応用

JAMSTEC の石川様に、日本の気候変動政策と沿岸域での適応策の取り組みを紹介いただいた。日本でのトップダウン、ボトムアップでの取組についての方法と課題について議論がなされた。対策の効果の把握にはモニタリング継続が重要であることが、認識された。

第三日目：コンセプトつくりのためのタスクフォースの結成と今後の予定

気候変動への適応と緩和のためのストラテジー作成と実施に向け、以下のスケジュールが合意された。

	リスクアセスメントと適応策	ブルーカーボン固定能力劣化のための緩和策
フェーズ1（18ヵ月）	潜在的な脅威と現状の分析 サマリーレポートカードの準備	ブルーカーボンインベントリーの作成 サマリーレポートカードの準備
フェーズ2（8ヵ月）	セクター別のリスクアセスメントの実施 潜在的な適応策の分析 サマリーレポートカードの準備	ブルーカーボン固定能力促進のための対策検討 サマリーレポートカードの準備
フェーズ3（6ヵ月）	適応策と緩和策のまとめと実行計画立案 実行効果モニタリングの計画 ROPME 委員会での承認	
フェーズ4（その後）	適応策と緩和策の実行とモニタリングによる見直し	

注：各フェーズごとに地域ワークショップを1～2回開催する。

４．JICA への期待

ワークショップのクロージングの際の ROPME　Dr. Mohammadi の挨拶では、EBM ストラテジーへの取り組みとも並行して行うことになり、JICA の関与に関する期待も示唆された。

以上

11 ₑ HABs = ▌

Ḩ ŧ ♠ ⁱ ∘ ˙˥ ŧ

ROPME/176/1

Provisional Programme

Meeting of the Regional Task Force on Eutrophication and HABs in ROPME Sea Area

Muscat, Sultanate of Oman, 16th-18th January 2018

Introduction:

ROPME is holding a meeting of the Regional Task Force on Eutrophication and Harmful Algal Blooms (HABs) to develop a 'Concept Note on Regional Eutrophication and Harmful Algal Blooms Strategy for ROPME Sea Area'. The meeting will:

- review international understanding of eutrophication and HABs issues;
- review and develop a common understanding of the potential ecological, physical and chemical dimensions of eutrophication and HABs in the ROPME Sea Area;
- review and develop a common understanding of how eutrophication and HABs may affect societies and economies in the ROPME Sea Area in terms of:
  - biodiversity
  - water resources (desalinisation and cooling water)
  - human health
  - fisheries and aquaculture
  - tourism and recreation
  - coastal development
  - infrastructure required for mitigation and management of point and diffuse pollution sources
- explore common policy objectives for assessing and addressing eutrophication and HABs in the ROPME Sea Area;
- review learning from other regions with established strategies/ programmes on eutrophication and HABs;
- discuss the development of the ROPME Sea Area Eutrophication and HABs Strategy.

Expected Outcome:

Agreed Concept Note on Regional Eutrophication and Harmful Algal Blooms Strategy for the ROPME Sea Area.

Provisional Programme of the Meeting:

DAY 1: 16th January 2018 - Eutrophication and HABs - Background and Impacts	
08:30 - 09:00	**Registration**
09:00 - 09:30	**Opening of the Meeting:** Welcome address Introduction and background to the meeting Objectives of the meeting
09:30 - 09:45	**Organisation of the Work:** Designation of chairperson and minute-taker Introduction of participants Adoption of the programme
09:45 - 10:45	**Plenary Session I: Eutrophication of our seas - an overview of causes and ecological impacts internationally and in the ROPME Sea Area** *Dr. Michelle Devlin, Cefas, UK* A review of the topic of eutrophication; drivers, extent and ecological impacts internationally, and what is known of the drivers, extent, and ecological impacts in the ROPME Sea Area - what is eutrophication? - what are the causes? - what are the ecological impacts? - international overview of eutrophication - regional overview of eutrophication **Q&As**
10:45 - 11:15	Coffee Break
11:15 – 12:15	**Plenary Session II: Harmful Algal Blooms – an overview of the causes and ecological impacts internationally and in the ROPME Sea Area** *Dr. Elisa Capuzzo, Cefas, UK* A review of the topic of HABs; drivers, extent and ecological impacts internationally, and what is known of the drivers, extent, and ecological impacts in the ROPME Sea Area - what is an algal bloom and when does an algal bloom become 'harmful'? - what are the drivers? - what are the ecological effects of HABs? - International overview of HABs - regional overview of HABs - monitoring of HABs **Q&As**

12:15 - 13:45	Lunch Break
13:45 -14:45	**Plenary Session III: Social and economic impacts of regional and international eutrophication and HABs** *Dr. Mark Breckels, Cefas, UK* Overview of current and potential future impacts of eutrophication and HABs on the following sectors in the ROPME Sea Area: - Biodiversity - Human health - Fisheries and aquaculture - Tourism and recreation - Ballast water - Coastal development - Infrastructure required for mitigation and management of point and diffuse pollution sources - Desalination and cooling water intakes - Other marine social and economic goods and services **Q&As**
14:45 - 15:15	Coffee Break
15:15 –15:40	**Plenary Session IV: Introduction to eutrophication and HABs policy commitments and objectives** *Dr. Will Le Quesne, Cefas, UK* Overview of international and regional policy commitments, objectives and work plans related to eutrophication and HABs in the ROPME Sea Area (UN SDGs, CBD, Global eutrophication programmes)
15:40 - 16:10	**Plenary Session V: International examples of eutrophication assessments, and adaptation and mitigation strategies 1** *Dr. Yasuo Fukuyo, Tokyo University, Japan* Facts of HABs as discussion basis for establishment of Mitigation Plan from Japanese Experiences
16:10 - 17:00	**Plenary Session VI: International examples of eutrophication assessments, and adaptation and mitigation strategies 2** *Dr. Mike Best, Environment Agency, UK* Coastal monitoring and assessment under the European Water Framework Directive – a river basin approach from the United Kingdom
End of Day 1	

DAY 2: 17th January2018 – Eutrophication and HABs Policy and Activities	
09:00 - 09:15	**Welcome back and outlook for Day 2**
09:15 - 10:00	**Plenary Session VII: International examples of eutrophication/HABs assessments, and adaptation and mitigation strategies 3** *Dr. Jon Brodie, James Cook University, Australia* Australia Great Barrier Reef – Quantifying eutrophication risk and developing a catchment based monitoring and measures strategy
10:00 -10:30	**Plenary Session VIII: International examples of eutrophication/ HABs assessments, and adaptation and mitigation strategies 4** *Dr. Birguy Lamizana, UNEP* The Global Programme of Action - A source-to-sea intergovernmental framework for addressing marine pollution
10:30 -11:00	**Plenary Session IX: Regional examples of eutrophication assessments, and adaptation and mitigation strategies 1** *Dr. Wahid Moufaddal, ROPME* ROPME Programme Activities on Eutrophication and HABs
11:00 - 11:20	Coffee Break
11:20 –12:00	**Plenary Session X: Regional examples of eutrophication assessments, and adaptation and mitigation strategies 2** *Dr. Gilan Attaran-Fariman, Chabahar Maritime University, I.R.Iran* HABs in the ROPME Sea Area
12:00 - 12:30	**Plenary Session XI: Regional examples of eutrophication assessments, and adaptation and mitigation strategies 3** *Dr. Jauad El Kharraz, MEDREC, Oman* Combating HABs Threat on Desalination Plants in Oman
12:30 - 14:00	Lunch Break
14:00 - 14:30	**Plenary Session XII: Regional examples of eutrophication assessments, and adaptation and mitigation strategies 4** *Dr. Maryam Al Shehhi, MASDAR, UAE* The effect of dust-induced eutrophication on outbreaks of HABs in the ROPME Sea Area
14:30 -15:30	**Plenary Session XIII: National marine and coastal eutrophication and HABs action overviews** National presentations on national commitments, policy drivers, objectives and activities related to marine and coastal eutrophication and HABs (10 minutes per country) **Q&As**

15:30 - 15:50	Coffee Break
15:50 - 16:30	**Plenary Session XIV: Overview of draft Work Plan** *Dr. Will Le Quesne, Cefas* Overview of the proposed ROPME Work Plan to develop a ROPME Eutrophication and Harmful Algal Blooms Strategy
16:30 - 17:15	**Plenary Discussion XV: Way forward to deliver the ROPME Work Plan. Potential ROPME activities to enable coordinated monitoring and assessment of eutrophication and HABs in the ROPME Sea Area** *Dr. Michelle Devlin, Cefas* Discussion
End of Day 2	

DAY 3: 18th January 2018 – Preparing a Regional Eutrophication and Harmful Algal Blooms Strategy	
09:00 - 09:15	**Welcome back and outlook for Day 3**
09:15 - 10:00	**Plenary Discussion XVI: Way forward – Potential ROPME activities to develop a regional analysis of drivers, impacts and trends in eutrophication and HABs in the ROPME Sea Area** *Dr. Elisa Capuzzo, Cefas, UK* Discussion
10:00 -10:45	**Plenary Discussion XVII: Way forward: Potential ROPME activities to support capacity development in relation to eutrophication and HABs monitoring and assessment** *Dr. Will Le Quesne, Cefas, UK* Discussion
10:45 - 11:15	Coffee Break
11:15 - 12:15	**Plenary Discussion XVIII: Review of the draft Concept Note for the Work Plan** Dr. *Will Le Quesne, Cefas, UK* Review and agree the proposed Work Plan to develop the Regional Eutrophication and Harmful Algal Blooms Strategy
12:15 - 13:45	Lunch Break
13:45 - 14:30	**Plenary Discussion XIX: Next steps** Future course of action and time frame Requirements for the Regional Task Force on eutrophication and HABs to implement the Work Plan
14:30 - 15:30	**Conclusion of the meeting and Recommendations** Discussion
End of Day 3 and Closure of the Meeting	

DRAFT

Concept Note on Regional Eutrophication and Harmful Algal Blooms Strategy for the ROPME Sea Area

1. Introduction

Eutrophication (undesirable impacts on the environment caused by excess nutrients) and harmful algal blooms (HABs) are a significant trans-boundary challenge that can affect all the ROPME Member States. This Concept Note proposes a preliminary Work Plan to develop a Regional Eutrophication and HABs Strategy to enhance capabilities and coordinate approaches to address the challenges of eutrophication and HABs in the ROPME Sea Area. This will also support ROPME Member States' commitments to address eutrophication and HABs under the United Nations Sustainable Development Goals and the Convention on Biological Diversity.

Eutrophication and HABs cause a number of adverse impacts, such as oxygen depletion and fish kills, that can directly affect marine and coastal ecosystems and human uses of the marine environment. Eutrophication can lead to sudden rapid growth of microscopic algae (phytoplankton) or seaweed that can block water intakes at desalination and industrial plants and reduce coastal amenity value. Changes in phytoplankton and macroalgae can also impact on the ecological functioning of the marine ecosystem by increasing water turbidity, with repercussions for other organisms in the marine food web. Blooms of harmful algae can contaminate seafood with toxins that are dangerous for human consumption or toxic to other species in the environment.

Nutrient enrichment and eutrophication is an issue of increasing concern in the ROPME Sea Area due to the rapid increase in the human population living along the coast, changes in the catchment adjacent to the ROPME Sea Area, and an increase in discharges entering the coastal areas. Similarly, HAB events are increasing, both globally and within the ROPME Sea Area. Eutrophication and HABs can be linked, as eutrophication is one of the factors that can lead to an increase in HABs, although other factors can also lead to HABs.

In response to the extended HAB event that occurred in the ROPME Sea Area in 2008, ROPME convened a Meeting of Experts on HABs in Fujairah, UAE, on 18 December 2008. The Meeting concluded that a Regional Task Force should be established to prepare a Regional Strategy and Work Plan addressing HABs. The remit of the proposed Work Plan has now been expanded to include eutrophication, and the objectives and outline activities for this Work Plan are proposed in this Concept Note.

Together with the Strategies for Ecosystem Based Management, Climate Change, and Marine Biodiversity, the Eutrophication and Harmful Algal Blooms Strategy will support delivery of ROPME's Strategic Goals for the Marine Environment. Although the separate Strategies are being developed to focus on different aspects of the marine and coastal ecosystem of the ROPME Sea Area, the interlinkages between the different components of marine ecosystems are recognised and the four Strategies are expected to support each other in recognition that the mitigation actions will provide support across marine systems.

Decision CM 16/3 of the Council-16 provides for the monitoring of variables affecting public health in the ROPME Sea Area, and the preparation of action plans for implementation. Furthermore, Decision CM 16/4 of the Council-16 provides for the protection and sustainable management of fisheries resources. This Concept Note is prepared in pursuance of the Council Decisions for a Regional Strategy with action elements on eutrophication and harmful algal blooms (HABs) of the ROPME Sea Area. The Work Plan and Strategy proposed by this Concept Note are designed to support and coordinate the efforts of ROPME Member States in protecting human health and the coastal and marine environment from the adverse effects of eutrophication and HABs.

2. International policies and targets relevant to the ROPME Eutrophication and HABs Strategy

In addition to supporting Member States address the challenges caused by eutrophication and HABs, the ROPME Eutrophication and HABs Strategy is designed to support Member States in meeting their national commitments for sustainable development and protection of the marine environment. In particular, implementing the ROPME Eutrophication and Harmful Algal Blooms Strategy would support Member States in meeting the following goals and targets:

United Nations Sustainable Development Goals

The most relevant UN Sustainable Development Goal would be Goal 14, *"Conserve and sustainably use the oceans, seas and marine resources for sustainable development"*, with the following target of most relevance:

14.1 "By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution".

The indicator proposed for Target 14.1 is: *"Index of coastal eutrophication and floating plastic debris".*

Convention on Biological Diversity Aichi Targets

Among the 20 Aichi Biodiversity Targets, the following target is the most relevant to the ROPME Eutrophication and HABs Strategy:

Target 8: *"By 2020, pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity".*

3. ROPME Eutrophication and HABs Strategy

Objectives of the Strategy

The objectives of the ROPME Eutrophication and Harmful Algal Blooms Strategy are to develop a coordinated regional approach to addressing the trans-boundary challenges of eutrophication and HABs, and to support ROPME Member States in meeting their commitments to the United Nations Sustainable Development Goals, and the Convention on Biological Diversity.

The ROPME Eutrophication and HABs Strategy will:

- Encourage the establishment of a common vision for meeting the challenges of eutrophication and HABs;
- Support the development of coordinated regional monitoring of eutrophication and HABs;
- Encourage the development and application of coordinated assessment methods and indicators of eutrophication and HABs;

- Support the development of regional understanding of the factors causing eutrophication and HABs, and of the impacts of eutrophication and HABs;
- Support the development of regional approaches to mitigating and responding to eutrophication and HAB events;
- Facilitate the development of regional knowledge, skills and capacity to monitor, predict and address issues related to eutrophication and HABs;
- Facilitate policy coherence.

4. Preliminary Work Plan

The ROPME Eutrophication and HABs Strategy will be developed through the implementation of a Eutrophication and HABs Work Plan.

Phases	Actions
Phase I: Review (12 months)	− Hold Regional Workshop of the Eutrophication and HABs Task Force to: ➢ Establish the Eutrophication and HABs Technical Support Group ➢ Agree terms of reference (TORs) for the Task Force and Technical Support Group ➢ Agree Phase I detailed work plan ➢ Hold initial meeting of the Technical Support Group − Draft a preliminary assessment report on regional extent, frequency and current understanding of the drivers and impacts of eutrophication and HABs in the ROPME Sea Area − Hold a technical drafting workshop for the Eutrophication and HABs Technical Support Group to support the preliminary assessment report − Hold national monitoring and analysis activity review workshops − Draft a report on national eutrophication and HABs monitoring and analysis activities and capability in the ROPME Sea Area, also identifying national and regional data sources and modelling capability − Hold second technical drafting workshop for the Eutrophication and HABs Technical Support Group to support the monitoring and analysis report

Phase II: Assessment (15 months)	− Hold Regional Workshop of the Eutrophication and HABs Task Force to: ➢ Review the preliminary report on regional extent, frequency, drivers and impacts of eutrophication and HABs ➢ Agree Phase II detailed work plan ➢ Hold meeting for the Eutrophication and HABs Technical Support Group to initiate the reports on monitoring and assessment guidelines − Prepare draft guidelines on coordinated regional eutrophication and HABs monitoring, analysis and data reporting aligned with international standards associated with the onset of eutrophication and HABs − Prepare draft guidelines for regionally coordinated assessment methods and standards for eutrophication and HABs − Draft report on regional eutrophication and HABs data housing and data exchange processes − Hold a technical drafting workshop for the Eutrophication and HABs Technical Support Group to support the monitoring, assessment and data housing reports − Propose options for regional eutrophication and HABs modelling, including operational modelling capability − Draft report on management and mitigation options to reduce the impacts of eutrophication and HABs, and to identify priorities of management actions to reduce the impacts of eutrophication and HABs, particularly in line with reducing the frequency of HABs outbreaks − Draft ROPME Eutrophication and HABs Policy Briefing Report − Hold a technical drafting workshop for the Eutrophication and HABs Technical Support Group to support the modelling, management and policy briefing reports − Hold regional algal species taxonomy technical training workshop − Hold regional eutrophication monitoring technical training workshop − Develop draft regional training and capacity development plan for inclusion in the Strategy − Hold Regional Workshop of the Eutrophication and HABs Task Force to: ➢ Review the recommendations for i) developing operational modelling capability, ii) data hosting and data exchange processes, iii) training plans

	➢ Review the ROPME Eutrophication and HABs Policy Briefing Report − Draft outline of the ROPME Eutrophication and HABs Strategy
Phase III: Prepare Eutrophication and HABs Strategy (6 months)	− Hold Workshop of the Eutrophication and HABs Task Force to review the draft Strategy and associated Implementation and Monitoring Plans − Hold a High-Level Regional Workshop to: ➢ Present the ROPME Eutrophication and HABs Policy Briefing Report ➢ Review and revise the draft Eutrophication and HABs Strategy ➢ Review and revise the draft Eutrophication and HABs Strategy Implementation Plan ➢ Review and revise the draft Eutrophication and HABs Strategy Monitoring Plan − Present the Strategy to the ROPME Council for adoption
Phase IV: Implement Eutrophication and HABs Strategy (ongoing)	− Implement the Eutrophication and HABs Strategy − Monitor implementation of the Eutrophication and HABs Strategy − Regional Workshops to report on success of the implementation of the Eutrophication and HABs Strategy and to identify next steps

5. Outputs

The ROPME Eutrophication and HABs Work Plan will produce the following outputs:

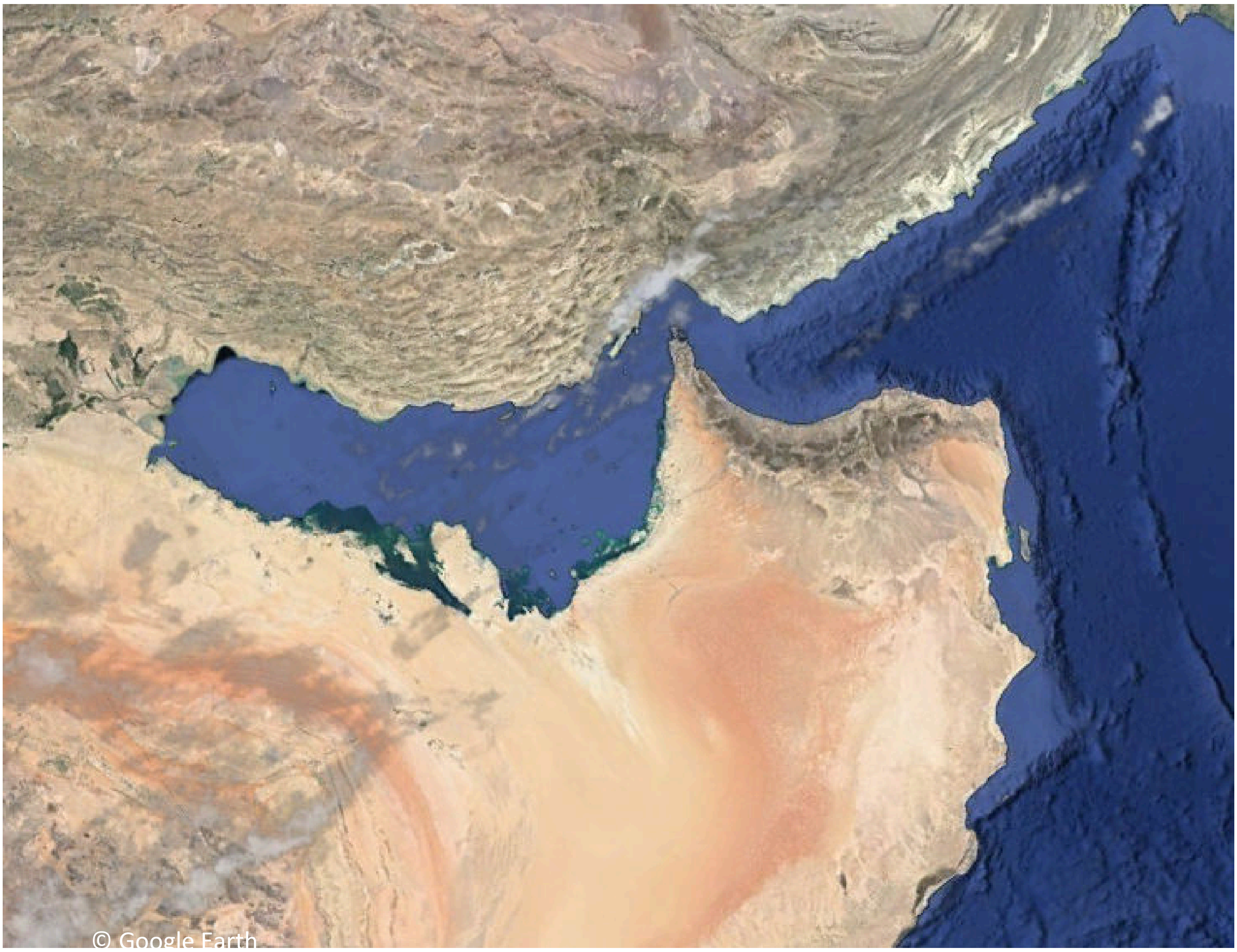
- Guidelines for coordinated regional eutrophication and HABs monitoring, analysis and data reporting
- Guidelines for regionally coordinated assessments of eutrophication and HABs
- Report on regional extent, frequency, drivers and impacts of eutrophication and HABs
- Final reports of Technical Training Workshops on eutrophication monitoring and algal taxonomy
- The ROPME Eutrophication and HABs Policy Briefing Report
- Final Regional Eutrophication and HABs Strategy
- Final Scheme for Implementation of the Strategy, follow-up and Monitoring

ROPME/176/3

Meeting of the Regional Task Force on Eutrophication and HABs

Muscat, Sultanate of Oman, 16th-18th January 2018

Regional Marine Eutrophication and HABs Adaptation and Mitigation Strategy for the ROPME Sea Area



Authors: Dr. Michelle Devlin, Dr. Elisa Capuzzo, Dr. Mark Breckels and Dr. Will Le Quesne

Contents

1. Introduction - why ROPME countries should be interested

The Regional Organization for the Protection of the Marine Environment (ROPME) was established in 1979, and acts as the Secretariat for the Kuwait Regional Convention for Cooperation on the Protection of the Marine Environment from Pollution (1978). The inner ROPME Sea Area (RSA) has a total surface area of ~240,000 km^2 and is characterised by large areas of shallow water, high temperatures, marked differences in salinity, and strong seasonal upwelling driven by monsoon winds. The RSA is bordered by eight countries, namely the Kingdom of Bahrain, Islamic Republic of Iran, Republic of Iraq, State of Kuwait, Sultanate of Oman, State of Qatar, Kingdom of Saudi Arabia, and the United Arab Emirates.

The 2013 State of the Marine Environment Report for the ROPME Sea Area identified a number of policy areas that must be addressed within the next 10 years to ensure sustainability in the RSA. This included eutrophication and nutrient management, noting that it was a matter of urgency to develop regional plans and programmes to address this area. The RSA has experienced chronic and ongoing water quality issues, driven by coastal pollution, sewage outfalls, warming temperatures and a changing hydrodynamic regime. In addition, the frequency of Harmful Algal Blooms (HABs) is increasing in the I-RSA, with incidences being reported throughout the ROPME Sea Area.

Eutrophication issues in the RSA are caused by the input of excess nutrients, which in turn can lead to excess primary productivity and accelerated growth of phytoplankton and macroalgae. Issues associated with elevated phytoplankton productivity include the proliferation of nuisance and toxic species. These, in-turn can cause a reduction in oxygen as the bloom decays, with impacts on biodiversity that include the inhibition of larval settling, fish kills and large increases in populations of opportunistic benthos (De Jonge *et al.*, 2002). Nutrient over-enrichment has a range of effects on coastal systems but, in general, it causes ecological changes that decrease biological diversity – the variety of living organisms – in the ecosystem. However, the complex relationship between increased nutrients and biological impacts is non-linear, and the extent of impact is dependent on a range of other factors such as temperature, light availability and the turbidity of the system (Cloern, 2001, Cloern & Jassby, 2009). This level of complexity means that there is no single observed effect, and that geographical differences in the RSA can cause different magnitude and nature of impacts.

Eutrophication effects can be wide ranging. Marine ecosystems, including coral reefs, seagrass beds, mangroves and other coastal habitats are vulnerable to impacts from degraded water quality. Effects may also be additive or in-combination, including cumulative stressors related to the interactions between degraded water quality, changing climate and shifts in hydrodynamic conditions among other issues.

This briefing document provides an overview of existing evidence for eutrophication and Harmful Algal Blooms (HABs) in the RSA, and describes the current state and possible projections for the future. Finally, consideration is given to what ROPME Member States can do to mitigate or manage the challenges ahead.

2. ROPME Sea Area

The ROPME Sea Area can be divided into three distinct zones. These areas are: the Inner ROPME Sea Area (I-RSA), that covers the marine area west of 56°E longitude, extending from Strait of Hormuz to the northern coast of Iran; the Middle ROPME Sea Area (M-RSA), that covers the Sea of Oman; and the Outer ROPME Sea Area (O-RSA) that covers the entire southern area of the RSA across the Arabian Sea.

The Outer ROPME Sea Area (O-RSA) is the northernmost part of the Indian Ocean with a typically monsoonal climate. The summer monsoon (April to September) results in strong winds from the southwest, high rainfall and produces strong upwelling. Sea surface temperatures in the O-RSA reflect the regions monsoonal nature. During the winter monsoon period sea surface temperature (SST) reduces from 26°C in November to 22-23°C in February. By contrast, with the onset of the summer monsoon, the temperature rises to ~ 28°C in May - until upwelling dominates and temperatures in the upwelled areas drop to below 22°C near the coast in August. The lower temperatures near the coast persist until the upwelling weakens in November.

The Middle ROPME Sea Area (M-RSA) is a deep 'arm' of the Indian Ocean that extends northwards and westwards for ~400km to connect with the Inner ROPME Sea Area through the shallow (maximum depth 100m) and narrow (narrowest width 56km) Strait of Hormuz. The M-RSA is affected by the Arabian Sea monsoons to varying degrees, but the effect diminishes with increasing distance from the Indian Ocean. In the Middle RSA, sea surface temperatures are not affected by the seasonal monsoons to the same extent as in the Outer RSA. Minimum winter SST of around 22°C occurs in February and maximum SST of 32°C occurs in August with water along the Arabian coast being generally warmer than along the Iranian coast (UNEP, 1994).

The Inner ROPME Sea Area (I-RSA) is a shallow shelf area (mean depth 35m) with the maximum depth occurring near the Strait of Hormuz. The bottom profile across the I-RSA is asymmetrical, with shallower slopes on the Arabian side and steeper slopes on the Iranian side. In the I-RSA the shallowness of the area accentuates seasonal differences in SST with temperatures ≤13°C occurring off Kuwait and Iraq in the north in February and nearing 35°C at the height of the long summer. The temperature difference between summer and winter is greatest (>20°C) in the north-western part and lowest (<11°C) at Hormuz (UNEP, 1994).

3. What are Eutrophication and HABs?

The majority of primary production in the seas, oceans and marine water bodies are represented by microscopic algae or phytoplankton. Just like plants on land, phytoplankton require nutrients, such as nitrogen and phosphorous compounds, and light for carrying out photosynthesis. Phytoplankton form the base of the marine food web, changes in the rate of phytoplankton production can affect the abundance and biomass of other aquatic organisms including fish.

Nutrients, essential for primary productivity, can enter the marine environment from a range of natural sources and human activities. Human activities such as sewage inputs, industrial discharges, aquaculture, and other maritime industries can increase nutrients loads in coastal waters leading to accelerated growth in phytoplankton and seaweeds. High nutrient inputs can result in eutrophic conditions where increases in algal biomass and production can lead to an undesirable disturbance of the ecosystem in terms of water quality and the balance of the organisms.

Eutrophication, as defined by the Oslo and Paris Convention (Malcolm et al., 2002), is the enrichment of water by nutrients causing an accelerated growth of algae and higher forms of plant life which causes an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned. Therefore eutrophication is seen as a three-step process that occurs when (step 1) human activities lead to elevated nutrient levels in the water, (step 2) which leads to increased growth and biomass of phytoplankton or seaweeds (algal blooms), (step 3) causing an undesirable change in water quality or the balance of organisms. The undesirable change in the ecosystem may be due to changes in the algae species composition, smothering by increased macroalgal growth, increases in the bloom frequency of phytoplankton or a decline in water transparency. Furthermore, following the collapse of an algal bloom, degradation of the increased biomass can lead to oxygen depletion resulting in mass death of benthic organisms and fish, as well as changes in species composition.

In addition, some types of phytoplankton can produce toxins which can be poisonous to marine organisms and indirectly to humans following consumption of contaminated seafood. Blooms of these types of phytoplankton are also called harmful algal blooms (HABs). Three types of HABs or nuisance blooms can be identified as:

- ❖ Toxic algae that can poison shellfish at low biomass (e.g. *Dinophysis*, fig 1 a);
- ❖ Algae which are potentially toxic at high biomass (e.g. *Pseudonitzschia*, fig 1 b);
- ❖ High-biomass blooms that cause problems due to the high biomass itself (e.g. *Myrionecta rubrum*, fig1 c).

Microalgal blooms can cause discoloration of the water (generally known as red tides), some of which can have harmful effects such as mass mortalities in fish, invertebrates, birds, and mammals. There are serious impacts of red tide incidences and occurrences of the harmful algal blooms (HABs) on human health, fishery resources, and marine ecosystems throughout the world. When toxic species are in bloom conditions, the toxins can be quickly transferred through the food chain and indirectly passed onto humans via fish and shellfish consumption, sometimes resulting in gastrointestinal disorders, permanent neurological damage, or even death (Faust & Gulledge, 2002).

Increased phytoplankton growth and the outbreak of HAB events can be exacerbated by a number of factors, such as climate change or a decline in predators, which can act cumulative or additively with the impacts of eutrophication. Similarly, HABs, oxygen depletion and mass death of fish can also be caused by factors not related to human nutrient enrichment. It is therefore important to monitor a range of factors influencing phytoplankton growth, and HABs should only be attributed to eutrophication when their occurrence and magnitude is related to anthropogenic nutrient inputs.

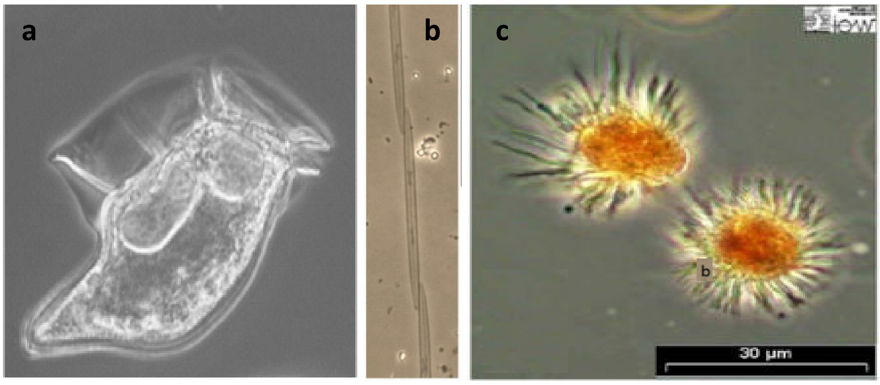


Figure 1: HAB forming algal species; a) *Dinophysis*, b) *Pseudonitzschia*, and c) *Myrionecta rubrum.* Figure c sourced from http://planktonnet.awi.de

4. What is happening now? Existing evidence for Eutrophication and HABs in the RSA

There are many anthropogenic discharges that can cause eutrophication in the RSA, including industrial or domestic waste discharge, groundwater inputs and atmospheric deposition. All major cities that are part of the RSA have experienced large increases in population growth, corresponding with rapid coastal expansion. Reductions in water quality and pollution from urban and industrial discharges and sewage inputs are associated with high coastal populations and rapid urban development. Anthropogenic activities which impact on the marine environment include diffuse loads associated with the Shatt al-Arab River and the connection of water between the northern I-RSA and the M-RSA.

Depending on the species and scale, phytoplankton blooms can have significant impacts on local or over wider areas. Examples of negative impacts caused by phytoplankton blooms in the RSA include mass mortality of marine animals such as fish kills (Gilbert *et al.*, 2002), shellfish (Richlen *et al.*, 2010), and alteration of marine habitat and community structure (Sheppard, 2016, Sheppard *et al.*, 2012, Sheppard *et al.*, 2010). HABs have been occurring more frequently in the RSA during the last few years.

Factors that lead to new invasions of HAB species are prevalent in the RSA. This includes considerable ballast water discharges from global shipping operations into warm waters with elevated nutrients. Reviews of issues have identified that the increases in anthropogenic discharges, combined with projected, episodic warming events (Sale *et al.*, 2011, Sheppard *et al.*, 2012) and the construction of further protected lagoons may continue to create suitable conditions leading to the expansion of HAB events throughout the RSA.

The mechanisms underlying the increasing prevalence of HAB events requires further investigation, and may include increased nutrient enrichment of coastal waters, natural meteorological and oceanographic forcing, and the introduction of HAB species through ballast water discharge. Most often, HABs have been transported from the O-RSA and the M-RSA which makes them a common threat to the region (Subba Rao & Al-Yamani, 1998). The presence of HABs has been detrimental to the water quality and the surrounding environment.

Adverse impacts in the RSA generally include, but are not limited to:

(1) the death of large quantities of fishes and crustaceans such as in Kuwait (Gilbert *et al.*, 2002), Oman and UAE (Al-Azri *et al.*, 2014, Al Gheilani *et al.*, 2011, Al Shehhi *et al.*, 2014, Claereboudt *et al.*, 2001, Richlen *et al.*, 2010) and UAE;

(2) their effect on human health by causing respiratory irritation (Sellner *et al.*, 2003, Tomlinson *et al.*, 2009);

(3) the suspension of desalination plants' operation, in some extreme cases, due to the high toxicity level in the water surrounding the plant intakes such as the desalination plants in Kalba, Fujairah, Khor-Fakan and Ras-Al-Khaimah (Ghaleelah) as reported by the Ministry of Environment and Water in the United Arab Emirates (UAE Ministry of Environment and Water, 2011) and;

(4) the spread of a bad smell in the air resulting from the organic decomposition of dead fish.

Low dissolved oxygen levels during algal blooms have been identified as one of the primary causes of benthic mortality (Guzmán *et al.*, 1990), and the combination of reduced surface light penetration and anoxia are likely to have rapidly decreased coral photosynthetic efficiency and increased respiratory rates (Jokiel & Coles, 1990). In 2008, a large-scale HAB event (> 500 km^2) in the M-RSA of the dinoflagellate *Cochlodinium polykrikoides* caused the loss of the branching corals, *Pocillopora* and *Acropora* spp., and substantial reductions in the abundance, richness and trophic diversity of the associated coral reef fish communities. Although the causative agents of this *C. polykrikoides* bloom are unknown, increased coastal enrichment, natural oceanographic mechanisms, and the recent expansion of this species range due to ballast water discharges are expected to be the main agents (Richlen *et al.*, 2010). Changes in coral cover within this area may have been due to the substantial reductions in oxygen and light attenuation during the HAB event (Bauman *et al.*, 2010). With rapid changes in oceanic climate, enhanced coastal eutrophication and increased global distribution of HAB species, large-scale HAB events are predicted to increase dramatically in both intensity and distribution and can be expected to have increasingly negative effects on coral reef communities globally.

The sudden emergence of *C. polykrikoides* across the RSA coincides with an apparent global expansion of this taxon, as well as a recent increase in HAB impacts observed in this region. A pattern of subsequent recurrence of *C. polykrikoides* blooms following an initial outbreak has been observed in other parts of the world, suggesting that this species may become a persistent HAB problem globally and in the RSA region.

As RSA countries rely on desalination plants as the primary source of freshwater, the disruption of plant operations by recurring *Cochlodinium* blooms poses a serious threat to the drinking water supply in the region, and represents an unprecedented HAB impact.

The understanding of HAB events in the RSA region is progressing, however, it is surprising that additional HAB events have not been documented (Sale *et al.*, 2011) given that the ongoing conditions that have led to the documented outbreaks are continuing.

In the face of population growth and increasing demand for water, rapid growth of agriculture, increasing environmental degradation and socioeconomic impacts, regular reporting of the status of the RSA with respect to nutrient enrichment will be an important source of information in the on-going investigations into the impact of anthropogenic discharges into the RSA coastal and marine waters and to provide advice for protection, rehabilitation and restoration.

5. Impacts on habitats and marine ecosystems

Several ecosystems, including seagrass beds, coral reefs, mangroves, and mudflats contribute to the productivity and biodiversity of marine resources in the RSA. Most of these habitats are rich in varieties of fish, which are in-turn a major source of food for people. Ecosystem benefits in the RSA are not limited to the provision of food, and extend to other services ranging from primary production and nutrient cycling to erosion and sedimentation control (Naser, 2014).

Seagrass beds are highly productive ecosystems that provide important ecological functions and economic services. Ecologically, seagrass ecosystems provide food sources and feeding grounds for several threatened species in the Inner RSA such as turtles and dugongs. They can also improve water quality by stabilizing loose sediment and by removing some water-borne pollutants.

Nutrient enrichment and excess turbidity can lead to the degradation of coral reefs (Fabricius, 2005, Fabricius et al., 2014). Coral reefs that are impacted by point source nutrients are characterized by (a) low or locally reduced coral biodiversity, (b) low, or failed, coral recruitment, (c) high rates of partial mortality, (d) reduced skeletal density, (e) reduced depth distribution, (f) high rates of bioerosion, and (g) a transition of hard coral dominated communities to communities dominated by non-reef building organisms, especially turfing and fleshy macroalgae (Brodie *et al.*, 2012, Devlin & Schaffelke, 2012, Schaffelke *et al.*, 2012).

Coral reef ecosystems provide a variety of ecological services such as sources of seafood, maintenance of genetic, biological and habitat diversity, recreational values, and economic benefits such as protecting coasts and infrastructure from waves and storm surges. Coral growth occurs in most of the RSA with the best examples on offshore shoals. Additionally, fringing corals occur along the coastlines of United Arab Emirates, Qatar, Saudi Arabia and Bahrain (Riegl and Purkis, 2012). Extremes in temperature, salinity and water quality in the Inner RSA restrict the growth and development of corals to patchy forms (Sheppard *et al.*, 2010). However, despite these harsh environmental conditions, corals in the Inner RSA exhibit remarkable resilience and vitality (Naser, 2014).

6. Key International policy drivers

Marine eutrophication is an issue of global concern and has been given a high priority for action at a global level through policy commitments to manage the undesirable consequences of nutrient enrichment and the occurrence of HABs. The primary international agreements relevant to eutrophication and HABs in the marine environment are the UN Sustainable Development Goals and the Convention on Biological Diversity. The ROPME Member States are signatories to SDGs and the convention and are therefore committed to developing measures to ensure compliance. The following section provides a brief overview of these commitments that ROPME members are committed to address.

On 19 July 2014, the United Nations Open Working Group (OWG) on Sustainable Development Goals (SDGs) forwarded a proposal for 17 "Global Goals" with 169 Targets to the UN Assembly. These included ending poverty and hunger, improving health and education, making cities more sustainable, combating climate change, and protecting oceans. Following negotiations, a final document was adopted at the UN Sustainable Development Summit, September 25–27, 2015, in New York.

Sustainable Development Goal 14 encourages countries to "Conserve and sustainably use the oceans, seas and marine resources". In the review of progress in relation to this goal the UN SDGs note that "global trends point to continued deterioration of coastal waters owing to pollution and eutrophication". UN SDG Target 14.1 states:

> *"By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution".*

The associated indicator specified by the UN SDG for Target 14.1 is:

> *"Index of coastal eutrophication and floating plastic debris density"*

All ROPME countries are signatories (Parties) to the UN Convention on Biological Diversity (CBD). From 6-17 October 2014, Parties discussed the implementation of the Strategic Plan for Biodiversity 2011-2020 and its Aichi Biodiversity Targets, which are to be achieved by the end of this decade. The Aichi Biodiversity Targets specifically identify nutrient pollution. Aichi Biodiversity Target 8 specifies:

> *"By 2020, pollution, including from excess nutrients, has been brought to levels that are not detrimental to ecosystem function and biodiversity".*

In addition, Aichi Biodiversity Target 10 states:

> "*By 2015, the multiple anthropogenic pressures on coral reefs, and other vulnerable ecosystems impacted by climate change or ocean acidification are minimized, so as to maintain their integrity and functioning*".

The indicators and actions associated with meeting these Targets include indicators for trends in algal blooms and hypoxic zones, as well as actions to identifying and controlling point sources of pollution and establishing coastal water quality guidelines.

7. Assessment of Eutrophication and HABs

Given policy commitments to address eutrophication and HABs it is important to develop assessment tools and quality standards to guide management. Assessments of eutrophication and HABs typically combine a selection of key indicators that enable evaluation of the overall status of eutrophication in coastal and marine waters. The outputs of these assessments enable managers and policy makers to make decisions on the mediation of problems linked to nutrient enrichment. Assessment of eutrophication is a technically challenging task, though in recent years a number of assessment methods have been developed and used to assess the status of coastal and marine waters for management of eutrophication risk.

The technical developments in eutrophication assessments have been driven by the establishment of policy objectives to address eutrophication. This has particularly been the case in Europe where multiple water-related directives have set objectives for the protection and maintenance of EU coastal and marine waters, these include the Urban Waste Water Directive [UWWTD (Cec, 1991a)], the Nitrates Directive [ND (Cec, 1991b)], the Habitats Directive (Directive, 1992), the Water Framework Directive [WFD, (Cec, 2000) and the Marine Strategy Framework Directive [MSFD (Cec, 2008)]), the Oslo Paris Convention (OSPAR, 2003, OSPAR, 2005), the Helsinki Commission (HELCOM, (Andersen et al., 2009)) and TRIX (Giovanardi & Vollenweider, 2004). These directives and policies specify objectives coastal water quality or control of coastal pollution and therefore require the establishment of assessment criteria. The assessment criteria developed for the policies all consider the assessment of eutrophication through measurements of key indicators such as nutrient concentrations, Chl-a concentrations and measurement of dissolved oxygen. Some of the more recent directives (e.g. EU Water Framework Directive and Marine Strategy Framework Directive) and OSPAR have also included the additional identification of secondary impacts and undesirable disturbance to the ecosystem.

The majority of the assessments include physico-chemical indicators (e.g. nutrient concentration in the water) and biological indicators (e.g. chlorophyll concentration and seaweed abundance), as direct effect to nutrient enrichment. Dissolved oxygen concentration, occurrence of nuisance algal blooms, losses of submerged perennial communities – seagrass and/or corals - (all indirect effects) are used in some assessments in combination with indicators of direct effects. In general, indirect effects are a result of a more advance problem and can be more critical and difficult to manage, compared to direct effects. This has been traditionally done through in-situ measurements and vessel sampling. However, in recent years, a move toward automated sampling platforms, modelling and satellite data has provided an invaluable source of high frequency data, particularly for linking measurements to assessment of eutrophication. High frequency data can provide greater certainty in the assessment and provide greater detail in areas that have a shifting baseline.

Innovation has continued to move forward in eutrophication assessments, with the ability to confidently model hydrodynamic and biogeochemical processes across coastal seas as well as model the input of pollutant loads into the coastal zones. Modelling of loads can provide direct links from assessments back to management of urban and agricultural activity.

In addition, the use of Earth Observation data, from satellites has now provided the scope to integrate data from across large temporal and spatial scales. The high variability of water quality parameters in time and space demands a high number of measurements (high frequency, dense spatial coverage) to attain the required accuracy and confidence in trend and threshold analysis. Consequently, the high level of monitoring effort for *in situ* sampling for appropriate eutrophication assessments may be augmented by utilising innovative monitoring and cross-integration of all available data. Satellite remote sensing provides synoptic data on the distribution of water quality parameters for large cross-border areas with similar or disparate monitoring methods. The utility of satellite remote sensing may provide a more cost-effective alternative data source and common ground for consistent basin-wide maps of water quality information across the ROPME Sea Area. The continual movement towards the reliable integration of all sources of data recognises the importance of consistency between methods and moving towards joint assessments of common indicators at ecological scales that cover areas across the regional seas.

During an assessment, a measure of state for each indicator is calculated and compared to thresholds or reference conditions. Outputs from different indicators can be combined in a final assessment score indicating the presence or absence of eutrophication. Confidence in the indicators and on the eutrophication status should be reported and rated. Depending on the area investigated assessments may be completed on a local or regional scale.

8. Why ROPME needs a Work Plan and what it might look like

The ROPME Member States have made commitments to tackle coastal water quality issues including eutrophication and HABs. Furthermore, a key recommendation in the 2013 ROPME State of the Marine Environment Report was that control of eutrophication was a priority activity for ensuring sustainability in the RSA within the next 10 years. These factors both support the conclusion of the 2008 Meeting of Experts in Fujairah that a Regional Task Force should be established to prepare a regional Work Plan and Regional Strategy to address eutrophication and HABs in the RSA.

A ROPME Regional Marine Eutrophication and HABs Strategy is proposed to address the challenges of eutrophication and HABs in the RSA in a regionally coordinated manner. The primary focus of the Strategy will be on identifying key risks and associated management and mitigation strategies to reduce the water quality issues within the ROPME Sea Area. The ROPME Eutrophication and HABs Strategy will act to help member countries meet their national commitments to resolving the significant issues associated with an impacted water quality condition and increasing outbreaks of HABs. Where possible, this will be done as specified by international and regional commitments in a regionally coordinated manner, but a ROPME specific programme that deals directly with the regional issues is also required.

A priority action will be the definition of coordinated monitoring and assessment criteria for eutrophication and HABs across the RSA to enable coordinated activity to be taken across all ROPME Member States.

Alongside the development of monitoring and assessment criteria, another priority task is to review of existing research and monitoring data. This will identify the main trends in the occurrence of eutrophication and HABs, and identify the main impacts associated with eutrophication and HABs in the RSA across a variety of spatial and temporal scales.

This review of long-term data and current research will help drivers, such as sewage outfalls, increased diffuse nutrient loads, climate change or recognition that cumulative drivers are impacting on many aspects of the coastal system. Identifying the causes and effects for eutrophication and HABs will allow ROPME to identify targeted management actions to reduce the adverse impacts. A novel element to the Work Plan is the potential application of 'decision support tools' to identify key threats and potential adaptation strategies.

9. References

Al-Azri, A. R., Piontkovski, S. A., Al-Hashmi, K. A., Goes, J. I., Gomes, H. D. R. and Glibert, P. M. (2014) Mesoscale and nutrient conditions associated with the massive 2008 Cochlodinium polykrikoides bloom in the Sea of Oman/Arabian Gulf. *Estuaries and coasts,* **37,** 325-338.

Al Gheilani, H. M., Matsuoka, K., Alkindi, A. Y., Amer, S. and Waring, C. (2011) Fish kill incidents and harmful algal blooms in Omani waters. *Journal of Agricultural and Marine Sciences [JAMS],* **16,** 23-33.

Al Shehhi, M. R., Gherboudj, I. and Ghedira, H. (2014) An overview of historical harmful algae blooms outbreaks in the Arabian Seas. *Marine pollution bulletin,* **86,** 314-324.

Andersen, J. H., Laamanen, M., Aigars, J., Axe, P., Blomqvist, M., Carstensen, J., Claussen, U., Josefson, A. B., Flemming-Lehtinen, V. and Järvinen, M. (2009) Eutrophication in the Baltic Sea-An integrated thematic assessment of the effects of nutrient enrichment in the Baltic Sea region.

Bauman, A. G., Burt, J. A., Feary, D. A., Marquis, E. and Usseglio, P. (2010) Tropical harmful algal blooms: An emerging threat to coral reef communities? *Marine pollution bulletin,* **60,** 2117-2122.

Brodie, J. E., Kroon, F. J., Schaffelke, B., Wolanski, E. C., Lewis, S. E., Devlin, M. J., Bohnet, I. C., Bainbridge, Z. T., Waterhouse, J. and Davis, A. M. (2012) Terrestrial pollutant runoff to the Great Barrier Reef: An update of issues, priorities and management responses. *Mar Pollut Bull,* **65,** 81-100.

Cec, C. O. E. C. (1991a) Council Directive of 21 May 1991 concerning urban waste water treatment Vol. Off J Eur Commun L135:40–52 (30.5.91).

Cec, C. O. E. C. (1991b) Council Directive of 31 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sourcesVol. Off J Eur Commun L375:1–8 CSTT, 1994.

Cec, C. O. E. C. (2000) Council Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for community action in the field of water policy. Vol. Off. J. Eur. Community L327, 1e73.

Cec, C. O. E. C. (2008) Council Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 Establishing a Framework for Community Action in the Field of Marine Environmental Policy (Marine Strategy Framework Directive).Vol. Off. J. Eur. Community.

Claereboudt, M., Hermosa, G. and Mclean, E. (2001) Plausible cause of massive fish kill in the Gulf of Oman*Proceeding of the first international conference on Fisheries, Aquaculture and Environments in the Northwest Indian Ocean (Muscat, Oman).* pp. 123-132.

Cloern, J. (2001) Our evolving conceptual model of the coastaleutrophication problem. *Marine Ecology Progress Series,* **210,** 223–253.

Cloern, J. E. and Jassby, A. D. (2009) Patterns and Scales of Phytoplankton Variability in Estuarine–Coastal Ecosystems. *Estuaries and Coasts,* **33,** 230-241.

De Jonge, V. N., Elliott, M. and Orive, E. (2002) Causes, historical development, effects and future challenges of a common environmental problem: eutrophication. *Hydrobiologia,* **475,** 1-19.

Devlin, M., Barry, J., Painting, S. and Best, M. (2009) Extending the phytoplankton tool kit for the UK Water Framework Directive: indicators of phytoplankton community structure. *Hydrobiologia,* **633,** 151-168.

Devlin, M. and Schaffelke, B. (2012) Catchment-to-reef continuum: Case studies from the Great Barrier Reef. A special issue--Marine Pollution Bulletin 2012. *Mar Pollut Bull,* **65,** 77-80.

Directive, H. (1992) Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora. *Official Journal of the European Union,* **206,** 7-50.

Fabricius, K. E. (2005) Effects of terrestrial runoff on the ecology of corals and coral reefs: review and synthesis. *Mar Pollut Bull,* **50,** 125-46.

Fabricius, K. E., Logan, M., Weeks, S. and Brodie, J. (2014) The effects of river run-off on water clarity across the central Great Barrier Reef. *Marine Pollution Bulletin,* **84,** 191-200.

Faust, M. A. and Gulledge, R. A. (2002) Identifying harmful marine dinoflagellates. *Contributions from the United States national herbarium,* **42,** 1-144.

Gilbert, P. M., Landsberg, J. H., Evans, J. J., Al-Sarawi, M. A., Faraj, M., Al-Jarallah, M. A., Haywood, A., Ibrahem, S., Klesius, P., Powell, C. and Shoemaker, C. (2002) A fish kill of massive proportion in Kuwait Bay, Arabian Gulf, 2001: the roles of bacterial disease, harmful algae, and eutrophication. *Harmful Algae,* **1,** 215-231.

Giovanardi, F. and Vollenweider, R. A. (2004) Trophic conditions of marine coastal waters: experience in applying the Trophic Index TRIX to two areas of the Adriatic and Tyrrhenian seas. *Journal of Limnology,* **63,** 199-218.

Guzmán, H. M., Cortés, J., Glynn, P. W. and Richmond, R. H. (1990) Coral mortality associated with dinoflagellate blooms in the eastern Pacific (Costa Rica and Panama). *Marine Ecology Progress Series,* 299-303.

Jokiel, P. and Coles, S. (1990) Response of Hawaiian and other Indo-Pacific reef corals to elevated temperature. *Coral reefs,* **8,** 155-162.

Malcolm, S., Nedwell, D., Devlin, M., Hanlon, A., Dare, S., Parker, R. and Mills, D. (2002) First Application of the OSPAR Comprehensive Procedure to Waters around England and Wales. . In: F. a. a. S. Centre for Environment (ed). Lowestoft, UK.

Naser, H. A. (2014) Marine ecosystem diversity in the Arabian Gulf: Threats and conservation*Biodiversity-The dynamic balance of the planet.* InTech.

Ospar (2003) OSPAR integrated report 2003 on the eutrophication status of the OSPAR maritime area based upon the first application of the Comprehensive Procedure*OSPAR Eutrophication Series.* Vol. Publication 189/2003. OSPAR Commission, . OSPAR Commission, London.

Ospar (2005) Common procedure for the identification of the eutrophication status of the OSPAR maritime area. Agreement 2005-3. . In: O. Commission. (ed). London, pp. 36.

Richlen, M. L., Morton, S. L., Jamali, E. A., Rajan, A. and Anderson, D. M. (2010) The catastrophic 2008–2009 red tide in the Arabian gulf region, with observations on the identification and phylogeny of the fish-killing dinoflagellate Cochlodinium polykrikoides. *Harmful Algae,* **9,** 163-172.

Sale, P. F., Feary, D. A., Burt, J. A., Bauman, A. G., Cavalcante, G. H., Drouillard, K. G., Kjerfve, B., Marquis, E., Trick, C. G. and Usseglio, P. (2011) The growing need for sustainable ecological management of marine communities of the Persian Gulf. *AMBIO: A Journal of the Human Environment,* **40,** 4-17.

Schaffelke, B., Carleton, J., Skuza, M., Zagorskis, I. and Furnas, M. J. (2012) Water quality in the inshore Great Barrier Reef lagoon: Implications for long-term monitoring and management. *Mar Pollut Bull,* **65,** 249-60.

Sellner, K. G., Doucette, G. J. and Kirkpatrick, G. J. (2003) Harmful algal blooms: causes, impacts and detection. *Journal of Industrial Microbiology and Biotechnology,* **30,** 383-406.

Sheppard, C. (2016) Coral reefs in the Gulf are mostly dead now, but can we do anything about it? *Marine pollution bulletin,* **105,** 593-598.

Sheppard, C., Al-Husiani, M., Al-Jamali, F., Al-Yamani, F., Baldwin, R., Bishop, J., Benzoni, F., Dutrieux, E., Dulvy, N. K. and Durvasula, S. R. V. (2012) Environmental concerns for the future of Gulf coral reefs*Coral reefs of the gulf.* Springer, pp. 349-373.

Sheppard, C., Al-Husiani, M., Al-Jamali, F., Al-Yamani, F., Baldwin, R., Bishop, J., Benzoni, F., Dutrieux, E., Dulvy, N. K., Durvasula, S. R. V., Jones, D. A., Loughland, R., Medio, D., Nithyanandan, M., Pilling, G. M., Polikarpov, I., Price, A. R. G., Purkis, S., Riegl, B., Saburova, M., Namin, K. S., Taylor, O., Wilson, S. and Zainal, K. (2010) The Gulf: A young sea in decline. *Marine Pollution Bulletin,* **60,** 13-38.

Subba Rao, D. and Al-Yamani, F. (1998) Phytoplankton ecology in the waters between Shatt-Al-Arab and Straits of Hormuz-the Arabian Gulf. *Plankton Biol Ecol,* **45,** 101-116.

Tomlinson, M., Wynne, T. and Stumpf, R. (2009) An evaluation of remote sensing techniques for enhanced detection of the toxic dinoflagellate, Karenia brevis. *Remote Sensing of Environment,* **113,** 598-609.

ROPME-JICA パートナーシッププログラム

2018 年 1 月オマーン出張報告

2018 年 1 月 19 日

JICA Study Team

1. 目的
   (1) ROPME 主催の"Eutrophication and HABs Task Force Meeting"への日本人専門家との参加
   (2) 東京ワークショップと海洋ごみワークショップの日程について

2. 日程：2018 年 1 月 16 日（月）～19 日（金）4 日間
   (1) 1 月 16 日（月）～18 日（木）タスク･フォースミーティング
   (2) 1 月 19 日（金）Dr. Mohammadi とのワークショップ日程の打合せ

3. 場所：オマーン国マスカット市インターコンチネンタルホテル

4. 出張者：海洋環境管理（公害・水質）担当　吉田和広（いであ㈱）

5. Eutrophication and HABs Task Force Meeting 参加報告

   (1) 本会議は ROPME の主催でイギリスの CEFAS (Centre for Environment and Fishery and Aquaculture Science) の協力のもと、オマーンの環境気候問題省（MECA）がホストとして開催された。

   (2) オープニング時には、MECA、農業漁業省及び港湾局の次官が参加し、MECA のスレイマン局長が開会の挨拶を行い、農業漁業省とのパートナーシップにより開催されることを強調された。（実際、農業漁業省、海洋水産センターからの参加者が多く、議論も活発に行われた。）

   (3) 1 日目は CEFAS による会議の目的や富栄養化及び有害藻類ブルーム (Harmful Algal Blooms: HABs) の概説と福代康夫先生（東大名誉教授）を含む国際的な経験と対策についての講演と議論が行われた。

   (4) 2 日目は ROPME 及び UN Environment を含む国際機関の講演とともに、メンバー国からの現状と課題についての報告がなされた。（バーレーン、イラン、クウェート、オマーン、サウジアラビア、UAE（MASDAR）の 6 カ国; イラク、カタールは報告なし）

   (5) 3 日目は CEFAS のファシリテーションにより、今後 3 年間のワークプランが議論されて、閉会となった。

【所感】

■福代先生には講演だけでなく、3日間を通じたコメントはHABの地域特性や科学的知見等、40年にわたる経験に基づくもので、ROPMEのDr. Mohammadi、Dr. Wahidをはじめ多くの参加者から高い評価を得ており、本会議に貢献していただいたと思料。

■オマーンの海洋科学・水産センターは、米国NASAの基金により、南カリフォルニアのコロンビア大学と共同で、リモートセンシングと数値モデルの利用による赤潮予測モデルの開発に取組んでおり、高いレベルの成果を報告していた。オマーンのコストシェア技協の実施において活用できる成果となると考えられることから、詳細計画策定調査の際には担当者と面談して情報収集することが有効であると思料。

※オマーンの農業漁業省出身の参加者は、ROPMEの活動が環境分野に偏っているという認識をもっており、コストシェア技協で目指す4機関協働によるプロジェクトの実施は国内だけでなく域内でも好事例になるものと思料。

【会議の写真】

（別紙）(

12 = ▌ שּׁ ךּ ♠ ♯ כ Ⱬ͆

ROPME/178/1

PROVISIONAL PROGRAMME

Workshop of the Regional Task Force on Marine Climate Change to launch the Work Plan for the Regional Marine Climate Change - Risk Assessment, Adaptation and Mitigation Strategy for the ROPME Sea Area

Muscat, Sultanate of Oman, 15 - 17 January 2019

Purpose

Following the recommendations of the Meeting of the Regional Task Force on Marine Climate Change Dimensions held in Kuwait during 10 - 12 April 2017, the purpose of this Regional Workshop is to:

- Launch the Work Plan to develop the Marine Climate Change - Risk Assessment, Adaptation and Mitigation Strategy for the ROPME Sea Area (hereafter referred to as the 'Marine Climate Change Strategy' or the 'Strategy');
- Review the Work Plan to produce the Strategy, and approve the detailed work plan for Phase I;
- Establish the Regional Task Force;
- Agree Terms of Reference (ToR) for the Regional Task Force and Technical Support Group;
- Review findings of the draft Marine Climate Change Impacts Evidence Report; and
- Conduct a rapid Marine Climate Change Impacts Prioritization and Scoring exercise based on the perceptions of the members of the Regional Task Force.

Outputs

- Establish Regional Task Force and agree ToR for the Regional Task Force
- Approve establishment of Technical Support Group and agree ToR for Technical Support Group
- Agree Phase I of the Work Plan
- Review findings of the draft Marine Climate Change Impacts Evidence Report
- Carry out perceptive Climate Change Risk Assessment

Programme

DAY 1: 15 January 2019 – Launch of Work Plan	
08:30 - 09:00	**Registration**
09:00 - 09:40	**Opening of the Meeting:** • Welcome remark by MECA • Opening remark by ROPME − Introduction and Background to the Meeting − Objectives of the Meeting *ROPME Secretariat*
09:40 - 10:00	Coffee Break
10:00 - 10:15	**Organization of the Work:** • Designation of Chairman and Minutes Taker • Introduction of Participants • Adoption of the Programme *ROPME Secretariat*
10:15 - 10:30	**Plenary Session 1A** • Announcement of the launch of Work Plan for the Marine Climate Change - Risk Assessment, Adaptation and Mitigation Strategy for the ROPME Sea Area *ROPME Secretariat*
10:30 - 11:15	**Plenary Session 1B** • Formally establish the Regional Task Force and agree Terms of Reference • Approve establishment of the Technical Support Group and Terms of Reference *ROPME Secretariat & Country Delegates*
11:15 -12:15	**Plenary Session 1C** • Country presentations on Key National Policies, Strategies, Plans and Priority Programme Activities on Marine Climate Change (10 mins each) Qs&As *Country Delegates (Bahrain, Iran, Iraq, Kuwait)*
12:15 - 13:45	Lunch Break
13:45 - 14:45	**Plenary Session 1D** Country presentations on Key National Policies, Strategies, Plans and Priority Programme Activities on Marine Climate Change (10 mins each) (Contd….) Qs&As *Country Delegates (Oman, Qatar, Saudi Arabia, UAE)*
14:45 -15:15	Coffee Break
15:15 - 15:45	**Plenary Session 1E** • Voting software preparation and practise for interactive sessions on Day 2 *Cefas to assist delegates*
15:45 - 17:00	**Plenary Session 1F** • Findings of the draft Marine Climate Change Evidence Report: - physical drivers of climate change in the ROPME Sea Area - impacts on marine biodiversity - impacts on society and economy Qs&As *Cefas*
End of Day 1	

DAY 2: 16 January 2019 – Climate Change Evidence Report	
09:00 - 09:15	**Welcome back and outlook for Day 2**
09:15 –10:00	**Plenary Session 1F** • Findings of the draft Marine Climate Change Evidence Report: - physical drivers of climate change in the ROPME Sea Area - impacts on marine biodiversity - impacts on society and economy Qs&As *Cefas*
10:00 -10:45	**Interactive Plenary Session 2A** • Selection of perceived priority top-level sectors from within biodiversity, society and economy *Cefas with participation of all delegates (using voting software tool)*
10:45 - 11:15	Coffee Break
11:15 - 12:45	**Interactive Plenary Session 2B** • Assess the list of impacts by sub-sector collated as part of the Marine Climate Change Evidence Report, have we missed anything? - Biodiversity - Economy &Society *Cefas with participation of all delegates*
12:45- 14:15	Lunch Break
14:15 -15:15	**Interactive Breakout Session 2E** • Mapping exercise: Breakout the participants into their groups (Biodiversity, Society and Economy) and provide each with a large map of the area and enough pens that they can all add notes on to the map: - What is happening, e.g. reef fishery? - Where is it happening? Mark on the map - Specific details, *Cefas with participation of all delegates (using large printed maps of the RSA)*
15:15 - 15:45	Coffee Break
15:45 - 16:45	**Interactive Breakout Session 2E (Contd…)** • Continuation of mapping exercise: Breakout the participants into their groups (Biodiversity, Society and Economy) and provide each with a large map of the area and enough pens that they can all add notes on to the map: - What is happening, e.g. reef fishery? - Where is it happening? Mark on the map - Specific details, *Cefas with participation of all delegates (using large printed maps of the RSA)*
End of Day 2	

DAY 3: 17 January 2019 – Climate Change Risk Assessment	
09:00 - 09:15	**Welcome back and outlook for Day 3**
09:15 –10:00	**Interactive Plenary Session3A** • Regroup to present and discuss outcomes of mapping exercise - Group Biodiversity - Group Economy & Society *Cefas with participation of all delegates*
10:00-10:45	**Plenary Session3B** • Summary of collective perceptive climate change risk assessment of services provided by the marine and coastal environments in the ROPME Sea Area *Cefas* **Qs&As**
10:45 - 11:15	Coffee Break
11:15 - 13:00	**Plenary Session3C** • Review activities and timescales of the Work Plan for producing the Strategy: - Phase I (Review) - Phase II (Assessment and Synthesis) - Phase III (Production of the Strategy) • Agree detailed Work Plan for Phase I • Conclusions and remarks • Next Steps *Cefas & ROPME* **Qs&As**
13:00 - 13:30	Lunch Break
End of Day 3 and Closure of the Meeting	

ROPME/178/2

CONCEPT NOTE

Regional Marine Climate Change - Risk Assessment, Adaptation and Mitigation Strategy for the ROPME Sea Area

1. Introduction

Recognising the shared and significant challenges posed by climate change, this Concept Note proposes a Work Plan to develop a Regional Marine Climate Change Adaptation and Mitigation Strategy for the ROPME Sea Area. The Strategy will be in support of ROPME Member States' commitments to the United Nations Framework Convention on Climate Change, the United Nations Sustainable Development Goals, and the Convention on Biological Diversity in a Regionally coordinated manner.

Climate change can impact marine and coastal environments in a number of ways. The direct impact of climate change is to change the physical and chemical environment in the sea. Increased atmospheric warming directly increases sea temperature, but this can also affect ocean currents and weather patterns (e.g. cyclone formation) that in-turn drive the physical environment of the seas. An example of indirect effect is the influence of rising temperatures on sea level rise due to physical expansion of seawater and melting of the glaciers on land. Rising levels of carbon dioxide in the atmosphere also cause chemical changes in the ocean, which in turn is resulting in the seas becoming relatively more acidic, an effect known as ocean acidification.

These changes in the physical and chemical environment can have a number of impacts on the productivity of fisheries as well as consequences for marine biodiversity and human activities dependent on the seas. For example, climate change may lead to a national or regional decline in food security and income from fisheries, or a reduction in tourism due to a decline in coral reefs. Adapting to these changes may require changes in fisheries practices and environmental management to adjust to the changing ecological conditions and to build resilience.

The changing distribution of species does not just affect species of fisheries and of biodiversity importance, but can also affect the distribution of harmful marine species such as hazardous algal bloom forming species and marine pathogens that directly affect human health. For example, the bacteria *Vibrio cholerae*, *V. parahaemolyticus* and *V.*

vulnificus exist in seawater and can cause major wound infections, gastroenteritis and occasionally human fatalities. The incidence of these species is known to be closely linked to warm seawater temperatures and they have been found in seawater samples from the ROPME Sea Area. Changes in water temperature can affect growth rates of farmed finfish and shellfish, increase the presence of parasites and affect the general suitability of coastal areas for aquaculture production.

Sea level rise can result in significant adverse impacts on coastal communities and ecosystems. Cities, towns and key national infrastructure are often located along the coast and if actions are not taken to protect or re-locate these structures, long-term sea level rise could lead to massive impacts on coastal communities and potentially human facilities.

Climate change in the marine and coastal environment can therefore cause a number of adverse impacts that will affect the social and economic services that people derive from the sea. These changes are also occurring alongside an increase in other human activities, such as coastal development, desalination and fishing, and the combination of these impacts occurring together may lead to cumulative impacts and reduce the resilience of marine ecosystems to cope with climate change.

As well as being impacted directly or indirectly by climate change, the marine and coastal environment can itself play a role in reducing the extent of future climate change through the uptake and sequestration of carbon. 'Blue carbon' is the term used to refer to carbon stored in coastal and marine ecosystems. Coastal ecosystems are some of the most productive on earth and in addition to providing important ecosystem services, such as coastal protection and nursery grounds for fish, they also sequester and store large quantities of carbon, and hence can play a role in climate change 'mitigation'.

There are two main actions that can be taken to address climate change, these are 'mitigation' and 'adaptation'. 'Mitigation' refers to limiting climate change by reducing the emissions of greenhouse gases and by enhancing the uptake of greenhouse gasses through promoting or protecting natural 'sinks', and 'adaptation' refers to reducing the adverse impacts of climate change by taking actions to prepare for the changes that will be caused by climate change.

1.1 ROPME Sea Area

ROPME was established in 1979 and acts as the Secretariat for the Kuwait Regional

Convention for Cooperation on the Protection of the Marine Environment from Pollution (1978). The ROPME Sea Area (RSA) is bordered by eight countries namely the Kingdom of Bahrain, Islamic Republic of Iran, Republic of Iraq, State of Kuwait, Sultanate of Oman, State of Qatar, Kingdom of Saudi Arabia and the United Arab Emirates. The inner RSA has a total surface area of around 240,000 km^2 and is characterised by shallow waters of high temperature, marked differences in salinity and seasonal upwelling, driven by monsoon winds.

The RSA region has been recognised as one of the warmest sea areas in the world, with both extreme positive and negative temperature variation (annual temperature range of 12–35°C). Like other semi-enclosed seas, the inner RSA is particularly susceptible to changing environmental conditions and recent projections from the IPCC suggest that sea temperatures may increase by 3.5-4.4°C over the period 2010-2099. The observed rate of temperature increase has been three times faster than the global average, and as such marine and coastal ecosystems within the ROPME Sea Area are considered to be particularly vulnerable. The 2013 ROPME 'State of the Marine Environment Report' recognised climate change as an emerging issue of particular concern for the Region.

2. ROPME Regional Marine Climate Change - Risk Assessment, Adaptation and Mitigation Strategy

As part of the UNFCCC, ROPME Member States have made commitments to tackle climate change and to adapt to its effects. Furthermore, a key recommendation in the 2013 ROPME 'State of the Marine Environment Report' was that "Member States, agree on plans and actions commensurate with the efforts of the international community to mitigate possible impacts of global climate change on the Region's marine ecosystems and coastal areas, according to the IPCC best agreed scenarios for the Region".

A ROPME Regional Marine Climate Change - Risk Assessment, Adaptation and Mitigation Strategy is proposed to address the challenges of marine climate change for the RSA. The primary focus of the Strategy will be on identifying adaptation strategies; however, consideration will also be given to mitigation through enhancing and conserving stores of 'blue carbon'.

The ROPME Marine Climate Change Strategy will act to help Member States meet their national commitments to marine and coastal climate change adaptation, as specified by international and regional commitments, in a regionally coordinated manner. The proposed ROPME Marine Climate Change Strategy is based on examples of 'best practice' of climate change risk assessments, adaptation plans and mitigation strategies that have been conducted internationally. The Strategy is based around two parallel strands of activity that separately address adaptation and mitigation.

The first step to preparing the Adaptation Strategy is to conduct a risk assessment to identify the main impacts associated with climate change in the marine and coastal environment. Once these impacts have been identified and prioritised, the key adaptation actions will be identified to reduce the adverse impacts.

The Mitigation Strategy will proceed by identifying the ecosystem components in the RSA that store and sequester blue carbon, and will then proceed to identify how these ecosystem components can be managed to gain the benefits of blue carbon storage and long-term sequestration.

The Strategy includes a Monitoring Plan to report on success of implementation ahead of the next IPCC AR6 assessment to be finalized in 2021.

2.1 International policies, strategies and targets relevant to the ROPME Marine Climate Change Strategy

ROPME Member States have committed themselves to developing national mitigation and adaptation plans through a series of international conventions and frameworks. In addition to commitments under the UNFCCC to take actions to mitigate and adapt to climate change, the UN Sustainable Development Goals and the UN Convention on Biological Diversity also include objectives related to mitigation and adaptation to climate change. The implementation of the ROPME Strategy for Marine Climate Change is designed to be both supported by, and to support, fulfilment of these existing national commitments.

The UN Sustainable Development Goal 13 is to ‘Take urgent action to combat climate change and its impacts’. This SDG recognises that “climate change presents the single biggest threat to development … [and] … urgent action to combat climate change and minimize its disruptions is integral to the successful implementation of the Sustainable Development Goals”. Actions related to climate change and ocean acidification are also called for to meet the objectives of UN Sustainable Development Goal 14.

Under the UN Convention on Biological Diversity, Aichi Biodiversity Target 10 states: “By 2015, the multiple anthropogenic pressures on coral reefs, and other vulnerable ecosystems impacted by climate change or ocean acidification are minimized, so as to maintain their integrity and functioning”. This recognises the impact of climate change on marine and coastal ecosystems and seeks additional management measures to support the resilience of these ecosystems as part of the adaptations to the impacts of climate change.

2.2 Objective of the Strategy

The objective is to develop a Regional Marine Climate Change Adaptation and Mitigation Strategy in support of ROPME Member States' commitments to the United Nations Sustainable Development Goals, the United Nations Framework Convention on Climate Change, and the Convention on Biological Diversity.

The Regional Marine Climate Change Adaptation and Mitigation Strategy will:

- Encourage the establishment of a common vision for meeting the challenges of climate change in the marine environment
- Coordinate the development of regional understanding of marine climate change impacts
- Encourage the development and application of tools for marine climate change risk assessment
- Support knowledge exchange and the development of best practices for marine climate change adaptation and mitigation
- Facilitate policy coherence

3. Preliminary Work Plan

Phases	Risk Assessment and Adaptation Activities	Blue Carbon Mitigation Activities
Phase I: Review (12 months)	Hold initial kick-off Workshop of the Regional Task Force on Marine Climate Change with policy delegates from all Member States to: - Launch the Marine Climate Change – Risk Assessment, Adaptation and Mitigation Strategy for the ROPME Sea Area - Establish the Regional Task Force and agree the ToR - Approve the formation of the Technical Support Group and agree the ToR - Agree the Work Plan for the development of the Strategy - Present findings of the draft RSA Climate Change Impacts Evidence Report - Conduct a rapid Marine Climate Change Impacts Prioritization and Scoring exercise on top-level sectors within biodiversity, society and economy Technical Support Group to draft a Marine Climate Change Impacts Evidence Report and Risk Assessment for the RSA based on existing data on impacts of marine climate change in the ROPME Sea Area. Hold first workshop of the Technical Support Group to: - Review and revise the RSA Marine Climate Change Impacts Evidence Report - Conduct an expert review of Marine Climate Change Risk Assessment based on initial findings of Evidence Report - Review structure and key messages for the ROPME Climate Change Impacts Policy Briefing Report - Agree structure and approach for developing the Blue Carbon Inventory Report for the RSA Technical Support Group to finalise (i) RSA Marine Climate Change Impacts Evidence Report, (ii) Risk Assessment Report and (iii) Climate Change Impacts Policy Briefing Report for review and approval by the Regional Task Force. Technical Support Group to draft a Blue Carbon Inventory Report for the RSA based on existing data on the distribution and state of carbon sequestration and storage capabilities of Blue Carbon ecosystems in the ROPME Sea Area. Hold second workshop of the Technical Support Group to: - Review and revise an early draft of the Blue Carbon Inventory Report for the RSA - Review structure and key messages for the ROPME Blue Carbon Policy Briefing Report - Draft an initial list of existing regional activities related to marine climate change adaptation, and management of Blue Carbon stores to be expanded on by the Technical Support Group during Phase II	

	Technical Support Group to finalise (i) Blue Carbon Inventory Report for the RSA, and (ii) Blue Carbon Policy Briefing Report for review and approval by the Regional Task Force. Technical Support Group to produce a first draft vision for the Marine Climate Change – Risk Assessment, Adaptation and Mitigation Strategy for the ROPME Sea Area.
Phase II: Synthesis and Recommendations (12 months)	Hold Regional Workshop of the Regional Task Force and Technical Support Group to: - Launch the ROPME Climate Change Impacts Policy Briefing Report and Blue Carbon Policy Briefing Report - Identify existing regional and national activities related to marine climate change adaptation and management of Blue Carbon stores - Agree structure of ROPME Adaptations Options Report - Agree structure of the ROPME Blue Carbon Best Practice Guidelines Report - Review the outline vision of the Marine Climate Change – Risk Assessment, Adaptation and Mitigation Strategy for the ROPME Sea Area - Consider and identify options for additional regional training activities related to marine climate change adaptation and mitigation - Review and agree detailed work plan for Phase II Technical Support Group to draft a Marine Climate Change Adaptations Options Report for the ROPME Sea Area, a sectoral based technical report on potential adaptation options to address predominant impacts and risks. Hold third workshop of the Technical Support Group to: - Compile a final summary of existing adaptation activities in the RSA - Review and revise the RSA Adaptations Options Report - Review structure and key messages for the ROPME Marine Climate Change Adaptations Options Policy Briefing Report Technical Support Group to finalise (i) RSA Adaptations Options Report, and (ii) Adaptations Options Policy Briefing Report for review and approval by the Regional Task Force. Technical Support Group to draft a ROPME Blue Carbon Best Practice Guidelines Report for the ROPME Sea Area, a review of existing activities to protect and/or extend Blue Carbon stores in the RSA, and identifying opportunities for additional carbon emission mitigation as well as potential carbon market. Hold fourth workshop of the Technical Support Group to: - Compile a final summary of existing Blue Carbon activities in the RSA - Review and revise the RSA Blue Carbon Best Practice Report - Review structure and key messages for the ROPME Blue Carbon Best Practice Policy Briefing Report

	Technical Support Group to finalise (i) Blue Carbon Best Practice Report, and (ii) Blue Carbon Best Practice Policy Briefing Report for review and approval by the Regional Task Force. Technical Support Group to produce a draft of the Marine Climate Change – Risk Assessment, Adaptation and Mitigation Strategy for the ROPME Sea Area.
Phase III: Prepare Adaptation and Mitigation Strategy (8 months)	Hold Regional Workshop of the Regional Task Force and Technical Support Group to: - Review and revise the Marine Climate Change – Risk Assessment, Adaptation and Mitigation Strategy for the ROPME Sea Area - Consider options for the implementation and monitoring of the Marine Climate Change Strategy - Consider and identify options for additional regional training activities related to marine climate change adaptation and mitigation - Review and agree detailed work plan for Phase III Hold National Engagement Meetings, one meeting in each of the Member States run by the Technical Support Group. Organization of a High-Level Regional Multi-stakeholder Workshop on Marine Climate Change (MCC) to: - Present and launch the Adaptations Options Policy Briefing Report and Blue Carbon Best Practice Guidelines Policy Briefing Report - Review and revise the Marine Climate Change – Risk Assessment, Adaptation and Mitigation Strategy for the ROPME Sea Area Technical Support Group to draft the ROPME Marine Climate Change Strategy Implementation and Monitoring Plans for review and approval by the Regional Task Force. Finalise the Strategy and the Plans and present them to the ROPME Council for adoption
Phase IV: Implement Adaptation and Mitigation Strategy (ongoing)	Implement Regional Marine Climate Change Adaptation and Mitigation Strategy across all Member States Monitor implementation of Regional MCC Strategy Regional Workshop to report on success of the implementation of the Regional Marine Climate Change Strategy and to identify next steps Provide inputs for the next IPCC AR6 assessment to be finalized in 2021

4. Expected Outputs

Phase I

- RSA Marine Climate Change Impacts Evidence Report
- RSA Marine Climate Change Risk Assessment Report
- Climate Change Impacts Policy Briefing Report
- RSA Blue Carbon Inventory Report
- RSA Blue Carbon Policy Briefing Report
- Draft Vision for the Marine Climate Change – Risk Assessment, Adaptation and Mitigation Strategy for the ROPME Sea Area

Phase II

- Marine Climate Change Adaptations Options Report
- Marine Climate Change Adaptations Options Policy Briefing Report
- ROPME Blue Carbon Best Practice Guidelines Report
- ROPME Blue Carbon Best Practice Guidelines Policy Briefing Report
- Draft of the Marine Climate Change – Risk Assessment, Adaptation and Mitigation Strategy for the ROPME Sea Area

Phase III

- Marine Climate Change – Risk Assessment, Adaptation and Mitigation Strategy
- ROPME Climate Change Strategy Implementation and Monitoring Plans

Centre for Environment Fisheries & Aquaculture Science

ROPME/178/3

WORKING STRUCTURE and TERMS OF REFERENCE

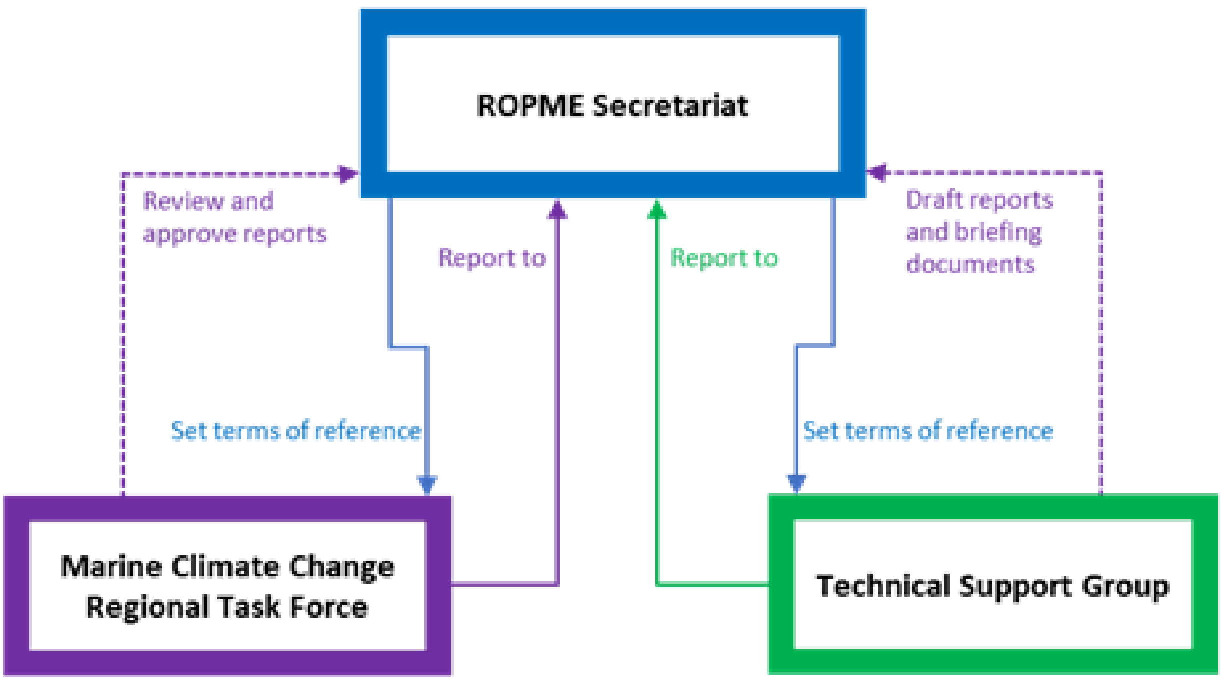
for the preparation of the

Regional Marine Climate Change - Risk Assessment, Adaptation and Mitigation Strategy for the ROPME Sea Area

A Marine Climate Change Work Plan (the 'Work Plan') will be conducted by ROPME to develop the Regional Marine Climate Change Strategy. The Work Plan will be implemented by the ROPME Secretariat, a Regional Task Force made up of National Delegates, and a Technical Support Group made up of topic experts on Marine Climate Change - Risk Assessment, Adaptation and Mitigation. The roles of these groups are described in the diagram below:

Co-ordinate Regional Task Force and Technical Support Group

Marine Climate Change Work Plan Co-ordinator
ROPME Secretariat staff



Oversee Strategy development and implementation; co-ordinate work and inputs at the national level

x2 National Delegates per Member State

Produce scientific reports, policy briefing documents and peer review articles

Core drafting group of 4-5 technical experts

Wider group of 20-30 regional and international technical experts for advice, consultation and review

ROPME Secretariat

The ROPME Secretariat has overall responsibility for the implementation of the Marine Climate Change Work Plan and will arrange and organise all of the activities, meetings and resources that are required to complete the Work Plan. The ROPME Secretariat will also be responsible for:

- communications between the Member States, the Regional Task Force and the Technical Support Group;
- monitoring the progress and implementation of the Work Plan as well as reporting back to the ROPME Council.

ROPME will appoint a dedicated member of the ROPME Secretariat staff to act as the Marine Climate Change Work Plan Co-ordinator (the 'Work Plan Co-ordinator'). This person will be the primary contact point in the ROPME Secretariat, responsible for overseeing and supporting implementation of the Work Plan.

The Terms of Reference (ToRs) for the Regional Task Force and the Technical Support Group will be reviewed and approved at the first Workshop of the Regional Task Force.

Centre for Environment
Fisheries & Aquaculture
Science

Terms of Reference for the Marine Climate Change Regional Task Force

The main role of the Regional Task Force (RTF) is to represent the views of the ROPME Member States during the implementation of the Work Plan. The Regional Task Force will:

- oversee the production of the Marine Climate Change Strategy;
- co-ordinate work and inputs at the national level;
- collect and compile necessary information on national policies and activities, and data from national sources required for the conduct of the Work Plan;
- consult with relevant national stakeholders on the development of the Strategy;
- provide review and approval on behalf of Member States during implementation of the Work Plan and preparation of the Strategy;
- support adoption of the Strategy by the ROPME Council and support its subsequent implementation.

The RTF will comprise two National Delegates from each Member State. The members of the RTF will be senior experts or managers who are nominated by the National Focal Points in each Member State. The National Delegates are expected to co-ordinate work at the national level, to be able to liaise with their government and national authorities and to have the capacity to assemble national teams and expertise where required. Member State delegates have an important role and they are expected to have the influence, authority and access to resources required to support the effective implementation of the Work Plan at the national level.

All Member States will participate in the RTF on an equal footing. The members of the RTF will be engaged through frequent communications and participate in regular RTF meetings. All formal communications between the RTF regarding the Work Plan will be via the Work Plan Co-ordinator.

Centre for Environment Fisheries & Aquaculture Science

Terms of Reference for the Marine Climate Change Technical Support Group

The primary role of the Technical Support Group (TSG) will be to prepare technical scientific reports, Policy Briefing Reports, the draft of Marine Climate Change Strategy and other technical inputs required for completion of the Marine Climate Change Work Plan. The TSG will:

- prepare technical reports and briefings as directed by the Regional Task Force to provide the evidence based required to support development of the Strategy;
- collate and review regional and international data, projects and polices, as required to incorporate international best practice;
- liaise with the Regional Task Force and ROPME Secretariat to finalise outputs of the Work Plan incorporating comments from national reviews;
- provide technical support to the ROPME Secretariat as required to obtain approval from the ROPME Council for the adoption of the Strategy.

The TSG will focus on the two technical strands of work in the Work Plan: marine climate change risk assessment and adaptation, and blue carbon and mitigation.

The TSG will consist of a ‘core’ group and a wider advisory group. The core group will lead the collation of information and drafting of documents during the implementation of the Work Plan. The core group will be supported by the wider advisory group through participation in technical workshops and intersessional consultation.

The core membership of the TSG will be established at the start of the Work Plan. The core members and any additional experts will be identified and engaged, and their tasks will be agreed by the Work Plan Co-ordinator and subsequently the Marine Climate Change Regional Task Force.

The TSG will be led by a Lead Scientist who is expected to fulfil this role for the duration of the Work Plan. The Lead Scientist is expected to be a marine climate scientist with expertise in the respective fields of climate risk assessment and blue carbon quantification.

The core group will consist of the Lead Scientist and 4-5 additional scientific experts who are themselves expected to fulfil this role for the duration of the Work Plan.

Member States and regional or international organisations may provide staff to be additional supporting members of the Technical Support Group, upon the approval of the ROPME Secretariat.

Workshop of the Regional Task Force on Marine Climate Change

2019 年 1 月 15-17 日

主な参加者 (　　)

ROPME-JICA パートナーシッププログラム　打合せ

2019 年 1 月 25 日

資料 1-1. オマーン出張報告（海洋気候変動ワークショップ参加）

1. 日程：2019 年 1 月 15 日（火）～17 日（木）3 日間
2. 場所：オマーン国マスカット市；ホリディイン･マスカット・アルシーブ
3. 参加者：添付「主な参加者リスト」参照
4. プログラム：別添参照
5. 会議の概要

(1) 今回は 2017 年 4 月にクウェートで開催された第 1 回に次ぐ会合であるが、各国で指名されたタスクフォース会議メンバーの初会合で、タスクフォース会議の ToR、ワークプランについて議論を行ったもの。

(2) 実施体制やワークプランは ROPME 事務局 Dr. Mohammadi と Cefas によって作成されたものであるが、イランからの各国が実際に取組めるアクションプランを早く作るべきという観点と、テクニカルサポートチームの構成と役割について、イラン、オマーンから修正意見が出され見直された。

(3) Cefas から海洋環境及び社会経済における気候変動の影響の証拠に関するドラフトが報告されたが、これまでの ROPME 海域での環境上の問題の再掲と AGEDI(Abu Dhabi Global Environmental Data Initiative)の気温上昇シミュレーション結果によるもので、その引用の妥当性について、多くの参加者から疑問が呈された。

(4) 各国のナショナルレポートは、国内での全体的な気候変動に対する取組みと海洋環境の脆弱性･防災の実態に関するもので、海洋環境における気候変動の緩和･適応についてはふれられていなかった。

(5) 本タスクフォースのアウトプットについて、イラク、UAE を除く各国の参加者から、国で策定して国際的にコミットする緩和･適応策との整合や、ROPME 域内としてのストラテジーやアクションプランに重複がなく成立しうるかという疑問も呈された。

(6) 本タスクフォース会議のメンバーは国を代表する者として本会議での意思決定に責任をもつという説明に対して、サウジアラビアの参加者からは、「決定権はなく、国に持ち帰って判断を仰ぐ必要がある」ということで、ToR とワークプランについて 1 ヵ月半後までに各国の確認をとることとなった。

【所感】

①議論は活発で、特にイラン、オマーン、バーレーン、サウジアラビアの参加者から多くの意見が出された。

②Cefas の作成資料、会議の進め方は、本タスクフォースが単独で、海洋環境分野に関してこの地域で初めてなされる場合のような前提でなされているように見受けられ、他の重要課題、特に関係の深い EBM ストラテジーや海洋生物多様性との情報共有がなされておらず、重複感が強く、アウトプットも明確でないという印象を受けた。

③技術的には、気候変動の影響の証拠と海洋環境（生態系）脆弱性及び社会経済問題との区別が明確になされておらず、アウトプットの枠組みに対する現況データの不十分さを補っていく難しさがあると考えられる。また、緩和策・適応策に対するアウトプットが明確でなく、アクションプラン策定への道筋が不明確であるとの印象を受けた。

④昨年 12 月の東京ワークショップの際に ROPME 事務局から提案のあった、タスクフォース会議のテクニカルサポートチームへの日本人専門家の参画については、戦略づくりやアクションプランづくりではなく、緩和策･適応策を計画･実行できる知識･経験をもった方の参画が可能であれば有効と考えられる。具体的には緩和策･適応策としての期待が高く、メンバー国共通の関心のある<u>マングローブ林または海草藻場の保全･再生分野（ブルーカーボンを含む）</u>や、適応策としての<u>サンゴ礁保全･再生分野</u>及び<u>防災分野</u>などが考えられる。

⑤その他、今後の ROPME での活動における共通事項として、下記の点に配慮することが望ましいと考えられる。

1) 生物生息場の保全再生に関する技術は、ROPME の重点課題である EBM、海洋生物多様性、海洋気候変動にとって共通してアクションプランの核になる技術であるといえ、戦略の枠にとらわれずに、これらの技術の共有と可能な限りの支援を行うことで、相乗的な効果が期待できる。

2) 各国のベースラインデータの不足はいかんともしがたく、ベースラインデータの分析→戦略策定→アクションプランの策定という手順ではとても現状に追いつかず、各国の実施に対するニーズからも乖離してしまうため、上記の分野でのよりプラクティカルな取組みを優先すべきであると考えられる。

3) リージョナルな戦略は必要である一方、各国のローカリティーや政策･施策での特色に対する配慮･対応が重要であり、日本と相手国との二国間での取組みに重点をおくことが望ましい。

4) ROPME の事務運用手続きでは、各国フォーカルポイントから実務担当への流れに偶然性が入る余地が高いうえ、会議参加者が最適かどうか、会議参加者から自国内へのフィードバック、共有が適切になされるか等は偶然性が高いと考えられる。このため、ROPME 事務局との連携とともに、これまでの会議を通じて蓄積された関係でのキーパーソン（例えばクウェートのアルザイダン局長、オマーンのバダル・アルブルーシ課長）を通じての情報収集・共有が有効であると考えられる。（2 月の渡航でこれからの活動計画を説明して、協力について依頼したい。）なお、バーレーンの最高環境会議やサウジアラビアの GAMEP のメンバーとは情報共有がしやすいので、2 月の渡航の中でルートを確定したい。イランの参加者は発言力･決定力は強いものの直接のコンタクトは避け、

ROPME 経由での接触が望ましいと思われる。イラク、カタールは ROPME もしくは上記 2 名を通じての接触が望ましい。

13 a ׄ ךּ ׅ ךּ אּ = ∂ √ ▌

⊤ = ▌

שּׂ ךּ ♠ ♯ ɔ Ⴀ̎

Ministry of Works, Municipalities Affairs and Urban Planning

ROPME-JICA Partnership Programme

Joint Workshop
on
Fishery Resource Conservation and Management in Coastal Area

Manama, Kingdom of Bahrain; 20 February 2019

Provisional Agenda

1. Background

Japan International Organization ('JICA') and Regional Organization for Protection of Marine Environment ('ROPME') signed a minutes of understandings ('MOU') on a partnership programme (the 'Programe') for contributing the marine environment conservation and rehabilitation in the ROPME Sea Area ('RSA') consisting of the inner RSA (inner gulf area from Hormuz Strait), the middle RSA (Oman Sea) and the outer RSA (Indian Ocean area). This programme aims to contribute not only for ROPME but also for each member state.

While ROPME and JICA have collaborated on many activities on marine environment aspects since November 2015, the most important activity is to establish a strategy on Ecosystem Based Management ('EBM'). The concept of EBM initiated by United Nations Environmental Programme ('UNEP') is to manage the marine environment conservation policies and measures based on the marine ecosystem aspect. This means that all activities related marine ecosystem should be considered, especially the environment and fishery are the most important aspects. Accordingly, the working group on the EBM Strategy was established with two focal points of environment and fishery fields from each member state.

Even though fisheries is a very important sector in the EBM strategy as it requires an environmental and socio-economic approaches, the Programme has tended to focus on marine ecosystem or biodiversity so far. For this reason, a workshop focusing on fishery resource conservation and management including aquaculture technology development has been planned between the focal point with fisheries sector from the Kingdom of Bahrain and JICA Study Team.

This workshop aims to share the technologies and experience on fishery resource conservation and management including aquaculture technologies in Japan, and to find hints for approaching the actual challenges on fisheries in Bahrain first. As the secondary work, we would like to seek the proper approach to EBM Strategy from the fisheries sector.

2. Date

20 February, Wednesday, 2019

3. Venue

Agriculture and marine resources Affairs, Ministry of Works, Municipalities Affairs and Urban Planning, Kingdom of Bahrain, Budaiya, Manama, Kingdom of Bahrain

4. Programme

Schedule	Contents
09:00-09:20	Opening Remarks - HE Shaikh Mohamed Bin Ahmed Al Khalifa Undersecretary of Agriculture and Marine Resources, Ministry of Works, Municipalities Affairs and Urban Planning, Kingdome of Bahrain - HE Mr. Hideki Ito, Ambassador of Japan to the Kingdom of Bahrain - Ms. Wakana Hirata, Deputy Resident Representative, Saudi Arabia Office, Japan International Cooperation (JICA)
09:30-10:30 (10:30-10:45) 10:45-11:45 (11:45-12:00)	Possibility of the Coastal Environmental Conservation and Fisheries Resource Conservation and Management in the Kingdom of Bahrain - Professor Yoshifumi Sawada, Aquaculture Research Institute, Kindai University (Break) Multi-purpose DNA-based identification technology of fish species, maternal lines, and individuals - Professor Yoshifumi Sawada, Fisheries Laboratory, Kindai University (Break)
12:00-13:00	Discussion (Moderator: Mr. Bassam Al Showaikh, Acting Head of Marine Resources Development Division, Directorate of Marine Resources, Ministry of Works, Municipalities Affairs and Urban Planning) - Application for approaches to challenges in Bahrain and prioritization - Future possibility of collaboration between Bahrain and Japan - Extension to EBM Strategy
13:00	Closing
	(22:50 Prof. Sawada will leave from the airport)

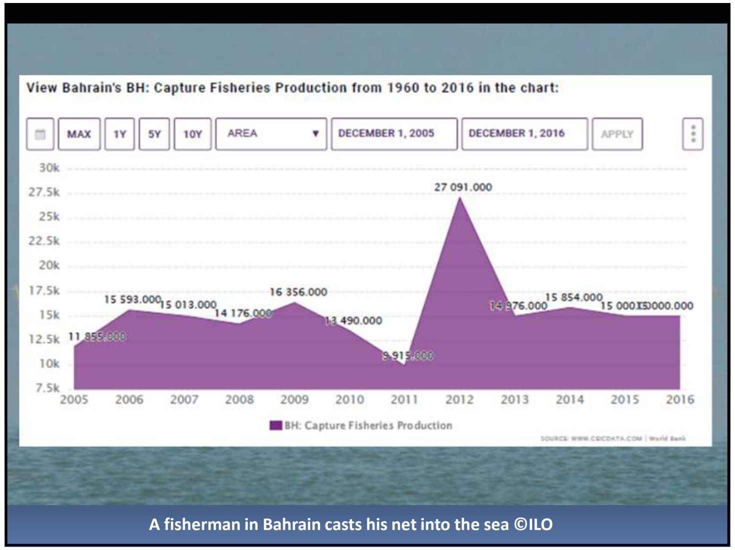
(END)

وزارة الأشغال وشؤون البلديات والتخطيط العمراني
Ministry of Works, Municipalities Affairs and Urban Planning

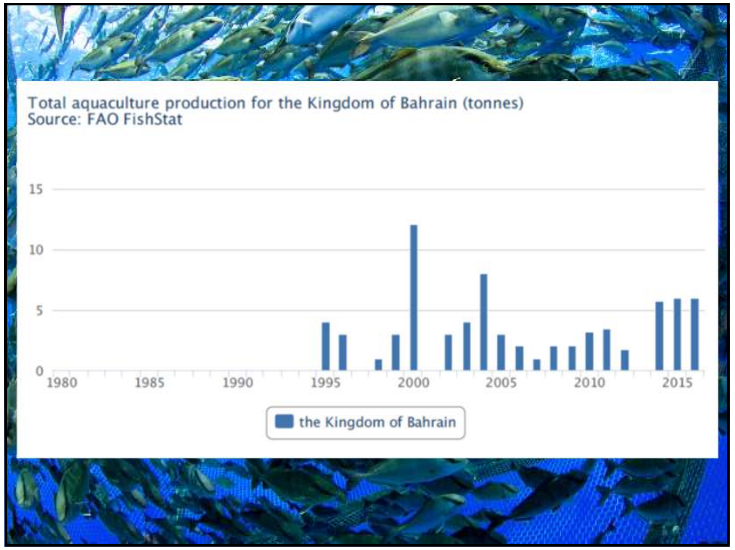
ROPME-JICA Partnership Programme

Joint Workshop Attendees (   )

1



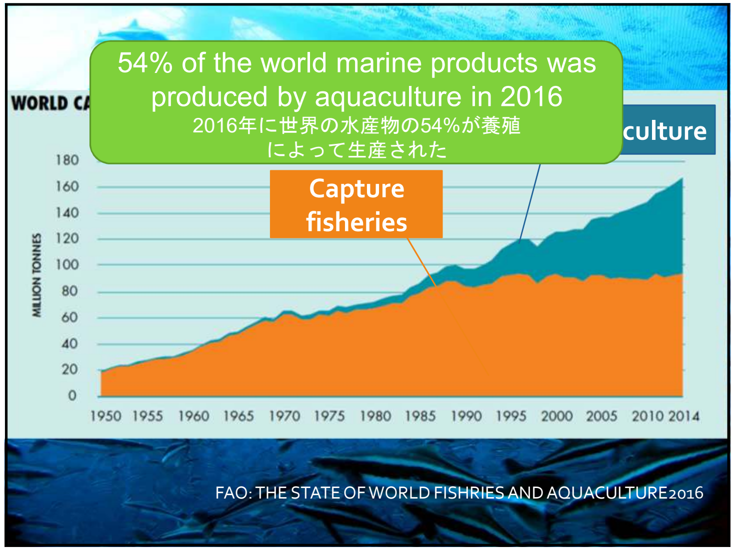
2



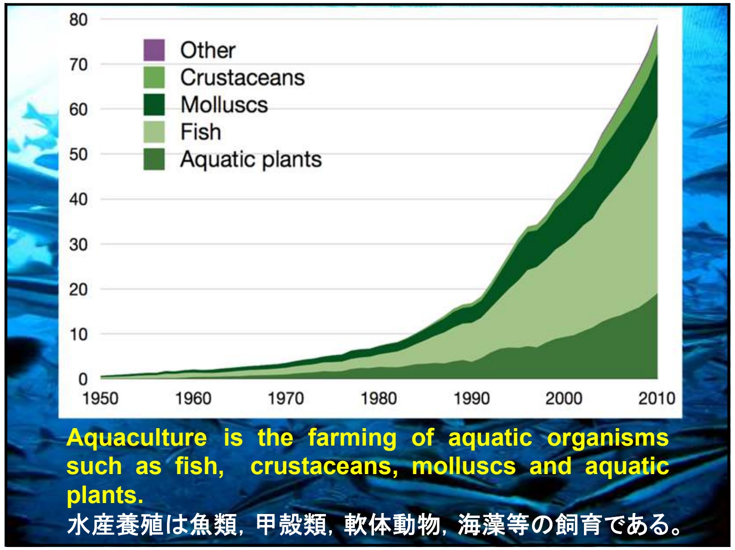
3

A goal of activities;
to make the sea food supply sustainable in Bahrain by developing the technologies and human resources for aquaculture, stock enhancement, and fisheries resource management with environmental conservation

4


54% of the world marine products was produced by aquaculture in 2016
2016年に世界の水産物の54%が養殖によって生産された
Capture fisheries
culture
MILLION TONNES
180
160
140
120
100
80
60
40
20
0
1950 1955 1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2014
FAO: THE STATE OF WORLD FISHRIES AND AQUACULTURE2016

5


Other
Crustaceans
Molluscs
Fish
Aquatic plants
80
70
60
50
40
30
20
10
0
1950 1960 1970 1980 1990 2000 2010
Aquaculture is the farming of aquatic organisms such as fish, crustaceans, molluscs and aquatic plants.
水産養殖は魚類，甲殻類，軟体動物，海藻等の飼育である。

6


Compatibility of fisheires and aquaculture production
in the underwater food production
水域における食料生産のパラダイムシフト

7


アラビア湾のマングローブ革命
中東石油王国UAEに出現する緑のオアシス
山本春樹
Haruki Yamamoto
PARADE BOOKS

8

Blue revolution：青の革命
Koichi Seko：世耕弘一
Cultivating the seas —— Koichi Seko
The size of both Japan's land and seas was reduced by its defeat in the Second World War.
Even if we increased the amount of food production on land, there would still not be enough food to feed the entire Japanese population.
'Japan will have no future unless we cultivate the seas and produce more seafood.'
It was under this philosophy that the Fisheries Laboratory was founded in 1948.

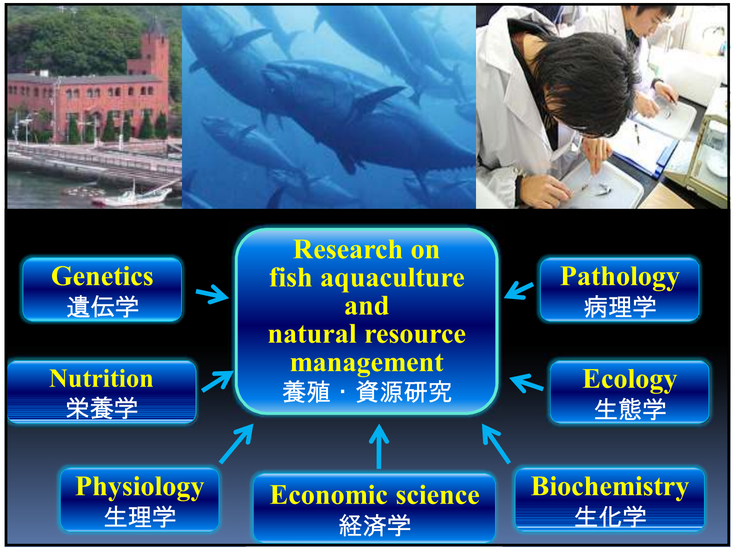
9

Aquaculture project in Kindai University
近畿大学養殖プロジェクト
Aquaculture Research Institute
水産研究所
Research & Education
研究・教育
A-marine Kindai Co., Ltd
（株）アーマリン近大
Fish Nursery Center
水産養殖種苗センター
Fish growout culture
成魚養成
Marketing
販売
Fish fingerling production
種苗生産
Technological development
技術開発

10

Amami
KOREA
P'yongyang
Seoul
SOUTH
JAPAN
Tokyo
Osaka
Fukuoka
Shanghai
Taipei
TAIWAN
Okinawa Islands

11



Research on fish aquaculture and natural resource management
養殖・資源研究
Genetics
遺伝学
Pathology
病理学
Nutrition
栄養学
Ecology
生態学
Physiology
生理学
Economic science
経済学
Biochemistry
生化学

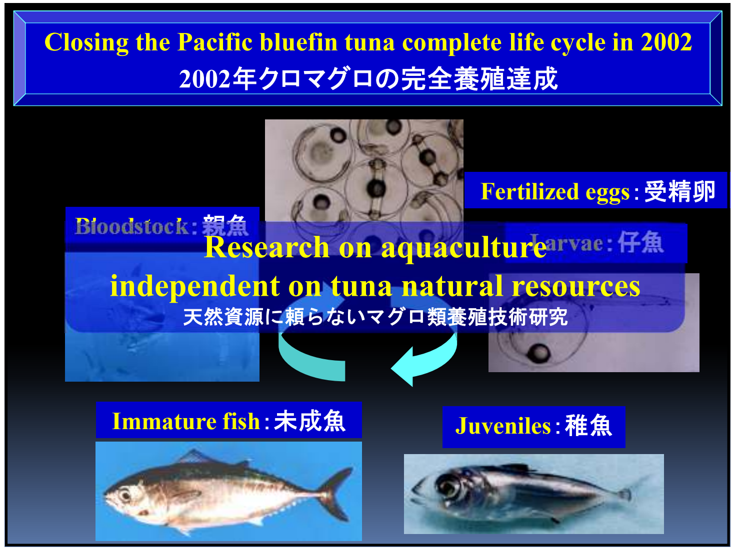
12


Development of human resource in Kinki University
for aquaculture and for fisheries resource management
近畿大学における養殖と資源管理に向けた人材育成
Human resource who can utilize
the professional knowledge
of aquaculture and resource management
in public agencies and private companies
養殖と資源管理の専門知識を活かして公的研
究機関や民間企業で活躍できる人材の育成
✓ Undergraduate school in the Faculty of Agriculture-4 years
農学部における4年間の教育
✓ Graduate school in the Graduate School of Agriculture
大学院農学研究科における教育
2 years for master Course 2年間の修士課程
3 years for doctoral course 3年間の博士課程

13


التونة ذات الزعانف الزرقاء

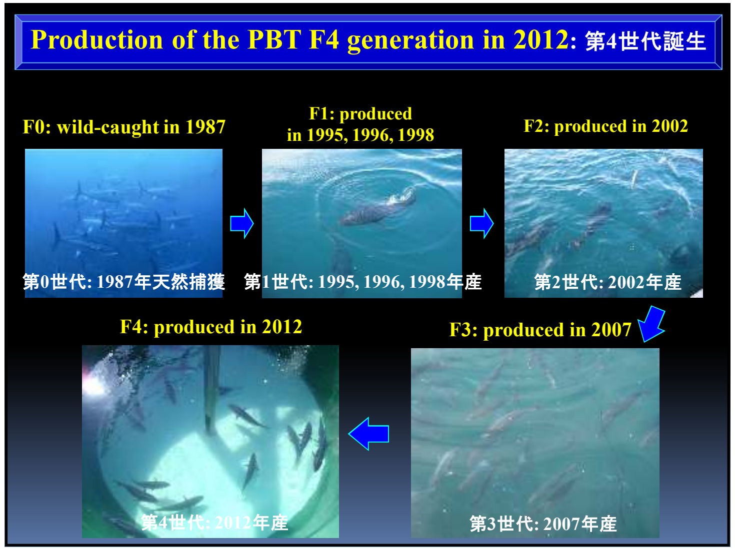
14


Closing the Pacific bluefin tuna complete life cycle in 2002
2002年クロマグロの完全養殖達成
Fertilized eggs : 受精卵
Bloodstock : 親魚
Larvae : 仔魚
Research on aquaculture
independent on tuna natural resources
天然資源に頼らないマグロ類養殖技術研究
Immature fish : 未成魚
Juveniles : 稚魚

15


Industrialization
of the PBF hatchery technology in 2004
2004年人工孵化技術の産業化

16


Production of the PBT F4 generation in 2012: 第4世代誕生
F0: wild-caught in 1987
F1: produced in 1995, 1996, 1998
F2: produced in 2002
第0世代: 1987年天然捕獲
第1世代: 1995, 1996, 1998年産
第2世代: 2002年産
F4: produced in 2012
F3: produced in 2007
第4世代: 2012年産
第3世代: 2007年産

17


Aquaculture of groupers (الهامور) has been studying for more than 50 years.
50年以上に及ぶハタ類研究の歴史
Commercial production cycle has been established.

18


主な研究対象魚
Fish species whose aquaculture technology has been developed in Kinki University Fisheries Laboratories, and such technology has been industrialized by the Fish Nursery Center of Kinki University
近畿大学水産研究所で開発し,近畿大学水産養殖種苗センターで産業化された魚類。

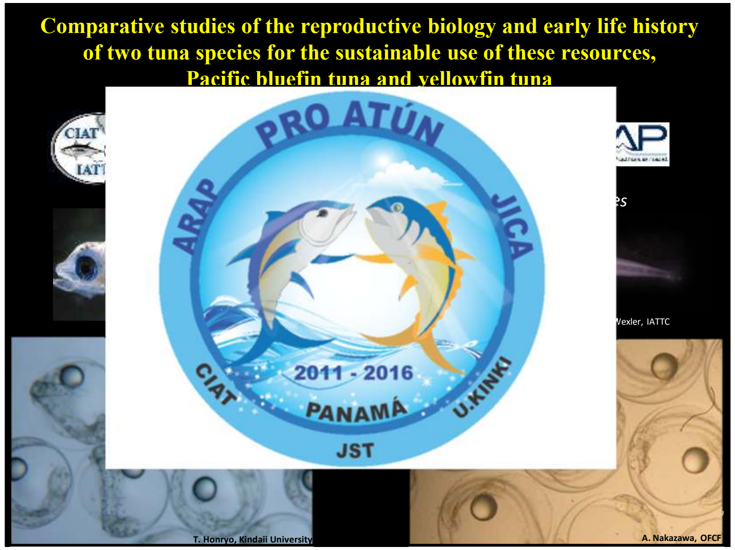
19


Cultured fish restaurants under the direct management of Kinki University in Osaka and Tokyo
大学直営の養殖魚レストラン(大阪・東京)
Umeda, Osaka:梅田・大阪
Ginza, Tokyo:銀座・東京

20

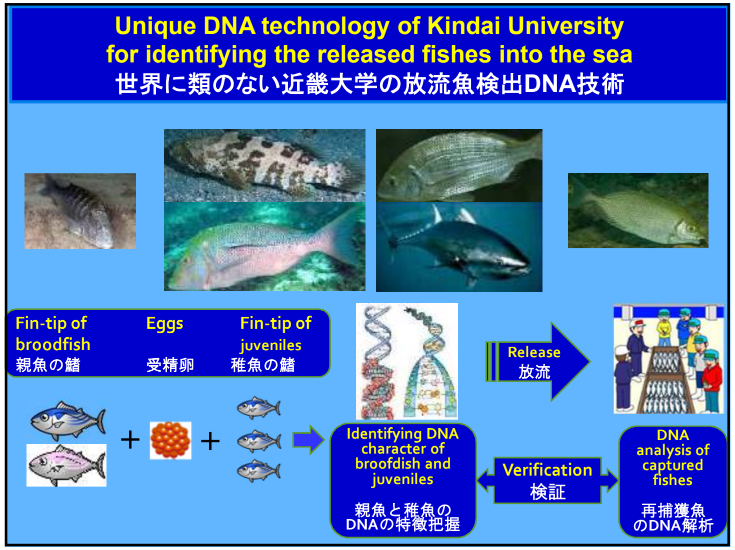

Tuna aquaculture and resource management
Research for sustainable use of tuna natural resources
マグロ類の養殖と資源管理ー資源の持続的利用を目指す研究

21

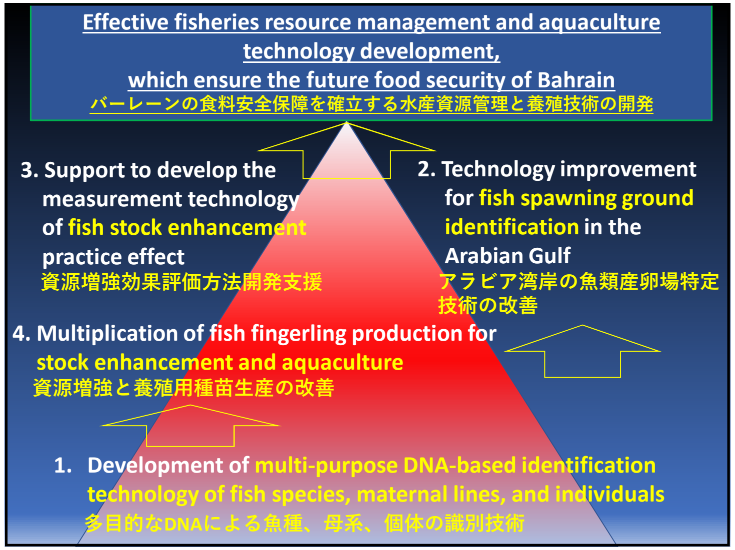

Comparative studies of the reproductive biology and early life history
of two tuna species for the sustainable use of these resources,
Pacific bluefin tuna and yellowfin tuna
PRO ATÚN
ARAP
JICA
2011 - 2016
CIAT
PANAMÁ
U.KINKI
JST
T. Honryo, Kindai University
A. Nakazawa, OFCF

22

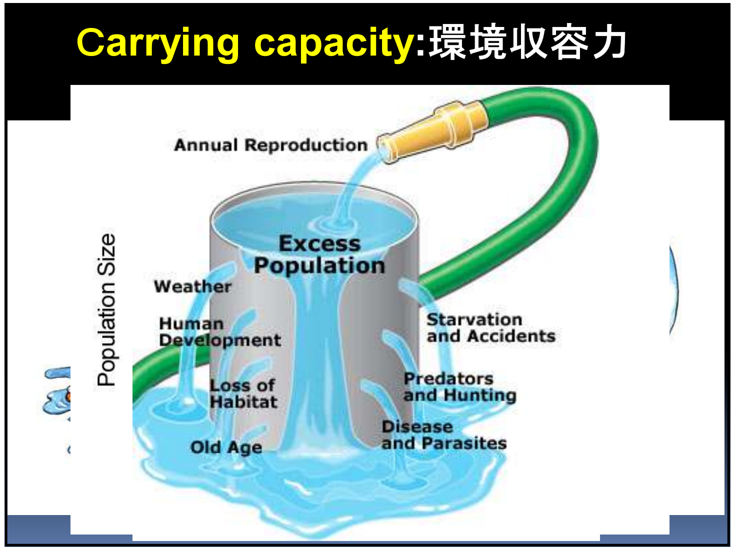
23


Unique DNA technology of Kindai University
for identifying the released fishes into the sea
世界に類のない近畿大学の放流魚検出DNA技術
Fin-tip of broodfish
親魚の鰭
Eggs
受精卵
Fin-tip of juveniles
稚魚の鰭
Release
放流
Identifying DNA character of broodfish and juveniles
親魚と稚魚のDNAの特徴把握
Verification
検証
DNA analysis of captured fishes
再捕獲魚のDNA解析

24


Effective fisheries resource management and aquaculture technology development,
which ensure the future food security of Bahrain
バーレーンの食料安全保障を確立する水産資源管理と養殖技術の開発
3. Support to develop the measurement technology of fish stock enhancement practice effect
資源増強効果評価方法開発支援
2. Technology improvement for fish spawning ground identification in the Arabian Gulf
アラビア湾岸の魚類産卵場特定技術の改善
4. Multiplication of fish fingerling production for stock enhancement and aquaculture
資源増強と養殖用種苗生産の改善
1. Development of multi-purpose DNA-based identification technology of fish species, maternal lines, and individuals
多目的なDNAによる魚種、母系、個体の識別技術

25


Carrying capacity:環境収容力
Annual Reproduction
Excess Population
Population Size
Weather
Human Development
Loss of Habitat
Old Age
Starvation and Accidents
Predators and Hunting
Disease and Parasites

26

27


Bahrain Tourism and Exhibitions Authority Launches Mangrove Tours in Tubli Bay
(Bahrain this week, July 20, 2018)

28


Conclusion استنتاج
>The Kingdom of Bahrain needs the sustainable sea food supply with environmental conservation
شُكْرًا لكُلّ شَيْء
>Activities in aquaculture, stock enhancement and fisheries resource management with environmental rehabilitation and conservation is the best way

29


Multi-purpose
DNA-based identification technology
of fish species, maternal lines,
and individuals
多目的なDNAによる魚種、母系、個体識別技術
Yoshifumi Sawada, Ph.D.
Professor
Aquaculture Research Institute
Kindai University
The ROPME-JICA Partnership Program; 20 February 2019

1


Marine food security
and
Marine products industry development
海の食料安全保障と水産業の振興
by
conservation of
fisheries resources
and
coastal water environment
水産資源と沿岸海洋環境保全による

2


1. Introduction
Marine food production by fisheries and aquaculture development are important for the food security of Bahrain.
バーレーンの食料安全保障にとって漁業と養殖の発展による水産物生産は重要
For this aim, technological developments of fish natural resource management, stock enhancement and aquaculture production, and environmental rehabilitation are necessary.
この目的のためには、漁業資源管理、資源増強、養殖、そして環境修復が必要
DNA technology developed recently is the most hopeful candidate of research and survey area which can be widely applied to this aim.
最近開発されたDNAテクノロジーは、この目的に広く活用できる最も有望な研究・調査技術である

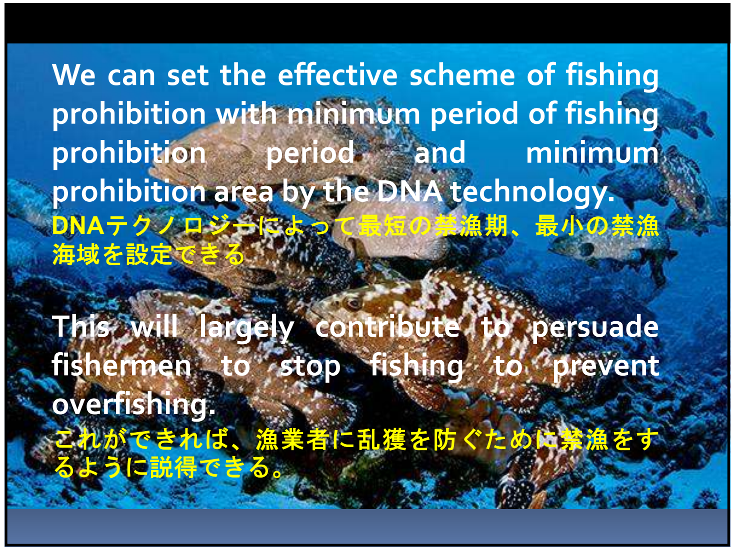
3


＞Elucidating the spawning ecology of fishes
魚類の産卵生態解明
＞conservation of the spawning grounds
産卵場の保全
＞prohibition of fishing during spawning seasons
産卵期の禁漁
The keys to secure fish reproduction resulting the successful fisheries resource management !!
これらは魚類の産卵を守り、漁業資源管理を成功させるキーとなる事項である。

4


It is ordinarily difficult to set the no fishing season, because of the decrease income of fishermen.
通常禁漁期を設定することは、漁業者の収入減を伴うため困難である

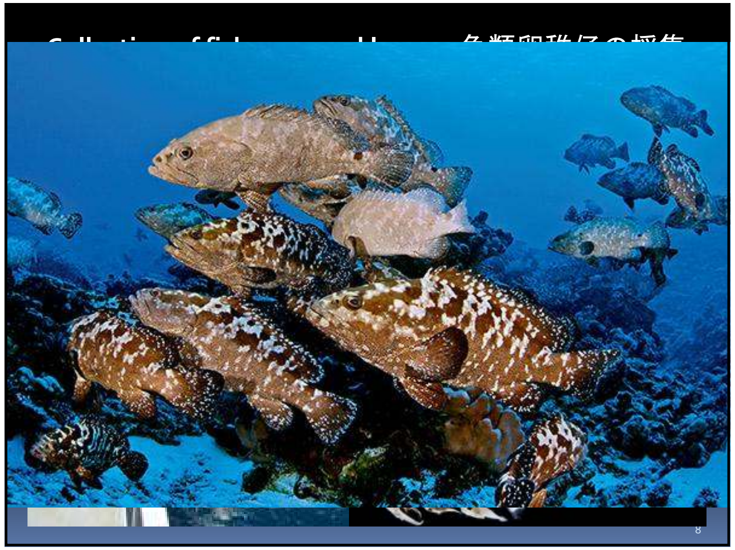
5


We can set the effective scheme of fishing prohibition with minimum period of fishing prohibition period and minimum prohibition area by the DNA technology.
DNAテクノロジーによって最短の禁漁期、最小の禁漁海域を設定できる
This will largely contribute to persuade fishermen to stop fishing to prevent overfishing.
これができれば、漁業者に乱獲を防ぐために禁漁をするように説得できる。

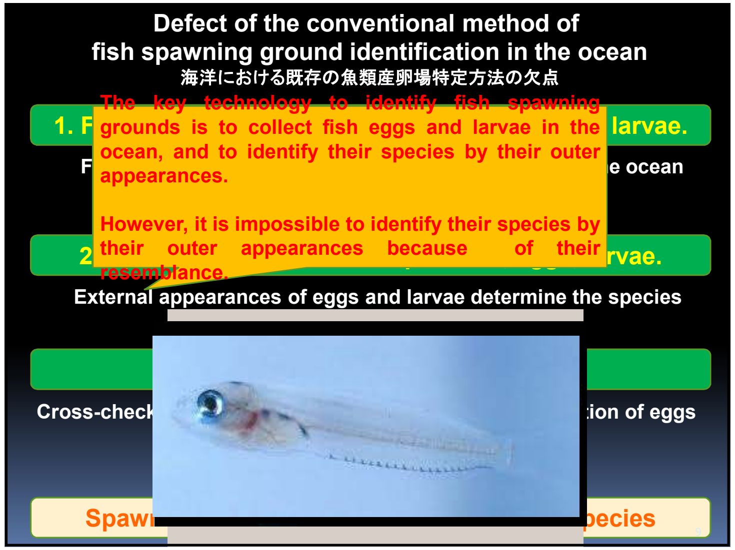
6


2-1. Best fitness-for-purpose：最も合目的
The accurate spawning ground identification of targeted fishes will be world-firstly accomplished by a brand-new DNA-based analytical technology of Kindai University, Japan． 産卵場の正確な特定は、日本の近畿大学の最新DNA解析技術で世界で初めて可能となった。
KINDAI UNIVERSITY

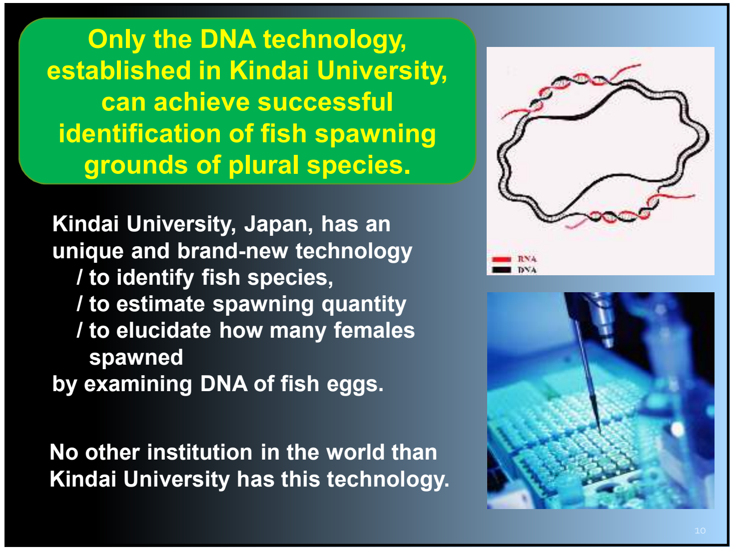
7



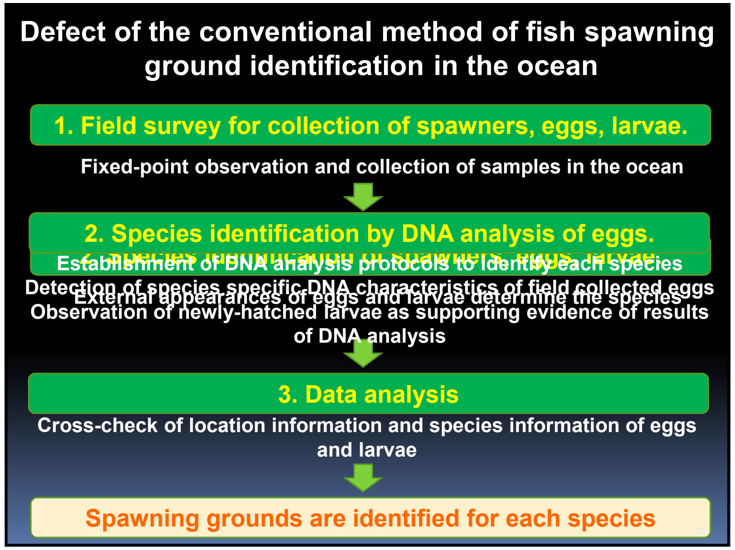
8


Defect of the conventional method of
fish spawning ground identification in the ocean
海洋における既存の魚類産卵場特定方法の欠点
The key technology to identify fish spawning grounds is to collect fish eggs and larvae in the ocean, and to identify their species by their outer appearances.
However, it is impossible to identify their species by their outer appearances because of their resemblance.
larvae.
e ocean
rvae.
External appearances of eggs and larvae determine the species
Cross-check
ion of eggs
Spawn
pecies

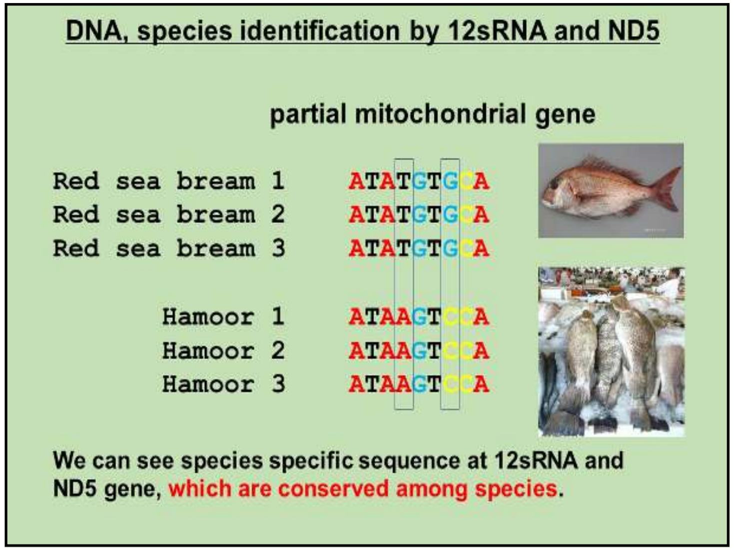
9


Only the DNA technology, established in Kindai University, can achieve successful identification of fish spawning grounds of plural species.
Kindai University, Japan, has an unique and brand-new technology
/ to identify fish species,
/ to estimate spawning quantity
/ to elucidate how many females spawned
by examining DNA of fish eggs.
No other institution in the world than Kindai University has this technology.

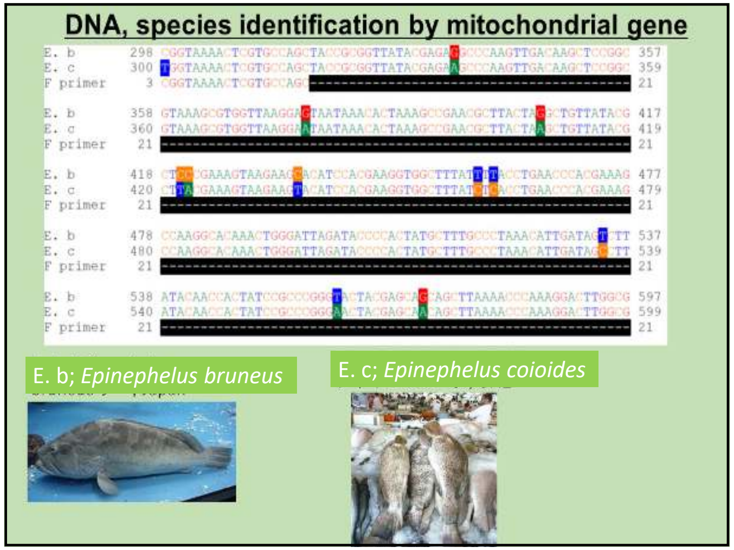
10


Defect of the conventional method of fish spawning ground identification in the ocean
1. Field survey for collection of spawners, eggs, larvae.
Fixed-point observation and collection of samples in the ocean
2. Species identification by DNA analysis of eggs.
Establishment of DNA analysis protocols to identify each species
Detection of species specific DNA characteristics of field collected eggs
Observation of newly-hatched larvae as supporting evidence of results of DNA analysis
3. Data analysis
Cross-check of location information and species information of eggs and larvae
Spawning grounds are identified for each species

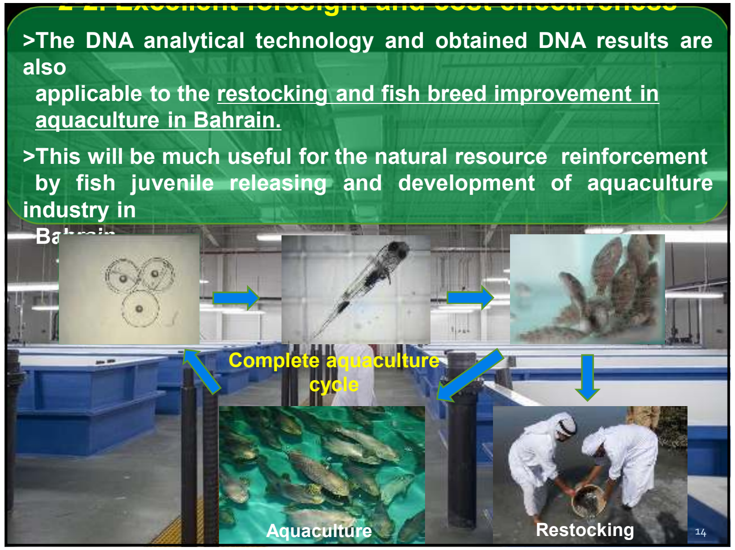
11


DNA, species identification by 12sRNA and ND5
partial mitochondrial gene
Red sea bream 1 ATAT TG A
Red sea bream 2 ATAT TG A
Red sea bream 3 ATAT TG A
Hamoor 1 ATAAGT A
Hamoor 2 ATAAGT A
Hamoor 3 ATAAGT A
We can see species specific sequence at 12sRNA and ND5 gene, which are conserved among species.

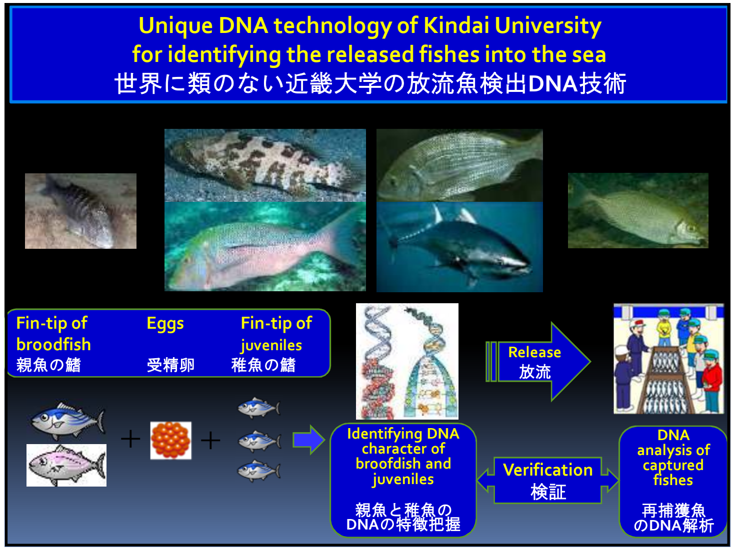
12


DNA, species identification by mitochondrial gene
E. b
E. c
F primer
E. b; Epinephelus bruneus
E. c; Epinephelus coioides

13


>The DNA analytical technology and obtained DNA results are also
applicable to the restocking and fish breed improvement in aquaculture in Bahrain.
>This will be much useful for the natural resource reinforcement by fish juvenile releasing and development of aquaculture industry in
Bahrain
Complete aquaculture cycle
Aquaculture
Restocking

14


Unique DNA technology of Kindai University
for identifying the released fishes into the sea
世界に類のない近畿大学の放流魚検出DNA技術
Fin-tip of broodfish
親魚の鰭
Eggs
受精卵
Fin-tip of juveniles
稚魚の鰭
Release
放流
Identifying DNA character of broodfish and juveniles
親魚と稚魚のDNAの特徴把握
Verification
検証
DNA analysis of captured fishes
再捕獲魚のDNA解析

15


Introduction, Spawning ecology of PBF
・Spawning season; from the end of June to August, at 21℃ or higher water temperature.
・Most of males can be sexually matured, in the spawning season while less females can be matured.
Female sexual maturation is the bottleneck of tuna spawning in captivity.
・High female ratio broodstock will be advantageous for successful production.

16

Sex Distinction of PBF

There is no any clear difference in the external morphology between males and females.

Conventional sex distinction method

・Observation of the gonad morphology.
Low survival after manipulation.

・Immunological detection of vitellogenin.
Limited to matured female.

Even if sex distinction is possible for adult PBF, it is very difficult the handling of large sized to fishes.

New technique is needed for PBF sex distinction.

17

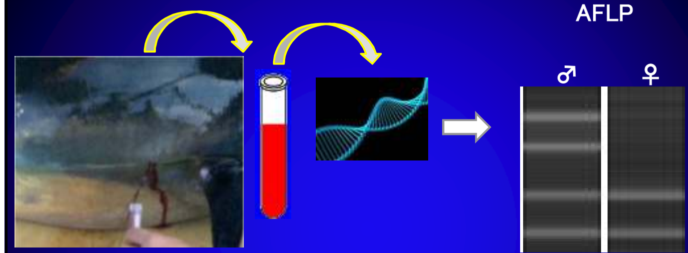
How about sex distinction by DNA test?

It is possible to know sexes in any ages, even in sexually immature fish by DNA test.
Young fish are relatively easy to handle with and transport.

Aim of this study;
Development of a PBF sex-linked DNA marker. It will enable us to organize a high female ratio broodstock in juvenile stage when they are easy to handle.

18

Materials and Methods



・3-year-old PBF, F3 cultured at ARIKU.

・4 males and 4 females were used for AFLP.

・Gonad phenotypes were recorded.

・Genomic DNA was purified from the blood.

・Then subjected to AFLP (Amplified Fragment Length Polymorphism, Vos et al. 1995) screening. Even in genome sequence unknown animals can be the target.

19

Male Characteristic Fragment was observed most of males by AFLP.

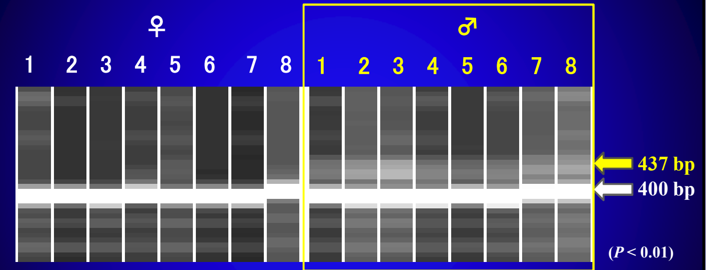
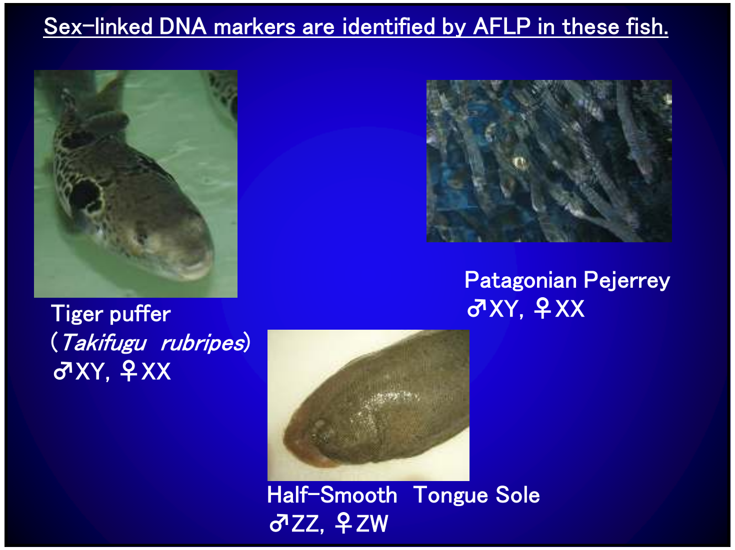


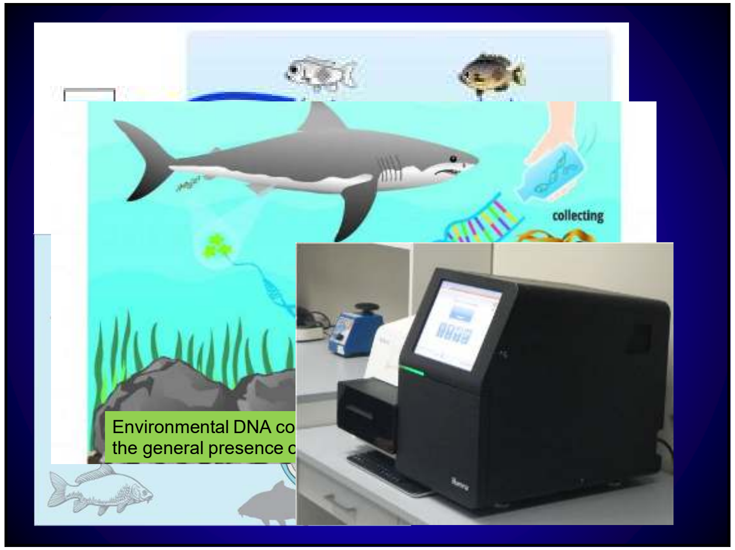
Figure 1. Male characteristic DNA fragment was observed by electrophoresis after AFLP, analyzed automatic DNA electrophoresis machine.

Agawa et al. 2011

20

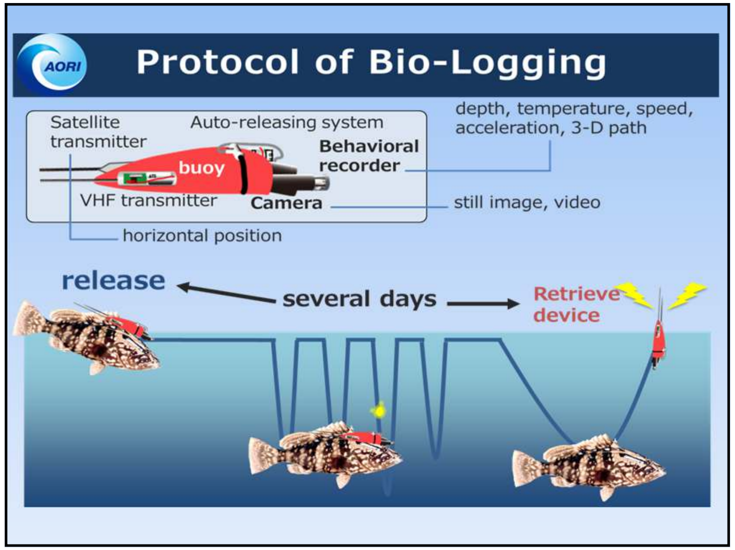

Sex-linked DNA markers are identified by AFLP in these fish.
Tiger puffer
(*Takifugu rubripes*)
♂XY, ♀XX
Patagonian Pejerrey
♂XY, ♀XX
Half-Smooth Tongue Sole
♂ZZ, ♀ZW

21

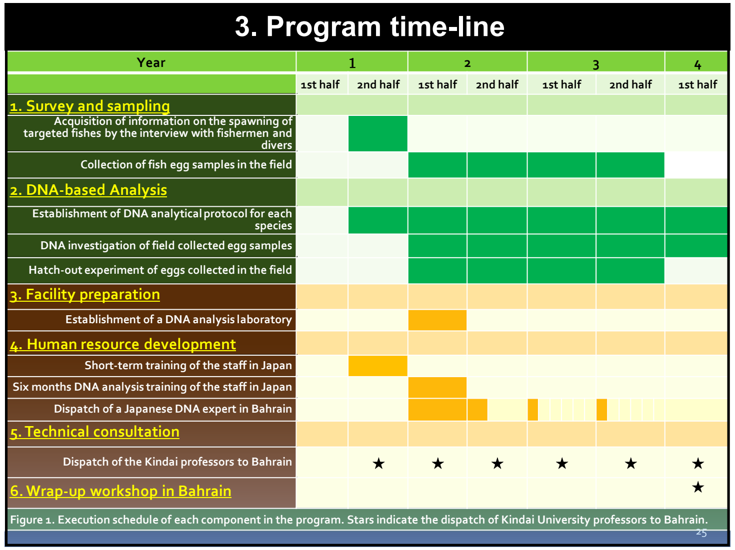

collecting
Environmental DNA co
the general presence c

22

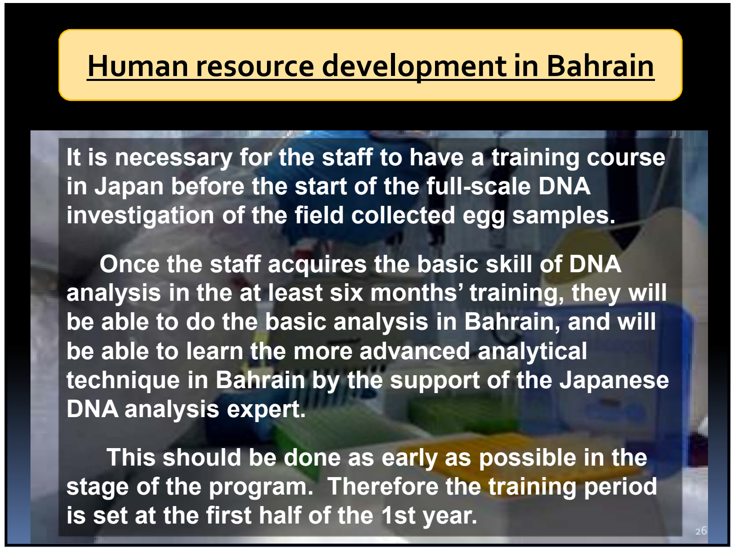
23


AORI
Protocol of Bio-Logging
Satellite transmitter
Auto-releasing system
Behavioral recorder
buoy
VHF transmitter
Camera
depth, temperature, speed, acceleration, 3-D path
still image, video
horizontal position
release
several days
Retrieve device

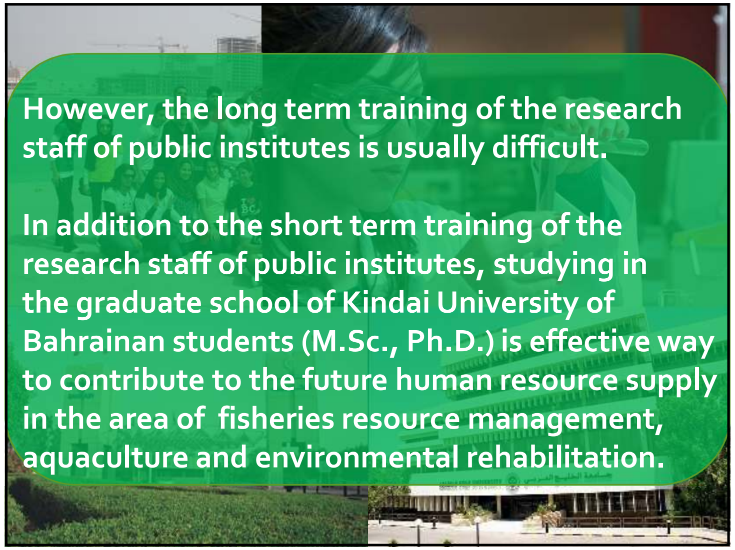
24


3. Program time-line
Year
1
2
3
4
1st half
2nd half
1st half
2nd half
1st half
2nd half
1st half
1. Survey and sampling
Acquisition of information on the spawning of targeted fishes by the interview with fishermen and divers
Collection of fish egg samples in the field
2. DNA-based Analysis
Establishment of DNA analytical protocol for each species
DNA investigation of field collected egg samples
Hatch-out experiment of eggs collected in the field
3. Facility preparation
Establishment of a DNA analysis laboratory
4. Human resource development
Short-term training of the staff in Japan
Six months DNA analysis training of the staff in Japan
Dispatch of a Japanese DNA expert in Bahrain
5. Technical consultation
Dispatch of the Kindai professors to Bahrain
★ ★ ★ ★ ★ ★
6. Wrap-up workshop in Bahrain
★
Figure 1. Execution schedule of each component in the program. Stars indicate the dispatch of Kindai University professors to Bahrain.

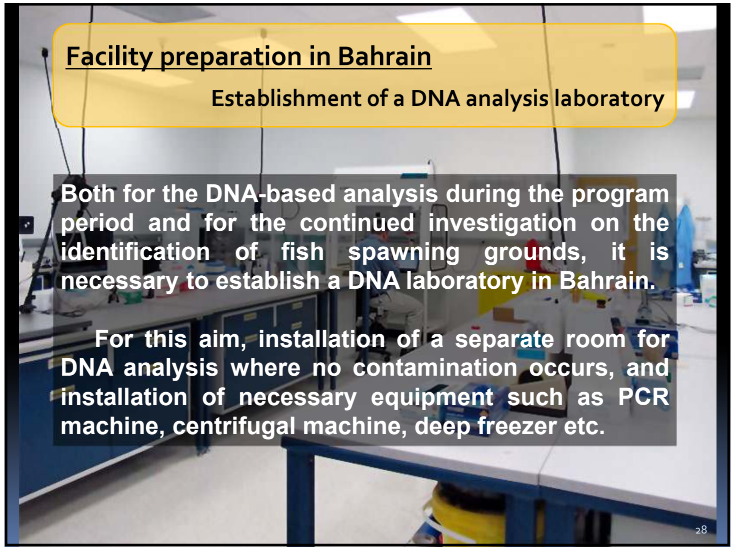
25


Human resource development in Bahrain
It is necessary for the staff to have a training course in Japan before the start of the full-scale DNA investigation of the field collected egg samples.
Once the staff acquires the basic skill of DNA analysis in the at least six months' training, they will be able to do the basic analysis in Bahrain, and will be able to learn the more advanced analytical technique in Bahrain by the support of the Japanese DNA analysis expert.
This should be done as early as possible in the stage of the program. Therefore the training period is set at the first half of the 1st year.

26


However, the long term training of the research staff of public institutes is usually difficult.
In addition to the short term training of the research staff of public institutes, studying in the graduate school of Kindai University of Bahrainan students (M.Sc., Ph.D.) is effective way to contribute to the future human resource supply in the area of fisheries resource management, aquaculture and environmental rehabilitation.

27


Facility preparation in Bahrain
Establishment of a DNA analysis laboratory
Both for the DNA-based analysis during the program period and for the continued investigation on the identification of fish spawning grounds, it is necessary to establish a DNA laboratory in Bahrain.
For this aim, installation of a separate room for DNA analysis where no contamination occurs, and installation of necessary equipment such as PCR machine, centrifugal machine, deep freezer etc.

28

29