ENVIRONMENTAL IMPACT OF DESALINATION PLANTS ON THE ENVIRONMENT

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ABSTRACT

Desalination of sweater is one of the main alternatives for the substitution of water shortage in the Arabian Gulf countries and other countries in the Middle East like Egypt. Although desalinating the seawater is costly, it is still an important option for compensating for the water shortage. Most of Gulf countries built power and desalination plants for water and power production. We should be aware of the fact that the effluent discharges from the plant back to the sea may have a negative impact on environment. They adversely affect the marine life and the ecology in the plant vicinity. The paper will present the negative impact of the desalination plants and how it can be minimized to keep the marine life and the ecological environment in a good condition.

Keywords: desalination, ecology, water quality, numerical models

1. INTRODUCTION

Desalination plants are being widely used in the Gulf countries as a main source of providing fresh water to overcome the water shortage. Some other Middle East countries have already started building desalination plants like Egypt which built a large plant on the Mediterranean coast. Most of the desalination plants are combined with power plants for power production. There are many desalination plants in the gulf region and there are plans to build more. Abu Dhabi Emirate, as an example, has 5 plants producing 550 MIGD water and 7,164 MW power. There is a plane to extend the capacity of the existing plants in parallel with building new ones to satisfy the rapid urban and industrial developments in the emirate. Figure 1 shows a general layout of the desalination plants in Abu Dhabi Emirate. The desalination plants in the Gulf region are built either on the coast of the Arabian Gulf or in the lagoons. They abstract the seawater through their intakes and discharge the effluents back to the sea through the outfalls. The effluent discharges have a high concentration of seawater temperature and salinity and other substances which may adversely affect the water quality in the plant vicinity species living in the area. The change in the water quality will impact the biota and the possible effects of the plant on water quality will be presented in Section 2. Section 3 will give a general overview on the rich ecological

environment in the Arabian Gulf waters, which may be affected by the desalination plants. The techniques used to minimize the effect of the plants on the environment will be discussed in Section 4. A case study on one of the desalination plant in Abu Dhabi Emirate will be presented in Section 5 and the Conclusions will be in Section 6.

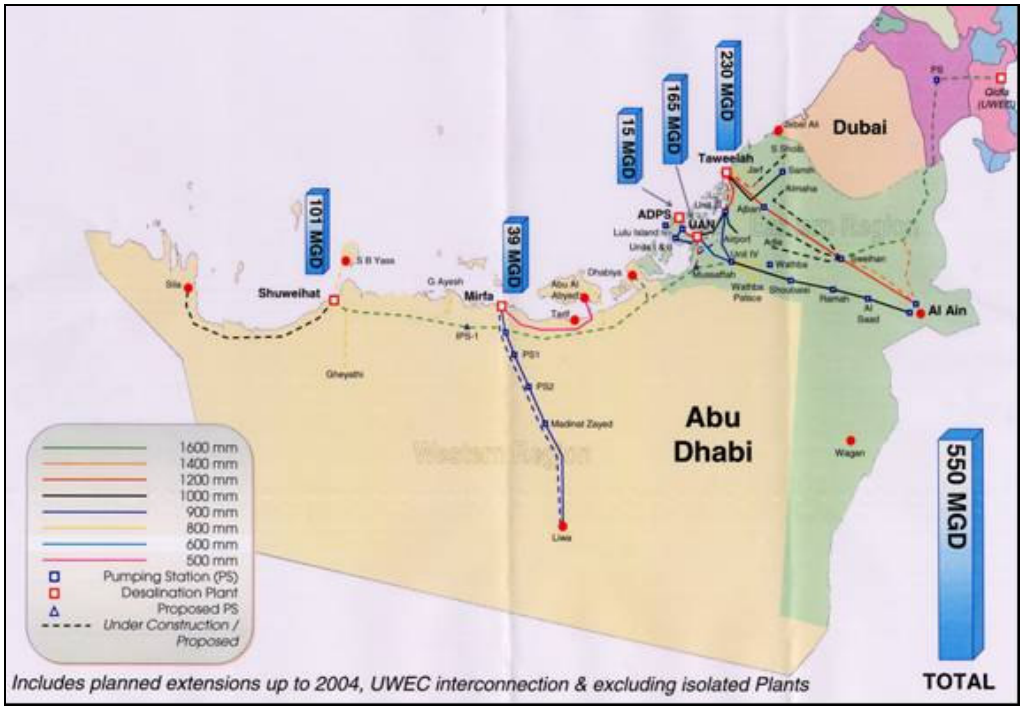

Figure 1: General layout of the desalination plants in Abu Dhabi

2. POSSIBLE EFFECTS OF THE EFFLUENTS OF POWER AND DESALINATION PLANTS

The effects on the marine environment arising from the operation of the power and desalination plant from the routine discharge of effluents. Water effluents typically cause a localized increase in sea water temperatures, which can directly affect the organisms in the discharge area. Increased temperature can affect water quality processes and result in lower dissolved oxygen concentrations. Furthermore, chlorination of the cooling water can introduce toxic substances into the water. Additionally, desalination plants can increase the salinity in the receiving water. The substances of focus for water quality standards and of concern for the ecological assessment can be summarized as follows:

- **Salinity:** High concentration of salt is discharged to the sea through the outfall of desalination plants, which leads to the increased level of salinity of the ambient seawater. Generally, the ambient seawater salinity in the Gulf is about 45 ppt and the desalination plants increases this level in its vicinity by about 4 to 5 ppt on average above the ambient condition.

- **Temperature:** If the desalination plant is combined with a power plant as the case in most plants in the Gulf area, the water temperature of the effluents of the power plants will be high and will increase the seawater temperature of the ambient water in the plant vicinity. In summer the ambient seawater temperature is about 35 °C on average and the power and desalination plants cause an increase in the temperature level in its vicinity by about 7 to 8 °C above the ambient condition.

- **Oxygen:** Dissolved oxygen in water in the plant vicinity is affected by the effluent discharges from the plant. The concentration and saturation of oxygen will decrease due to the higher temperature and salinity of the effluents. The concentration of dissolved oxygen depends on the seawater temperature in the plant vicinity, concentration of oxygen in the discharge and the mixing of the discharge with the ambient water.

- **Chlorine Concentration:** Chlorine concentration in the effluents of the plants depends on the dosing rates used in chlorination of the seawater. Increasing the concentration of residual chlorine may affect the water quality of the ambient water and hence, the ecological system. The concentration of Chlorine in the discharge depends on the number of dosing per day concentration of the Chlorine used in each dosing.

- **Un-ionized ammonia:** Ammonia is one of the substances of concern as unionized ammonia (NH3) is very toxic to aquatic species. In the environment, both ionized and unionized species occur. The ratio of the two species is a function of the pH. If pH is high then the concentration of the un-ionized ammonia is high and may affect the marine life.

The concentrations and levels of these substances in the plant vicinities depend on the size of the plant and the ambient seawater conditions. Generally the concentrations and levels of these substances should be within the water quality standards to avoid the negative impact on the environment.

3. DESCRIPTION OF MAIN ECO SYSTEM IN THE ARABIAN GULF

The main hydrodynamic forcing in the Arabian Gulf is the tide. Large areas of tidal flats are in the Arabian Gulf. These areas are flooded during high tide and dried during low tide. Tidal flats, subtidal areas and mudflats are good environment for many habitat and species. The following ecotopes are the main ecosystem in the Arabian Gulf region:

Mangrove swamps: They are extensively grown in the tidal flats. The combinations of the mangrove swamp and the large neighboring mudflat is an important eco system for many birds.

Seagrass meadows: Dense and spare seagrass were observed in large areas in the Arabian Gulf water. They differ in types and density from one location to another. Seagrass plays an important role in the Gulf marine environment. About 9 % of the Gulf's faunal texa are endemic to seagrass meadows (48 out of 530 recorded species). Of these, about half are molluses. Seagrass also play a major role as a sole food for endangered species such as dugong and the main food source for all marine turtle species, but in particular green turtle. Among the commercial species, the pearl oyster often settles in or near seagrass beds and of course many important fisheries species, such as shrimps. Seagrass helps in stabilization of mobile sands and therefore shorelines.

Corals: Coral areas in the Arabian Gulf are primarily controlled by the availability of suitable substratum. They are extensively found in the Gulf region with marvelous colures. Coral reefs are the most diverse environment of the marine realm. They are not only important biodiversity batteries, but also important for fisheries. While the mortality of a part of the coral reef system may have somewhat decreased the number of fishes.

4. TECHNIQUES TO MINIMIZE THE NEGATIVE IMPACT OF DESALINATION PLANT ON ENVIRONMENT

The role of the water and power research centers in the Arab countries; especially in the Gulf area is very important in minimizing the impact of the desalination plant on the environment. It is a big challenge to get use of the desalination techniques with a minimum adverse impact on the water quality and environment. A comprehensive environmental impact assessment study should be carried out before building a new desalination plant or extending the capacity of the existing one to limit the negative impact of the plant.

The Water and Power Research Center of Abu Dhabi Water and Electricity Authority has set up study procedures to be followed on the study of the environmental feasibility of building or extending the capacity of the desalination plants. These procedures are as follows:

4.1 Baseline Data Collection

Field measurements should consist of hydrodynamic, water quality and biological measurements as follows:

Hydrodynamic field measurements: Measurements should be carried out in the plant vicinity and should include water levels, current flow velocities and directions and flow discharges. The hydrodynamic measurements will be used in understanding the flow pattern in the plant vicinity and in the calibration of the hydrodynamic model of the area.

Water quality measurements: water quality measurements should be carried out to evaluate the concentrations of the substances of importance to the water quality and aquatic species. The substances include residual chlorine, dissolved oxygen, ambient seawater temperature and salinity, pH and ammonia. The measurements will be used to evaluate the water quality with regard to the water quality standards and used for the water quality model calibration.

Biological survey: A biological survey should be carried out in the plant vicinity to evaluate the ecosystem in the area. A detailed sampling grid should be constructed in the plant vicinity and surveyed by the ecologist. Data should provide a detailed description of local habitats and species. Photos on the ecosystem should be taken on the grid by divers with underwater camera. The value of the ecosystem in the study area can be evaluated by the ecologist based on the finding of the survey.

4.2 Develop the Numerical Hydrodynamic Flow Model:

The flow velocities and flow pattern is the main transport and dispersion mechanism of the effluents from the outfall. A numerical flow model simulates the flow pattern in the plant vicinity and the configuration of the intake and outfall of the plant should be developed and calibrated with the field measurements. In the Arabian Gulf the main driving hydrodynamic force is the tide. The model will reproduce the flow pattern which will be used as an input for the water quality model. The flow pattern from the hydrodynamic model can be used to predict the morphological changes of the shoreline due to the construction of the intakes and outfall of the plant.

4.3 Develop the Numerical Water Quality Model

A numerical water quality model should be developed. The goal of water quality modeling is to simulate the water quality of the waters around the plant, as influenced by the discharges from the power and desalination plant. The diffusion and dispersion of the modeled substances discharged from the outfall to the sweater will be simulated. The flow pattern from the hydrodynamic model will be used as an input for the water quality model as it is the main transport mechanism of the substances. The model calibration will be carried out by with the water quality measurements.

4.4 Evaluation of the Water Quality Results

Water quality model results should be evaluated against the water quality standards. If the modeled substances violates the water quality standards and may affect the marine life, the configuration of the intake and outfall of the plant should be modified (I.e. using pipeline instead of open channel) in the hydrodynamic model and repeat the water quality model computations until the modeled substances meet the requirements.

4.5 Habitat Evaluation Procedures

The Effect of the water quality change due to the outfall discharge should be evaluated against the nature of the habitat in the plant vicinity. The output concentrations of the modeled substances obtained from the water quality modeling should be compared with the species thresholds. If the study shows that the plant discharge will adversely affect the environment, measures should be taken to minimize this effect like changing the proposed configurations of the intake and outfall structures to redistribute the substances in the effluent discharge in a way to reduce their concentrations. Hydraulic structures can be designed and used to guide the flow pattern and flow velocity to control the diffusion and dispersion of effluents. This can be a solution to minimize the negative impact of the effluents on the environment.

5. CASE STUDY

5.1 Plant Description

Taweelah Power and Desalination Plant is one of the main plants in Abu Dhabi Emirate. The Plant is located at the coast of the Arabian Gulf, as it can be seen in Fig. 2.

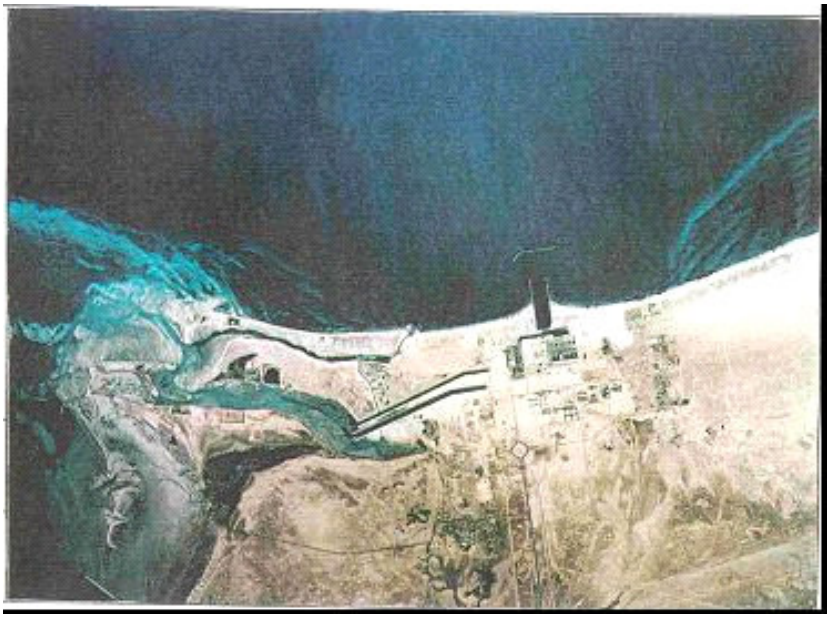

Figure 2: General layout of Taweelah plant

The plant produces 1000 MW and 100 MIGD of power and water, respectively. It is proposed to extend the plant capacity by 66.5 MIGD.

Water quality modeling and ecological study were carried out to evaluate the impact of the proposed capacity extension on the water quality and the marine life in the plant vicinity. An ecological reach and unique sea area with coral reefs, dense seagrass, mangroves and aquatic life is located at Ras Ghanada, which is about 1 km east of the plant intake. A biotopes survey was carried out in the vicinity of the plant to collect information on the species and habitat living in this area. Figure 3 shows the biotope map of the habitat in the vicinity of the plant.

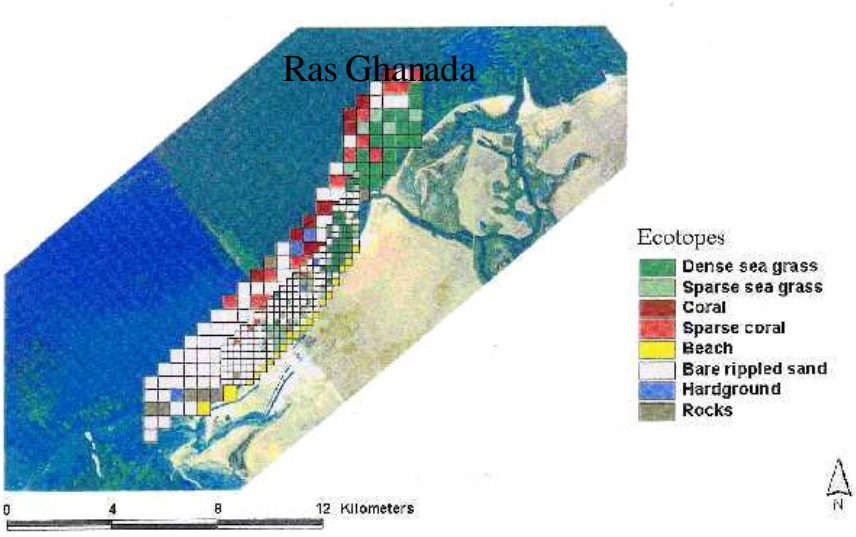

Figure 3: Ecotopes at the marine environment near Taweelah Plant

Data was digitized and mapped into a GIS. Ecological information was gathered on their specific sensitivities and threshold values for abiotic parameters, such as temperature, salinity and oxygen. A water quality model was developed describing the transport, diffusion and dispersion of a number of typical pollutants associated with the power and desalination plant. The results from the water quality model serve as an input for the study to assess the impact on the environment and quality of local habitats.

5.2 Set up of the Water Quality Model

The water quality model was set up after the feasibility of the hydraulic extension is confirmed. A number of the important substances for the marine life were modeled. These substances are the fraction of water from the discharge, age of water from the outlet, dissolved oxygen in water and chlorine concentration. Modeling considers the effects of the loads of the plant discharges as given in Table 1.

Table 1: Concentration of substances in the outfall discharge

	Discharge concentration	**Peak concentration**	**Remarks**
Oxygen	2.68 (mg/l)	-	67% saturation
Chlorine low decay	0.15 (mg/l)	-	
Chlorine high decay	0.15 (mg/l)	0.6 (mg/l)	Peak 1 hour at High tide
Acid wash	-	$5.7x10^{-4}$ (m^3/m^3)	10 minutes at high tide
Fraction water	1.0 (m^3/m^3)		

The basis for the water quality model is the hydrodynamic model. The water quality simulations use the computed water levels and velocities from the hydrodynamic computations as an input.

Three situations are modeled as follows:

1- The present situation (reference);

2- T03: proposed extension is a hybrid of RO + MSF plant. The intake of the RO is an offshore pipeline at about 3.8 km offshore and it uses the existing outfall. The intake of the MSF is onshore at about 1200m to north-east of the existing intake and the outfall of the plant is about 2 km from its intake.

3- T32: same as T03 but the intake of the RO is at 2000 m offshore and the outfall of the MSF is moved 2000 m further north east.

Figures 4 to 7 show the spreading and the distribution of the main substances influence the eco-system. In the figures the water quality results are presented as a contour plots comparing the extension scenario with the present design capacity for the two wind conditions. These substances are dissolved oxygen, residual chlorine, seawater temperature, and salinity, respectively. The figures show that the residual chlorine and seawater salinity will not be affected by the proposed extension in the ecologically rich sea area of Ras Ghanada. The seawater temperature and dissolved oxygen in the sea area nearby Ras Ghanada will be affected by the proposed extension. The figures show that no wind condition is the worse than with a daily wind cycle because of the longer residence times of the water.

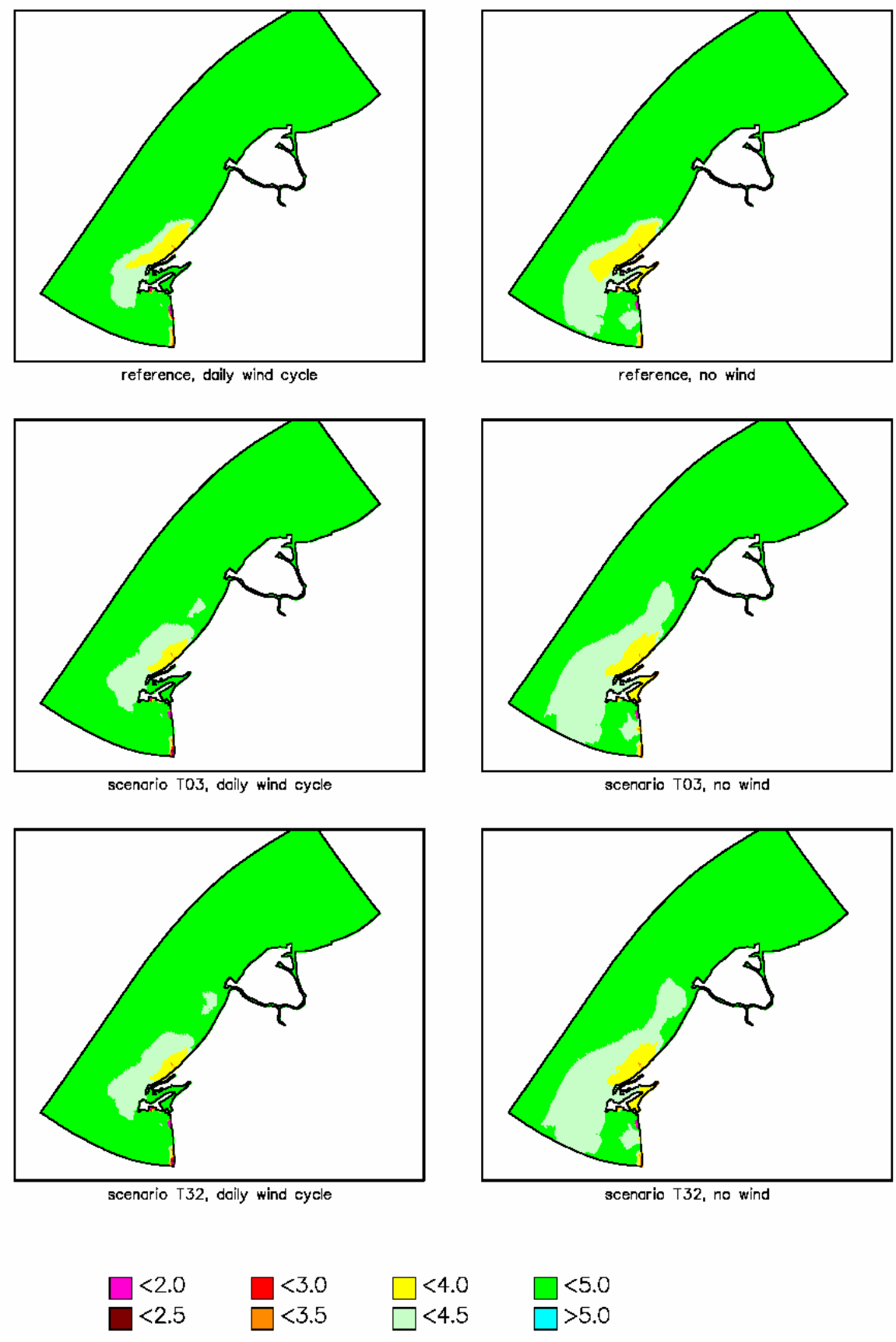

Figure 4: Dissolved oxygen distribution (mg/l)

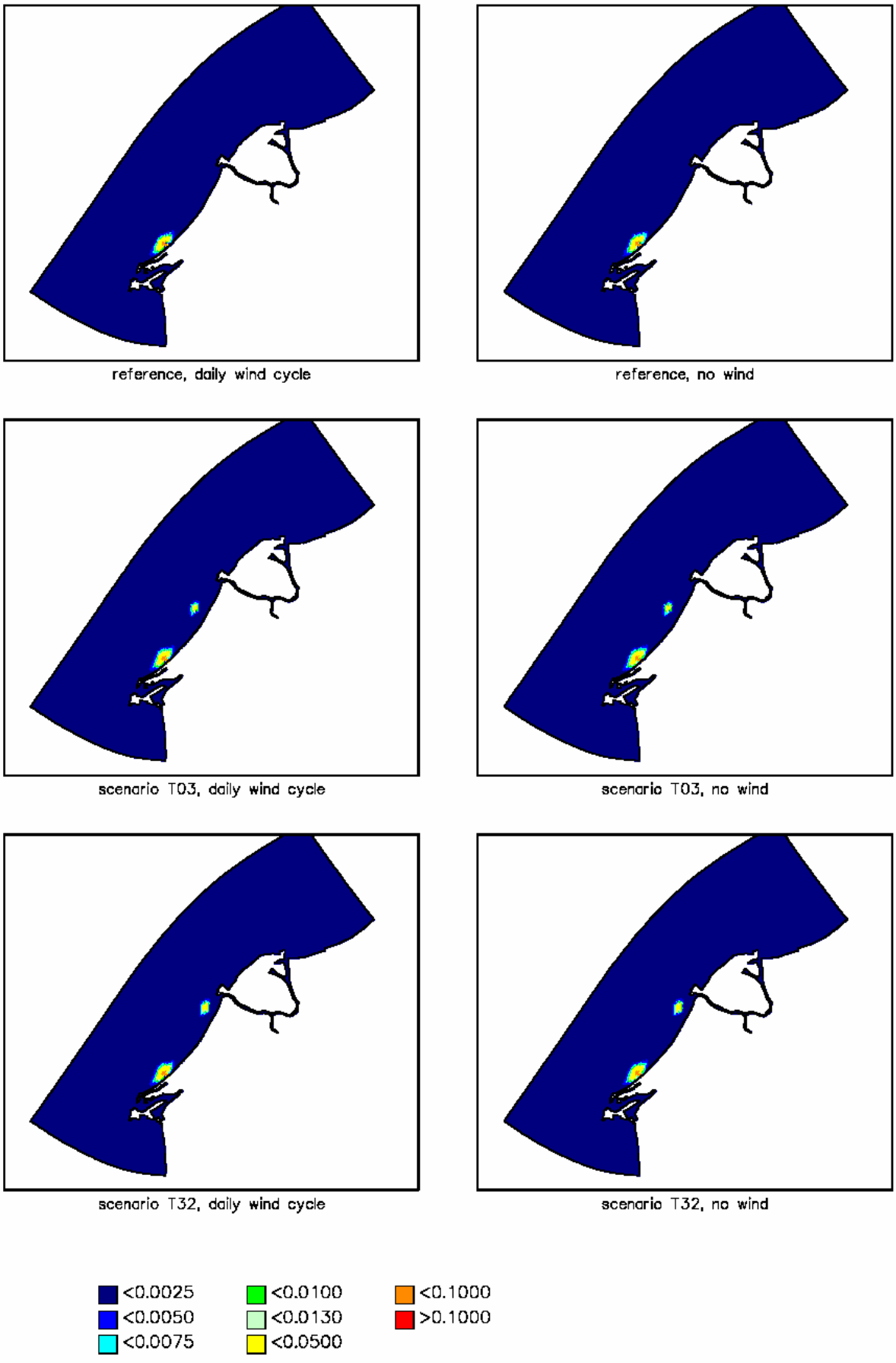

Figure 5: Residual chlorine distribution (ug/l)

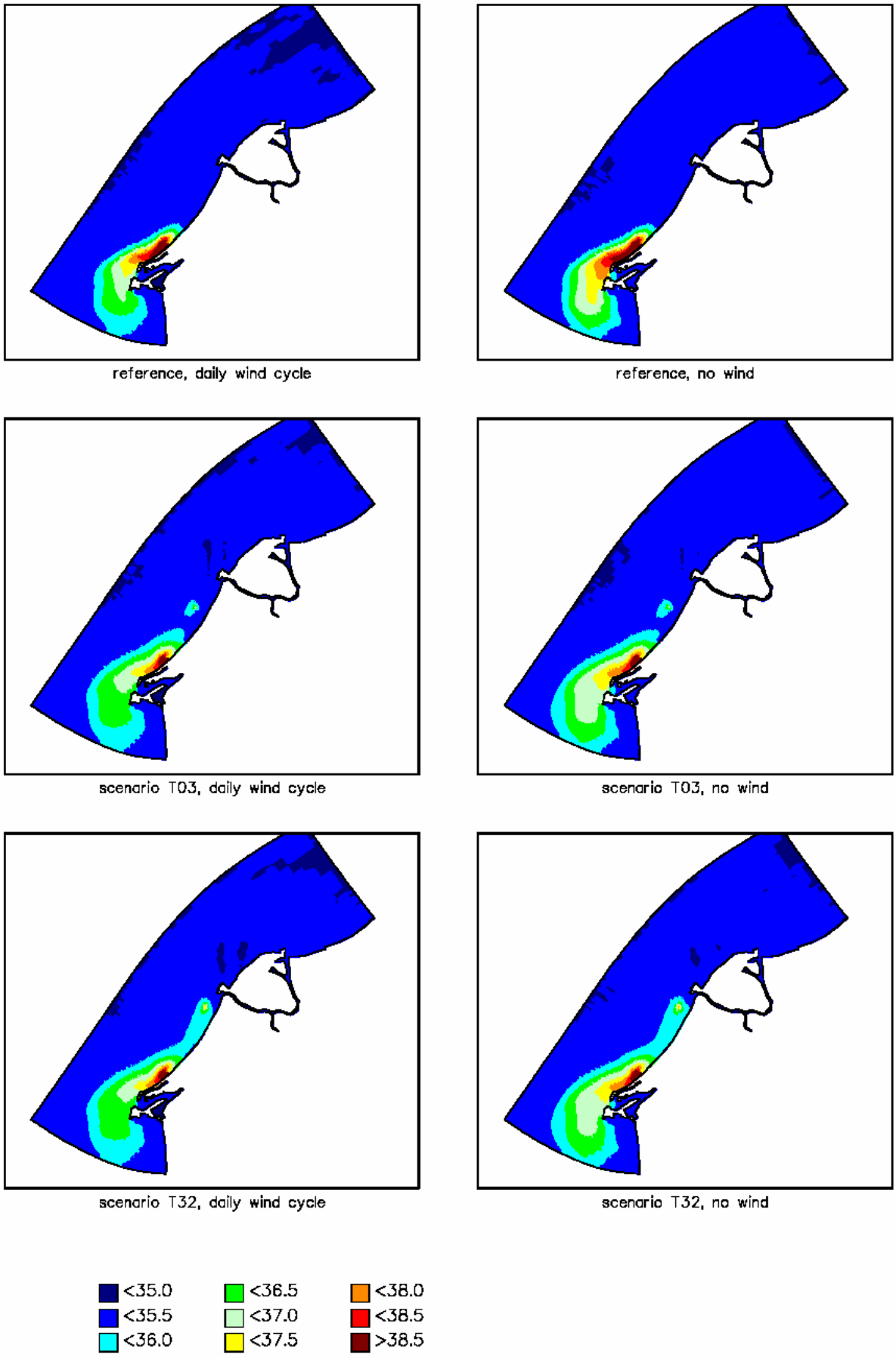

Figure 6: Temperature distribution (c)

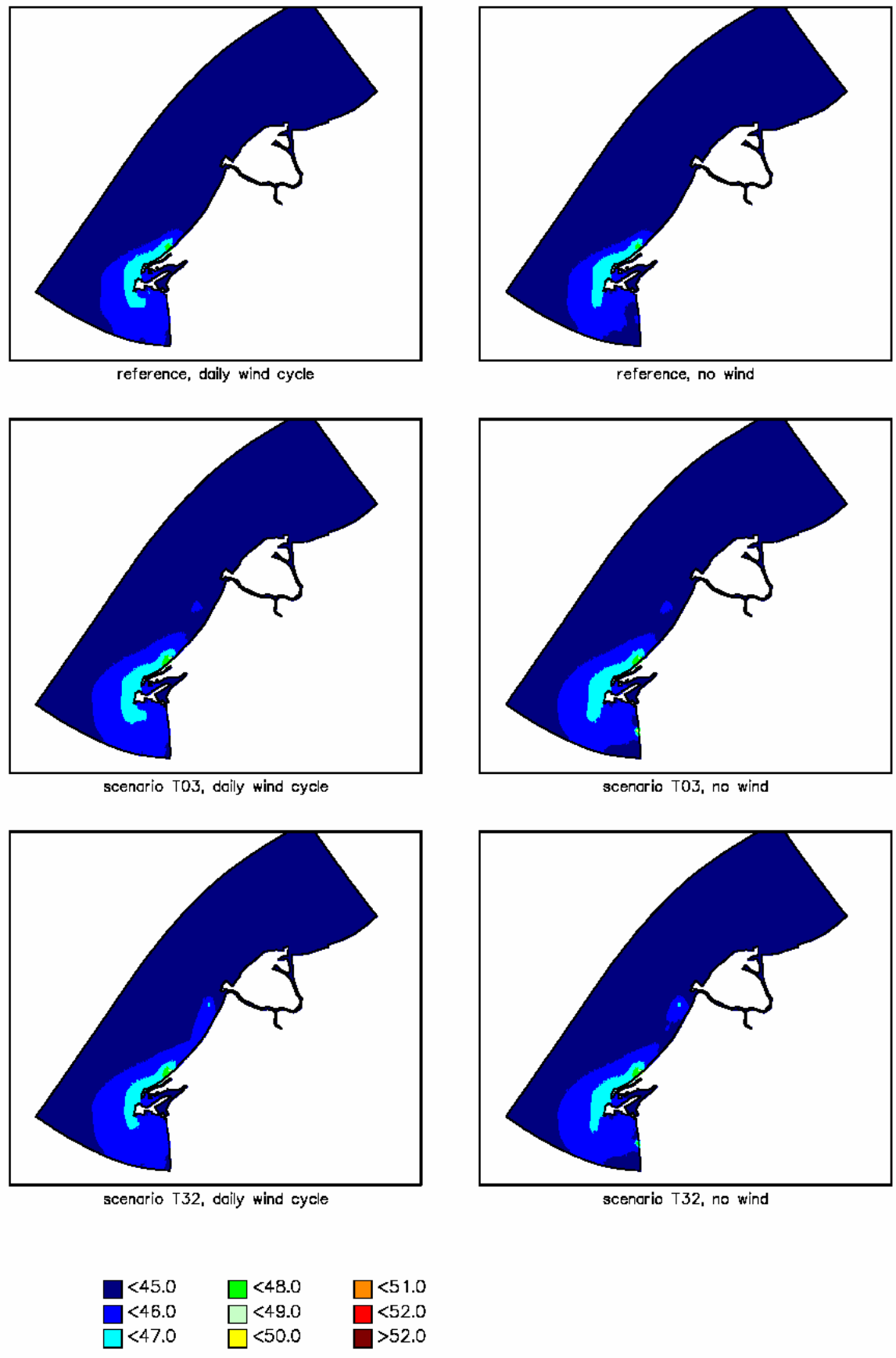

Figure 7: Salinity distribution (ppt)

Table 2 presents the area violating the water quality standards as computed by the water quality model. In the table the notations a and b indicate the daily wind and no wind, respectively.

Table 2: Summary of water quality results as compared to water quality standards. Worst case situations for each parameter is indicated as a shaded area

Scenario	Area violating WQ standard (ha)					
	Oxygen (<4mg/l)	**Chlorine (>13 ug/l)**	**Chlorine (>7.5 ug/l)**	**Temperature (>+2 ^{o}C)**	**Temperature (>+3 ^{o}C)**	**Temperature (>+5 ^{o}C)**
Reference-a	840	72	114	1871	1061	199
Reference-b	1313	74	119	2305	1396	280
T03-a	471	98	156	1944	726	90
T03-b	991	96	166	2456	1123	113
T32-a	452	110	169	1932	692	76
T32-b	1018	108	172	2560	1045	109

a) daily wind cycle b) no wind

The effect of change in the water quality due to the proposed capacity on the marine life was obtained based on the knowledge on the species in the area. From the figures and tables it can be seen that the extension will have an effect on the water quality and marine life, but it is acceptable by the environmental authority. In some other plants the area violating the water quality is not acceptable by the client or the environmental authorities. In such cases a re-design of the intakes and outfall layout should be adjusted. The outfall can be an offshore pipeline instead of its location onshore.

6. CONCLUSIONS

The very limited water resources in the Arab countries are very big challenges. One of the solutions is to desalinate the seawater using the desalination plants, which are mostly combined by power plants for power production. The effluents from power and desalination plants may adversely affect the water quality in its vicinity. This in turn will affect the environment and the ecosystem in the surrounding areas. Research and comprehensive studies to minimize the negative impact of power and desalination plants should be carried out in the water and power research centers and the water authorities. The Water and Power Research Centre in Abu Dhabi Emirate has set up procedures to study and minimize the negative impact on the environment. The procedures include field measurements, hydrodynamic and water quality study and habitat evaluation procedures.

It should be emphasized that the cooperation and exchange experience between the water research centers in this field will definitely lead to the optimum use of desalination plants with a minimum impact on the environment. Exchange experience and information on different desalination techniques used in the Arab countries are very essential.

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