



An environmental study of Ghulifqh Bay, Red Sea as a basis for the establishment of cage culture of fish in Yemen

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ARTICLE INFO

Article History:

Received: April 19, 2021

Accepted: April 29, 2021

Online: April 30, 2021

Keywords:

Ghulifqh Bay,
Yemen,
aquaculture,
cage culture,
environmental factors

ABSTRACT

A comprehensive environmental study on the Ghulifqh Bay, Red Sea as a basis for the establishment of cage culture of fish in Yemen was undertaken including physical factors, type of soil, biodiversity, pollution, and the density of population in the region and their professions. Results showed that the rainfall rate is about 40 mm/y, while the rate of evaporation is 24 mm/y. In winter, the wind reaches its highest speed recording 18 knots in a south-southeast direction. It was noticed that the maximum speed of water currents was 6.3 km/h to the north, while the highest tide was about 60 cm, and the spring tide ranged between 25-75 cm. The bay coast is a mixture of sand materials, where the wide areas are coated with clay, while a layer of grass mostly covers the coast by which little pollution is hence guaranteed. The Bay is characterized by high biodiversity, where the density of marine phytoplankton is very high, with large groups of other marine organisms, especially fish and some crustaceans. In addition, a high diversity of pelagic fish species are inhabiting the bay, and this is a good vital indicator that the environment of Ghulifqh Bay is a suitable habitat for fish. The location of the bay protects it from environmental hazards. Additionally, the earthy dam on the western border of the bay breaks the currents and reduces any negative impacts. Thus, the bio-environmental factors are important indicators to guarantee the qualification of the region for a rearing fish project in cages. In this context, the current study proved that the Ghulifqh Bay is a promising area for aquaculture projects in cages.

INTRODUCTION

The fishery resources including aquaculture have an influential importance on the economy of the countries, especially those with marine coasts and/or inland waters. They support the national economy of the country and the food security. With the decline of fish production, fish farming projects and systems have been adopted and are in force in all countries to fill the gap between production and consumption. Nowadays, aquaculture projects are greatly expanded using all farming systems and modern techniques to support and increase fish production from the wild. The International Food and Agriculture Organization (FAO) noted that fish farming is the only solution to enhance fish production and fill the global food shortage, especially in the countries of Africa, and it would be the main fish resource within the next few years (Al-Mahdawi *et al.*, 2010).

Although aquaculture has been receiving a great attention globally, yet Yemen has not given that much concern except for one shrimp farm that uses earth ponds. Moreover, the environmental studies are very sparse, especially those considering bays and gulfs that would show the suitability of those areas to establish cage culture of fish projects as well as the ecological studies that regard farming and rearing the marine fishes.

The biodiversity of seas and oceans represents the basis specified in establishing all aquacultural projects, where the aquatic food chains and the biodiversity constitute the key elements needed to be studied to build sustainable development projects (**El-Gamal, 2005**).

The Yemeni coasts on the Red Sea are known for warm waters, prosperity and growth of coral reefs and mangrove forests as well as a diversity of marine life. All these features represent the shelter and protection for the larvae and young living organisms, and many adult marine fishes as well. Furthermore, both phytoplankton and zooplankton, the base of the food pyramid and the food web for all consuming aquatic animals, flourish in abundance.

Consequently, this work was conducted to present a preliminary scientific study to determine and choose the appropriate site and the best environmental conditions (biological and ecological) to establish cage culture of fishes in Yemen. Due to the limited environmental data on such projects, the Ghulifqh Bay was chosen to investigate its environmental factors to test its suitability for initiate an investment project for cage culture of fish. Furthermore, the current study was organized to sustain a database for further investigations on the attempts to establish huge economic and investment projects in Yemeni coast, that would guarantee a supported national economy, an achieved food security and a promoting sustainable development of marine resources.

MATERIALS AND METHODS

The preliminary environmental data were gathered to enrich researchers in concern of the present study from field visits, consideration of previous literature, and interviewing the fishermen working in the study area.

1. Study area

The Ghulifqh Bay is situated in the south of Hudaydah city, at a distance of 35 Km on coordinates of 42° 57.0' E and 14° 30.0' N (Fig. 1). The length of the bay extends about 16 km, and its width varies between 3 and 5 km. To the west boarder, a land bar of 2-3 Km width lies parallel to the eastern coast. The water exchange takes place from the northern part only (Fig. 1), and the bay is fully protected from the intensity and strength of direct water currents and winds. A plant coverage with many palm trees covers the bay where muddy and sandy coast and very little rocks are seen (Fig. 2).



Fig. 1. Map showing the location of the Ghulifqh Bay in relation to Hudaydah city.



Fig. 2. The coast of the Ghulifqh Bay.

On the coast of the Bay, the village of Al-Mabrouk is found, about 1 km from the coast from the end of the Bay, with a population no more than 300 people. Another village, with the name of Madian, has only 7 houses, with a population of about 30 people. In both villages, most of the people are working in fishing, agriculture and grazing. There are also some wild plant made-up nests established on the coast, used as rest sites for fishermen, preservation of fish and fishing equipments as well (Fig. 3). The fishing methods used are gill nets and small traps (Sakhwa) (Fig. 4) and large traps (petah), with small boats made of wood or fiberglass used in fishing operations in areas near the coast.



Fig. 3. Fishermen's nest.



Fig. 4. A small trap (al-sukhwa).

2. Field trips

Field trips were undertaken to selected areas in the bay to collect the following data: the population density and situation, ecological parameters, species composition and density for the plants on the coast, the pollution resources and its density, fish species composition and types of fishing gears and environmental data.

The data, dealing with the rain rates, evaporation rates, rates of precipitation, water current, wind speed and directions were obtained for the past several years from the annual statistical books.

3. Sampling

Seven sites were selected on the coast, from which samples were taken from the coastal soil and the bottom soil and the surface distance that extends from the coast to a 5 m deep. In addition, the lowest tide was measured to determine the distance of this depth in meters. The depths were measured by means of a marked rope in meters and a stone (the primitive method), owing to the lack of a modern depth measurement device. Moreover, the depth map obtained from Google Earth was considered (Fig. 5), where the readings were close to the depths obtained from field measurements.

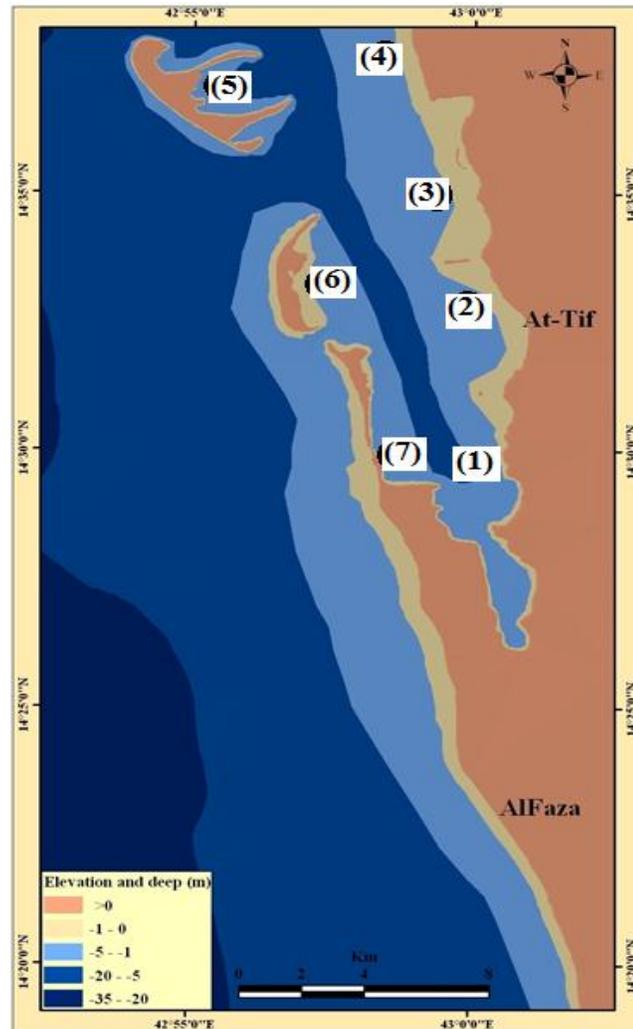


Fig. 5. Map of Google Earth showing the depths and stations selected on the Ghulifqh Bay.

RESULTS AND DISCUSSION

Physical parameters

Temperature is one of the major factors that affects the aquatic organisms as well as the chemical and physical characteristics of the water. However, in the bay, the temperature lies in the optimal range for most of the aquatic organisms. The estimated range of water temperature was 25 - 30° C, while the range of salinity was 36 - 38 ‰, and that of the dissolved oxygen in the surface water was between 4 and 5 mm/l. The high values of temperature and salinity are due to the high evaporation rate which characterizes the Red Sea.

Statistically, no difference was recorded in the amount of rainfall in Hudaydah governorate throughout the past years. A non-seasonal rain reaching high rates on the eastern parts and mountain heights are viewed, while sometimes it decreases to record no rain on the coastal strip of the Red Sea. In 2012, it reached an amount of 859.2 mm / year throughout the governorate (**Statistical Yearbook, 2012**) with an average of about 110.3 mm / year. The quantity on the Yemeni coast of Red Sea was about 40 mm / year, which is more or less stable around this value, and has no noticeable effect on the quantity or the level of water in the Red Sea. **Al-Mahdawy and Shoraem (2011)** stated that the rainfall on the Red Sea coasts of Yemen is usually few and in short batches, and often has average annual amounts of 50 mm / year. The southern areas of the Red Sea near the Gulf of Aden receives a decline in the amount of rainfall reaching about 43 mm / year.

The results showed that the amount of the evaporated water (Evaporation) was very high in proportion to the rainfall. This may be due to the fact that this area is exposed to the winds and high temperatures continuously. The evaporation rate ranges between 61 and 81%. In case that the amount of water coming into the sea is compared to the amount of evaporation, an increase was observed in the evaporation rates. Though the percentage of the evaporated or the lost water was greatly higher than the amount of water coming into the sea, this difference was compensated with the water currents coming from the Gulf of Aden and the Arabian Sea, mainly through the Bab Al-Mandab Strait, or by the flooding incoming to the Red Sea from the Tehama valleys. **Al-Mahdawi et al. (2002)**, **Al-Mahdawi et al. (2010)** and **Al-Mahdawy and Shoraem (2011)** mentioned that the region of the Red Sea is characterized by dry and rainy weather with dust storms, and the rate of the rainfall is much lower than the amount of the evaporated water, and the Red Sea is devoid of any estuary. The annual rate of evaporation of the Red Sea water is estimated at about 183-200 cm / year, the lowest rate of evaporation occurs in the southern part, which is about 24 cm / year, and the highest rate occurs in the northern and the far southern part of the Red Sea, due to the strong winds in these areas.

The annual average of the humidity ratio in the province of Hudaydah ranged between 18 and 71% (**Annual Book of Statistics, 2012**), because the evaporation rate is relatively high showing no significant differences in the average of humidity throughout the year. Additionally, the percentage of moisture in the coastal areas is fairly high and may reach 85 degrees.

Regarding the wind speed and its direction with water currents, they represent environmental factors of great importance when embarking on the establishment of projects to raise fish in cages. This is due to their direct impact on the durability of the

cages, that are determinants of the feeding process. It is clear that the highest wind intensity in Hudaydah governorate reached 18 knots towards the south (**Statistical Yearbook, 2012**), and the general rate was 11.3 knots, which is an acceptable rate and not very severe. The intensity of the winds in Hudaydah governorate represents a great variation in different seasons of the year. In winter and spring, the intensity of the winds is at its peak, and its direction is generally south-western in a north-east direction at known times, “where the winds blow in the southern part of the Red Sea from the south-southeast (SSE) during winter, while winds’ direction changes to blow north-western in the months of summer (**Al-Mahdawi & Al-Shawafi, 2012**). The Ghulifqh Bay is protected by a sandy bar that represents the western borders of the bay with a width of 3-5 km, extending from the south to the north parallel to the sea coast, acting as a natural windbreak to mitigate its intensity.

Furthermore, the intensity and direction of the water currents affect the nature of the construction and establishment of the cages. It was observed that the intensity of the currents is at its peak in winter, reaching 6.4 km / h from the southwest to the northeast. In winter, the average intensity of water currents was about 5.5 km / h. **Al-Mahdawi et al. (2007)** stated that the high salinity of surface waters are affected by the prevailing winds i coming from the north in summer, forming surface currents in a south-southeast east direction, at a velocity of 12 cm/second. In addition, the currents’ velocity increases in the south of the latitude 18o, and reach 14 cm/second at Bab Al-Mandab strait. In winter, as a result of the winds coming from the southeast direction, the low salinity surface water flows from the Gulf of Aden into the Red Sea, and the southern region is affected by surface marine currents towards the north, reaching a speed of 154 cm/second.

The intensity of the currents in the Ghulifqh Bay does not heavily affect the proposed cages to be established, because they do not rise to the level of breaking them. Moreover, the fact that the area is protected from the western side by an earthen bar that breaks the intensity of the currents and mitigates their negative effects is another inspiring factor.

It was observed that the highest tide affecting the Ghulifqh Bay is about 60 cm during the spring tide, which is a natural phenomenon (not by force or intensity) that affect negatively on the durability of the cages in the Bay. This, in addition to the other facts including that the bay is protected by its western borders that separate it from the open sea water and is an effective breaker and a natural buffer for currents and waves. **Al-Mahdawi and Al-Shawafi (2010, 2013)** and **Al-Mahdawi and Shoraem (2011)** indicated that the phenomenon of tides occurs in the Red Sea twice a day (half a day), where the highest spring tide level is about 90 cm with a variable nature, and there is a time difference of about 6 hours between the highest tide reached by the sea water in the north and that in the south. This means that the highest tide in the south of the Red Sea is matched by the lowest low tide in the northern Red Sea and vice versa. The tide levels vary from one region to the other in the Red Sea, and it usually ranges between 25–75 cm in many areas.

Type of soil and bottom of the bay

The soil of the coast and the bottom of the Ghulifqh Bay have a mixed composition (a mixture of sand and mud) in its widest areas, with a exception of few areas consisting of fossilized soil. In some areas the color of the soil tends to be light black, which may be due to the organic materials resulting from the biological reactions

of marine organisms and their decomposition or those that are deposited, or a result of human remnants (fishing operations) or animals. It is observed that there is no marine pollution in the coastal areas of the Ghulifqh Bay. This is due to the limited human activities in this area. No source of pollution was detected such as sewage, ports or oil tankers, docking places or other pollutants. Additionally, a few inorganic materials such as nylon bags and other types of garbage or the remnants of fishermen were observed. This result is similar to the findings of **Shodhari and Shoraem (2005)**, who stated that the Gulf of Ghulifqh coast consists of a mixture of sand and mud, and most of it tends to blacken due to the deposits of organic materials or the throwing residues of oils used in fishing boats.

In respect to the bottom of the Bay, it was plane with no rocks, steep slopes or growing corals.

The depth ranges of the Bay

Measuring the surface distance to determine its closure to the coast, where the 5 m depth is an appropriate depth for cages, it was found that the least distance to the 5 m depth was about 15 m at the fourth station (Table 1; Fig. 5). This was followed by station three, as the distance reached about 30 m, while in the other stations (1, 2, 5, 6, 7), the distance was very far, exceeding in some stations a distance of 100 m from the coast. Results revealed that stations 4, 3 & 2 are located in the eastern side of the Bay, and are qualified with all the basic requirements needed to establish a project to farm fish in cages, among which are: the good exchange and renewing water as well as the easy access to the cages. In addition, the coast is a good place to establish and create stores to save food, ice factory, processing factory and the other necessary requirements that support the project. In general, the bay is a good site for constructing the project, and the fourth station comes at the forefront, followed by the third and then the second. As the proximity of the project to the coast helps to harvest the crop and market it with little effort and costs, while providing services and monitoring in an easy and economical way.

Table 1. The studied stations and their distance from the coast (m) to a depth of 5 m.

Station	Distance from the coast	Notes
1	200	The end of the bay, the lack of renewed water & the difficulty of access and the provision of services.
2	100	East of the bay, good renewed water & far a bit for service delivery.
3	30	East of the bay, very good renewed water & not far, can provide services.
4	15	East of the bay, excellent renewed water & easy access and service delivery.
5	60	West to the bay, moderate renewed water & difficult access and difficult service provision.
6	90	West to the bay, moderate water renewing & difficult access and service provision.
7	150	West to the bay, weak renewing water, difficult access and provision of services.

Biodiversity in the Bay

The Ghulifaqh Bay has a high biodiversity, and this may be due to the good presence of plankton and its diversity, which represents the main link in the aquatic food web. Furthermore, its presence in water means the presence of other marine organisms, as they are important nutritional sources for many marine life. Findings showed a presence of two groups of phytoplankton, almost found in all samples, namely; flagellates and diatoms, and the dominance in this study area was for flagellates. The Pelagic blue-green algae of the order Cyanophyceae, especially the genus *Trichodesmium*, are also present, which form an important part of phytoplankton in tropical regions. Several other types of algae like *Phaeophyta*, *Chlorophyta*, *Xanthophyta* and *Rhodophyta* are abundant in all regions of the Red Sea, especially in its southern regions. The species *Turbinaria padina*, and some other algae are present in relatively small quantities, as they are among the species that live on rocky coasts. **Al-Surimi (2000)** recorded the presence of 283 species of phytoplankton and about 139 species of zooplankton, as well as large numbers of algae, of which the dominant species are four main types, which amount to about 446 species (Table 2). **Shodhari and Shoraem (2005)** mentioned that there are 485 species of marine algae in the Red Sea, of all kinds, and nearly 50% of them were detected in the southern part of the Red Sea.

Table 2. The number of algae species recorded in the Yemeni Red Sea coasts.

Types of algae	Number of groups	Number of species	.Availability%
Green	15	108	14.2
Brown	8	72	16.1
Blue green	15	64	14.4
Red	1	202	45.3
Total	446	39	100

In addition, the presence of different zooplankton groups, such as crustacea, macrophages, foraminifera, which belong to the class Sarcodia of the carriers of silicic or calcareous shells with polyps, as well as Radiolaria, belonging to the same previous class. Some species of Ciliata have also been seen, with a chitinous protective plate and a trumpet-like body.

A number of crustacean groups, like copepods, were recorded in the studied area with some gelatinous animals and planktonic larvae which are present in high proportion in tropical and subtropical waters (**Shodhari & Shoraem, 2005**).

Results revealed the growth of different types of sea grasses and seaweeds over the soft substrates in intertidal areas. Due to its importance as one of the richest and most productive environment, it is called sensitive environment. In addition, the presence of approximately 11 species of seaweeds were allocated along the Red Sea coast in shallow

waters, in the form of stems or rhizomes and roots on the land adjacent to the coast. Moreover, some flowering plants are observed capable of living underwater in the marine environment. **Shodhari and Shoraem (2005)** mentioned that 8 types of seaweed were recorded on the Yemeni coast of the Red Sea, namely: *Halodule uninervis*, *Thalassia hemorichii*, *Halophila ovalis*, *Cymodocea serrulata*, *Enhalus acoroides*, *Cymodocea rotundata*, *Thalassodendron ciliatum* and *Halophila stipulacea*.

Al-Mahdawi et al. (2010) stated that the productivity of warm water from the grass cover is more prosperous, and the amount of productivity in the Red Sea is about 1500 to 3000 g cm⁻² y⁻¹. In addition, the aquatic plants and seaweed provide the shelter and food for many fish larvae and invertebrates. **Shudhari and Shoraem (2005)** indicated that the grassy areas in the Red Sea coast are supporting and shelter places for some types of economic shrimps such as *Penaeus semisulcatus*, and some types of fish such as: the family Mugilidae, horse mackerel and scads. Seaweed is suitable for feeding young green sea turtles and hawksbill

In addition, cephalopod species (squid, sepia and octopus) and *Cerithidae cingulato*, *Balanus amphitrite*, coexist with several groups of other invertebrates such as Sponge, Coeleterates, Echinoderms, and their presence was less than the rest of the species. There are also different types of snails (Mollusca) in Ghulifaqh Bay (Fig. 6), such as: *Nerita undata*, *Planaxis sulciatus*, *Terebralia palustis*, *Conus tessolatus* and *Nerita polita*.



Fig. 6. Some types of gastropods in Ghulifqh region

Isopoda crustaceans have also been observed in sandy areas at the coast in the intertidal areas such as: Amphipoda and Cirripedae, a member of the family Penaeidae, which includes different species of shrimps, plus few groups of crabs, and the hermit crab. **Shudhari and Shoraem (2005)** stated that shrimps are found most frequently in sandy and muddy areas and among mangrove trees and seagrasses. The previous authors also mentioned that, different types of crustaceans were found, starting from Copepoda, to commercial species that belong to the order Decapoda, and detected about 14 species of crustaceans in Ghulifaqh Bay of about 53 species of crustaceans on the coasts of the Red Sea. The most common crustacean groups were isopoda, penaeidae, cirripedea, amphipoda, hippidae, stomatopoda, alpheididae, portunidae, grapsidae, procellanidae, diogenidae and linuridae.

Echinoderms, such as sea stars and sea cucumber were observed, and the species *Astropecten* sp., *Asterias* sp., *Holothuria nobilis*, *Holothuria fuscogilva*, *Thelenota ananasa* *Holothuria scabra*, *Holothuria atra* and *Holothuria* sp. are common.

The high fish abundance in Ghulifqh Bay is a natural reflection of the abundance of plankton. Since all species of planktons, which fish and other marine life exploit for their food, are located near the light area of the bay, most pelagic fish groups are found in that area. This is an extra indicator for the suitability of the bay for aquaculture. Different and many commercial fish species that fishermen work to catch and market are abundant in the bay. These fishes include: mullets, Indian mackerel, anchovies, emperor, small spotted grunt, catfish, and a few number of *Djeddaba crevaela*. In addition to the presence of sepia, squid, shrimps and crabs, and the presence of small-sized fishes on the bay coast that are called ruffles, in addition to other types of marine life exploited by the industrial fleet.

Consequently, Ghulifqh Bay is considered one of the good places to establish a project specialized in culture fish in cages, because it has all the requirements for successful establishment of such projects. The success of such projects in that region will lead to the prosperity of the whole region and will attract more fishes to get their food, and this can turn the Bay into a good fishing area. **Al-Mahdawi et al. (2010)** indicated that establishing a fish breeding project in a specific area could develop it and make it an important fishery area to support natural fishing and the general fish production of the country.

Rushdi et al. (1994) and **Heba (1994, 1999)** mentioned that the Red Sea is characterized by the high diversity, but for the Yemeni coast, the fish abundance is more intense in the northern region making it a suitable area with good environment conditions for fishing and fish reproduction. The Yemeni coast of the Red Sea also has a high fish diversity, of which about 15 species are exploited by the artisanal fleet at a commercial scale. There are about 87 species of fish in the Red Sea, the bony fishes belong to 39 families, while there are 33 species of cartilaginous fish, and 3 migratory families that may include 31 species from the Indian Ocean. Marine Biology Research Center / Yemen stated that “there are about 416 species of marine fish found in the Red Sea and the Yemeni coast, in addition to the presence of many varieties of colorful ornamental fish that live and exist on / among the coral reefs.

CONCLUSION AND RECOMMENDATIONS

In the light of this preliminary environmental study, it could be concluded the suitability of the Ghulifqh Bay to establish a project for cage culture of fish for the following findings; the studied physical environmental factors do not represent any obstacle to the establishment of such projects, and also the specified bay is protected by an earthen bar that acts as a good buffer and current breaker. Moreover, the suitability of the soil type and the topography of the bay, and the relative proximity of the project to the coast, facilitate the provision of various services and the maintenance of the cages and their monitoring with little effort. The possibility of using the coast to build some facilities for the project (stores, management and guard rooms, a hatchery plant, and some auxiliary ponds) is attainable.

Ghulifqh Bay is distinguished by its biological diversity of different marine organisms, the availability of natural food, in addition to the presence of various types of commercial fish, which prompt the establishment of a commercial project to farm fish in cages.

It is recommended to conduct a more comprehensive study of the Bay as well as to conduct comprehensive environmental studies for the whole Yemeni coast of the Red Sea. This would identify the most appropriate areas for establishing projects for cage culture of fish. The participation of the country and the encouragement of the investors to invest in aquaculture projects and the rational exploitation of Yemeni coastal waters are also demanded to support the economy and ensure food security.

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