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المستخلص

البحار تلعب دور مهم في تحقيق التنمية الاقتصادية للشعوب وتوفير الغذاء الامن وتقليل الفقر. ولكن للنقص الشديد في التنسيق بين العوامل الخارجية والصحاب المصلحة (المنتفعين من الموارد البحرية) من مختلف القطاعات ادي الي حدوث نزيف للموارد البحرية الطبيعية. تأثير الكائنات الغازية علي الشعوب يفوق تاثير الكوارث الطبيعية من الناحية الاقتصادية. والكائنات البحرية الغازية استوطنت البحر الابيض والقادمة من البحر الاحمر عبر بوابة قناة السويس في الاونة الاخيرة وذلك بسبب نقص كمية المياه العذبة المنصبة من نهر النيل نتيجة لبناء السد العالي في ستينات القرن الماضي وتغير المناخ والتلوث البحري وتنمية وتطوير السواحل وكذلك لتعرض والتهديد بالانقراض للمفترسات البحرية مثل السلاحف البحرية والتي تتغذي علي الكائنات البحرية الغازية مثل قنديل البحر. والورقة تركز علي توضيح المعوقات التي تعوق الاستخدام الامثل للموائل البحرية للبحر الابيض المتوسط. وكذلك دراسة الاسباب التي ادت الي ذلك. ومعالجة ذلك من خلال الاعتماد علي التكنولوجيا الحديثة لمنع وتخفيض من حدة انتشار الكائنات البحرية الغازية وكذلك حماية المفترسات الطبيعية كمانع طبيعي. والاهداف الرئيسية هي تحقيق الفائدة الاقتصادية واستدامة الموارد البحرية.

Abstract

Oceans have significant importance in achieving countries' economic growth, increasing food security, and lessening poverty. However, a lack of coordination between externalities and stakeholders from various departments has caused adverse impacts on marine resources. Invasive marine species' impacts on countries' Gross Domestic Products (GDP) are higher than a natural disaster. In addition, they invaded the Mediterranean as a result of opening the Suez Canal and building the Aswan High Dams in the 1960s decreasing the amount of poured fresh water in the Mediterranean. Moreover, the number of natural predators such as sea turtles along the Mediterranean shoreline of Egypt has decreased because of marine pollution, climate change, and coastal development.

This paper focuses on identifying the challenges impeding the future harnessing of the Mediterranean services and goods. In addition, identifying reasons that led to. This research paper contains qualitative data to examine the significance of depending on developing technologies and natural deterrents of invasive marine species to attain commercial benefits and sustain marine resources as well.

Keywords: Marine Invasive Species, Great Bitter Lakes, Salinity, Acoustic Deterrents, Suez Canal.

1. Introduction:

Since the United Nations Conference on Sustainable Development in 2012, The Blue Economy notion has gained popularity. The blue economy has the same driving targets emanated from the 'Green economy' notions where oceans have significant importance in attaining countries' economic development, the social, and environmental targets (Sarjoon, 2021).

The challenges impeding exploitation of the marine resources are divided into two parts, firstly naturally exist because of the wrong notion where seas deemed as everlasting resources for attaining countries' economic goals (María Martínez-Vázquez et al., 2021), and absence of enough states' commitments to the requirements of the UNCLOS treaty (Shiiba et al., 2022).

The second challenge because of human activities, for example, coastal development, global warming impacts, and invasive species that collapse biodiversity and coastal habitats loss (Prakash & Verma, 2022).

The number of invasive marine species in the Mediterranean is about one thousand (Uysal, 2019). In addition, In the last three decades the total cost of the marine invasive species in the Mediterranean was about \$27 billion with annual cost about \$1 billion (Kourantidou et al., 2021).

Challenges impeding the future harnessing of Mediterranean services and goods are divided into two parts. The first challenge is, in retrospect, the reason of constructing the Suez Canal in 1859 was to connect between the Red Sea with the Mediterranean. Moreover, The Suez Canal opened in 1869. The positive attributes of such a connection has facilitated the speed of transportation of goods and the low cost of transportation between countries, decreased the

transit time, and GHGs emissions (Castellanos-Galindo et al., 2020)

What is axiomatic today is that the Suez Canal is considered a link that connects 3 continents namely Asia, Africa, and Europe. Moreover, the trade volume transported by sea represents almost 80 percent of the total world trade (Lee & Wong, 2021). Furthermore, the total number of ships crossed the Suez Canal in 2021 was 20,694 and approximately 1.27 billion tons (Suez Canal Authority, 2021), 12 percent of total seaborne trade (Baker et al., 2021; Martin, 2021). Undoubtedly, Ever Given crises in the Suez in March 2021, economic specialists have determined financial losses from the consequential blocking at \$9.6 billion per day, increasing across-the-board concerns of destructive impacts on the international supply chain (Ghosh, 2021). Furthermore, the Suez Canal is a main pillar of the Egyptian economy whereby the revenue of the Suez Canal was about \$5.3 billion in 2019 (Romer, 2022)

Meanwhile, Great Bitter Lakes (GBL) is situated in the middle of the Suez Canal its water density was considered a natural barrier to prevent invasive species to invade the Mediterranean because the (GBL) water density was higher than both the Red Sea and the Mediterranean but bypassing days as a result of runoff in the (GBL) the water density have diluted and then their salinity equalized with the Red Sea (El-Serehy et al., 2018) while the salinity of the Mediterranean increased after the rate of freshwater pumping to it decreased with the establishment of the Aswan high dam in the 1960s (Soliman et al., 2021). Furthermore, increasing the (GBL) water depths to accommodate the giant ships with big drafts has decreased the water salinity in the lakes

(Biton, 2020). Thus, decreasing the water salinity in the (GBL) have facilitated crossing marine invasive species the Suez Canal.

The second reason that enabled marine invasive species to invade the Mediterranean is the number of natural predators has reduced such as sea turtles and which feed on some of the invasive marine species for example jellyfish. Moreover, sea turtles according to IUCN Red List on the Mediterranean coast of Egypt are considered a threatened marine species and critically endangered. In contrast, Invasive Alien Species (IAS) Such as lionfish and which invaded the Mediterranean in 2012, and jellyfish bloom causing adverse impacts on public health and tourism activities (Castellanos-Galindo et al., 2020). Furthermore, jellyfish feed on indigenous species such as fish larvae and shrimps (Otero et al., 2013). Thus, they depleted the food web and cause cumulative impacts on biodiversity in the Mediterranean (Corrales et al., 2018).

Therefore, for a more sustainable ocean economy, cooperation between stakeholders with the government is required. Thus, blending management with science would control and prevent the spread of marine invasive in the Suez Canal that is through studying the movements of the marine invasive species by detecting them by using environmental DNA (Yip et al., 2021) or Underwater Autonomous Vehicle (UAV), and acoustic sonar (Martínez-González et al., 2021). Therefore, its spread can be reduced by depending on emerging technology methods, for example, electrical, acoustic, and hydrological deterrence (Castellanos-Galindo et al., 2020). In addition, this paper aims to address, and analysis of the reasons that led to the spread out of alien species from the Red Sea to the Mediterranean via the Suez Canal. Furthermore, it examines the

relevant deterrents and ways to limit and control their spread out. To, rehabilitate the East Mediterranean ecosystem.

2. Marine Invasive Species in the Mediterranean:

The main reasons for marine species' invasion of the Mediterranean are Suez Canal, vessels (ballast water and sediments, hull fouling), global warming, and fish farms. However, some marine invasive species attain economic profits in the Mediterranean fish market (Kleitou et al., 2022).

The sea surface temperature of the Mediterranean Sea in the last four decades has shown a warming trend (0.13 °C/y) above those specified by the Intergovernmental Panel on Climate Change (IPCC) (0.035 °C/y, 2016–2035). Moreover, the marine protected areas (MPAs) in the Mediterranean have been invaded by non-indigenous marine species. Therefore, they have caused a significant environmental, social, and economic impacts (Galil et al., 2017).

2.1 Untreated Ballast Water and Ships Fouling

Changing ships' ballast water either at sea or in ports transfers about ten thousand alien species on daily basis from one place to another. Moreover, the amount of ballast water transferred via ship from one country to another is about 10 billion tons annually (Saglam & Duzgunes, 2018). The entry of alien marine species from the Red Sea to the Mediterranean through the Suez Canal may occur either by a deliberated action from ships, for instance, changing untreated ballast water or accidentally adhesion alien species on the giant vessel's fouling underwater hull (Bereza et al., 2020).

The last extension of the Suez Canal in 2015 has helped in increasing the number of tons of

seaborne cargo transiting the Suez Canal because it targeted an economy of scale ships. Thus, this led to a significant increase in the number of tons transported compared to the number of ships transiting the canal (Bereza et al., 2020). However, the Suez Canal has contributed to a raise in the number of alien marine species such as lionfish and jellyfish that are transported through ships either by untreated ships' ballast water (Wang et al., 2022) or by ship's hull fouling that accumulated on the submerged hull. In general, the alien marine species have invaded the Mediterranean and caused adverse environmental, socioeconomic impacts (Atvur & Oğuz, 2019).

2.2. Bitter and Timsah Lakes

Historical Great Bitter Lakes (GBL) is named because of its high evaporation rates and low rainfall. In addition, the degree of salinity of the Mediterranean and the Red Sea was less than of the lakes. So, the (GBL) was a natural barrier, which prevents transferring marine species from the Red Sea to the Mediterranean. The (GBL) represents almost a quarter of the Suez Canal in terms of length and about 85 percent in terms of the canal's water volume (El-Serehy et al., 2018).

On the other hand, over time, the natural barrier has disappeared because the salinity of the lakes has decreased and neutralized with the Red Sea salinity (Hossain, 2018). In addition to, the new bypass for the Suez Canal (See Figure 1) pass away from the Timsah lake has helped the invasive species transit without passing through the Timsah lake which was natural barrier preventing the nonindigenous species to cross the Suez canal toward the Mediterranean (Bereza et al., 2020).

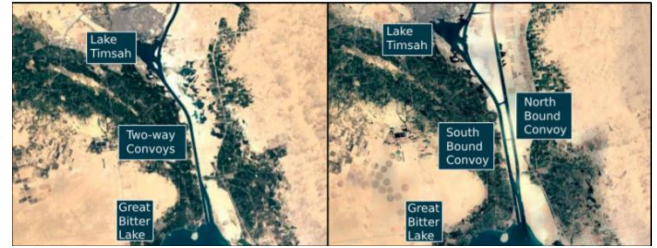
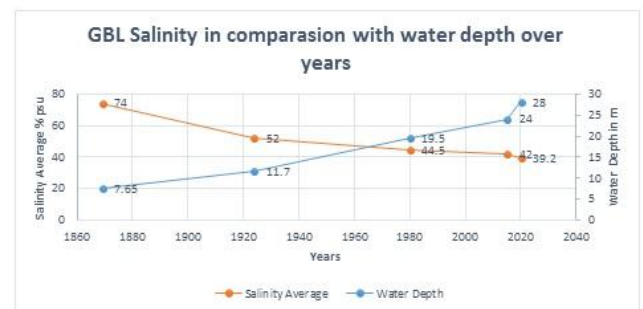


Figure 1: GBL before & after last expansion in August 2015

Source: (Bereza et al., 2020).

The water density in the GBL has been diluted for two reasons. The first reason is due to increasing the water depth in the Suez Canal expansions to enable the lakes to accommodate giant vessels with big drafts (WÜST, 1935) (El-Serehy et al., 2018) (Biton, 2020) (See Line Graph 1). The second is the increase in drainage freshwater, whether agricultural or industrial (Abd-El-aziz, 2021). Therefore, human activities and unsustainable use of marine resources have caused adverse environmental impacts.



Line Graph (1): GBL salinity changing in comparison with water depth over years

Sources: (WÜST, 1935); (El-Serehy et al., 2018); (Biton, 2020).

2.3 Aquaculture

In recent years, Egypt's production of fish farms has increased to fill the gap between the supply and demand of fish and secure food for millions of people. In addition, Egypt comes in first place in Africa in aquaculture production. Furthermore,

Egypt's yearly production of fish is almost 2million tons, about 1.6 from aquaculture and 0.4 million tons from natural resources, so the aquaculture produces 80 percent of the total fish production in Egypt, and about 24 kg per capita (FAO, 2021).

On the other hand, fish farms are a source of marine invasive species (Saber et al., 2022). Moreover, marine invasive species introduced accidentally as a result of, for instance, they attached with the desired introduced ones in fish farms (Mannino et al., 2017). In addition, the marine invasive species introduced due to the absence of adequate monitoring and legislation in some fish farms locations (Zahran et al., 2021).

2.4 Climate Change

In the last three decades from 1991 to 2020, the sea surface temperature (SST) of the Mediterranean coast of Egypt has increased approximately 1.5° C while in a century the average world temperature has increased by almost 0.75°C. Furthermore, in the Mediterranean approximately 52 types of invasive species, 47 of which come from the Red Sea via the Suez Canal and five from the Atlantic ocean (Gentilucci et al., 2021). Therefore, the raised in seawater temperature has helped in increasing the number of invasive species numbers from the Red Sea to the Mediterranean via the Suez Canal (Tang & Hadibarata, 2022).

Climate change and alien invasive species are the biggest factors causing adverse impacts on the Mediterranean marine resources and biodiversity. In addition, the average world temperature has raised about 0.74° C in the last century (Gentilucci et al., 2021). Moreover, recently marine invasive species have invaded the Mediterranean and they have decreased fish production and biodiversity. Thus, invasive

species have caused environmental and social impacts (Bonanno & Orlando-Bonaca, 2019). Furthermore, global warming impacts as the warming of the Mediterranean make conditions more favourable for the movement of species from the Red Sea toward the Mediterranean through the Suez Canal (Gentilucci et al., 2021).

2.5 Scarcity of Natural Predators

Sea turtles are considered a deadly marine trap for some kinds of non-indigenous species. Because jellyfish is a favourable target for sea turtles to feed on (See Figure 2) (P. Casale et al., 2021).

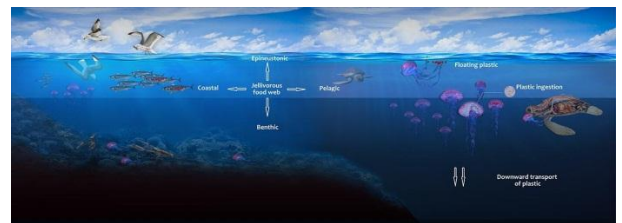


Figure 2. Green sea turtle feeds on jellyfish and floating plastic.

Source : (Macali & Bergami, 2020)

There are three types of sea turtles in the Mediterranean, namely (Green, leatherback, and loggerhead). Furthermore, the Egyptian Mediterranean shoreline is the preferred location for nesting and feeding sea turtles (green and loggerhead) (Casale et al., 2021) especially in Bardwell lake (Attum & Rabia, 2021).

However, there are many threats affect the marine turtle population in the Mediterranean either accidentally, such as boat strikes, illegal fishing (dynamite fishing), and bycatch or deliberate, for instance, marine pollution (plastic, oil, and sewage), coastal development, and climate change (P. Casale et al., 2021).

Egyptian fishers target sea turtles despite their consumption, and catching are prohibited and illegal nationally and internationally because their

valuable meat (National Marine Fisheries Service & U.S. Fish and Wildlife Service, 2021). Furthermore, According to the International Union for Conservation of Nature (IUCN) report, all three sea turtles are on the Red List of threatened marine species. Where green turtles are categorized as endangered while both leatherback and loggerhead are categorized as vulnerable (Abdelwarith & Jribi, 2020). In addition, the highest mortality rates of marine turtles in the Mediterranean because of fishing gears (Casale et al., 2018).

In terms of management and legislation, Egypt is obligated by international conventions regarding protecting marine species and maintaining biodiversity, such as the Barcelona convention 1976 and its amendments 2000 regarding Protection of the Marine Environment and the Coastal Region of the Mediterranean. Moreover, Egypt ratified the Convention on Biological Diversity (CBD) and the Convention on Wetlands (RAMSAR). Furthermore, In 2017 Egypt developed National Action Plan by a team of subject matter experts and supported by the collaboration between the Egyptian Environmental Affairs Agency (EEAA) with UNEP/MAP Regional Activity Centre for Specially Protected Areas (RAC/SPA). However, people's awareness and change in their behaviours, and capacity building are needed actions by decision-makers to protect endangered and vulnerable sea turtles (Naguib et al., 2020).

3. Mitigation of marine invasive species impacts in the Mediterranean

Egypt seeks to limit and mitigate the spread out of IAS along the Mediterranean coast of Egypt and at ports in order to protect the marine environment. Moreover, Egypt is a member state and committed by the Barcelona Convention

measures, which was adopted in 1976 and entered into force in 1978. Furthermore, under this treaty, member states, either separately or jointly, undertake to take all suitable actions to save and maintain biological diversity in the Mediterranean (Atvur & Oğuz, 2019).

In addition, relying on emerging technologies in the early detection stage could limit and mitigate invasive marine species' spread out. Because if they invaded a novel area, it is no longer possible to limit their spread out (Deák et al., 2021). Therefore, using all trials to eradicate marine invasive species and if not possible, all efforts will be on preventing their introductions (Cupp et al., 2018). In addition, using modern technologies as a non-physical barrier in monitoring and controlling alien invasive species will be a more appropriate method in terms of time and cost (Martinez et al., 2020).

3.1 Desalination plants

Egypt is turning to desalination plants as a strategic alternative to confront the expected decrease of freshwater from 53 billion m³ (BCM) to approximately 50 billion m³ (BCM) in the year 2025 (Tran et al., 2016) (See Line Graph 2). Moreover, the population increase, and the economic growth will increase the need for water. Therefore, relying on desalinated water will increase to achieve the united nations agenda regarding sustainable development goals in 2015 to eradicate poverty by 2030 (Kotb et al., 2021).

Increasing the salinity of the Bitter Lakes through relying on the disposed of brine water of desalination plants located near the Bitter Lakes (Castellanos-Galindo et al., 2020) such as Ismailia drinking water desalination plant in Timsah Lake (El-sharkawy et al., 2021). Yet, disposal of brine water from desalination plants changing both water salinity and dissolved

oxygen that has negative effects on the environment (El-Hady Kashyout et al., 2021). Meanwhile, the brine water disposed of by desalination plants in the (GBL) increases the water salinity. Therefore, increasing the salinity of the (GBL) will work as a non-physical barrier preventing invasive species to invade the Mediterranean (Castellanos-Galindo et al., 2020). However, this process should be under control and monitored to avoid undesired consequences on the environment.

3.2 Analysis Samples of Ballast Water tanks Environmental DNA

The first step is to detect targeted invasive species by analysing samples of ships' ballast water tanks by using environmental DNA (See Figure 3) (Rey et al., 2019) and tracking them by using SONAR where early detection will ease the process of surveillance. After that, a surveillance process via either on small scale, for example, using images or videos, or on a large scale (remote sensing) by using environmental drones or satellites. Thus eradicating and preventing targeted alien species of spread out, will be a quite easy process (Juanes, 2018).



Figure 3: Taking a sample of a ship's ballast water tank.

Source: (Rey et al., 2019)

The use of environmental DNA is distinguished from traditional methods in the surveillance process by the fact that it is low cost and high-

accuracy in discriminating between targeted species as well as in the process of a strong scientific evidence (Morissette et al., 2021). Today, Managing invasive species by using artificial intelligence (AI) image recognition either image or video can test the image of selected invasive species and obtain computerized results of targeted species within seconds (Morissette et al., 2021).

The International Maritime Organization (IMO) via the 2017 Ballast Water Management Convention has enforced guidelines and commitments to decrease the spread out of marine invasive species via ship ballast water, and hull biofouling (Wang et al., 2022). Moreover, Egypt has ratified the Ballast Water Management Convention since 2004.

3.3 Electric Barrier

Marine species barriers are divided into two types, physical and non-physical deterrents. In addition, physical barriers such as dams and weirs that prevent passing both of native and alien species (Zielinski et al., 2019). Moreover, electric deterrent is non-physical system and more influential and more damaging than other fish deterrent methods (Yalçinkaya et al., 2017). Furthermore, the electric barrier kills both alien and native species. Moreover, using the electric deterrent will be good in water that has low recreational activities and it is lower than physical barriers in maintenance costs (Johnson et al., 2021). However, electric and physical (weirs and locks) barriers are not always fully effective to prevent invasive species spread out (Treanor et al., 2017) because small fish may not be affected by the electric barrier (Suski, 2020).

The method of electric barriers is done by installing sensors in the barrier that differentiate between native and non-native fish by allowing

native fish to pass through spawning groups and prevent and eliminate the non-native fish from the passage. Moreover, There is not a single registered case of injury or death of people due to the electrical barrier (Zielinski et al., 2019).

3.4 Underwater Acoustic Barrier

The acoustic deterrent is a nonphysical barrier contained on speakers and sound bubbles curtains decreasing fish mortality because sound plays a key role in fish behavior a method used to guide native species to desired locations away from human activities by affecting the sensory system of fish by issuing attraction stimuli and at the same time decrease spread out of alien species by disgusting stimuli. In addition, Sound has innate advantages in comparison with light and odor because the underwater sound is weakened at a slow pace, long-range, ease of orientation, and directing not obstructed by low light or water turbidity. However, some alien species navigate away from acoustic stimuli. In addition, sound bubbles curtains are affected by the current and the movement of ships. Moreover, Acoustic deterrents are not fully controlling for some species and need quite relevant conditions. Furthermore, to avoid environmental and economic losses technology monitoring is required (Putland & Mensinger, 2019).

3.5 Pumping Dissolved CO₂ or Deploying Biocides at Sea

Deploying dissolved (CO₂) solution into water is the best emerging technology method to keep invasive alien species away from desired locations (Treanor et al., 2017). Moreover, eradicating invasive alien species is an almost impossible option while prohibiting their entry to a novel area is a better possible managing alternative. Furthermore, some fish avoid confined water areas abundant and concentrated

by CO₂ because CO₂ change their behaviour and performance. Therefore, using a threshold level of CO₂ will be relevant in confined areas such as ship locks and yards and a specific season of the year (summer). In addition, fish avoid areas abundant in CO₂ (Suski, 2020). Furthermore, it is a non-physical deterrent that cripples or fends fish and does not impede navigation in a waterway. However, it does not use in streaming water because it failed to meet CO₂ concentrations requirements (Cupp et al., 2021). Moreover, according to some marine invasive species, the threshold level of CO₂ did not influence their avoidance in case they were deprived of food for a while such as Largemouth bass, or because of their personality such as Bluegill. Moreover, a combination between CO₂ and another a non-physical barrier such as an acoustic deterrent could be a fully effective deterrent and at the same time put undesired environmental consequences on native fish into consideration (Suski, 2020).

Poisoning is suitable to eradicate invasive species on land such as red fox but deploying the highly propagated biocides at sea is quite harmful to the marine environment, food web, non-targeted species, and people's health. However, according to experts, deploying biocides in areas completely occupied by marine invasive species, and the presence of native marine species is quite rare is preferable to decrease environmental hazards (Giakoumi et al., 2019).

3.6 Do nothing approach

Early detection of alien species facilitates the process of combating them. But some invasive species for example *C. taxifolia*, when they invade the Mediterranean, at first bloomed and at the end collapsed, so business-as-usual or no intervention techniques and the "do nothing"

decision approaching maybe tackle this issue (Giakoumi et al., 2019).

4. Conclusion:

This paper aims to restoring natural barriers such as re-salting the GBL again, and marine turtle's rehabilitation along the Mediterranean coast of Egypt prevent the marine invasive species to invade the Mediterranean.

The combination between emerging technologies deterrents such as a combination between deploying the CO₂ with electric or acoustic barrier limit the spread out of marine invasive species in desired locations. In addition, applying the "Do Nothing" approach and waiting until the marine invasive species diminished without people intervention is the easiest and cheapest method but careful monitoring is required.

Decision making should take corrective actions to avoid undesired environmental consequences. Thus, by blending management with science would control and prevent the spread of marine invasive species via the Suez Canal. However, a discrepancy between scientists' and stakeholders' preferences for example the researcher prefers to publicize environmental examinations, and stakeholders lean to find governance resolutions.

In this regard, the government trade-offs between establishing projects to attain economic goals or mitigating environmental issues such as marine invasive species spread out.

5. Recommendations:

- 1) Cooperation between stakeholders (fishers, education institutes, shipping lines) and the government is required to decrease marine invasive species spread out.
- 2) Improving education and capacity building in dealing with marine invasive species disaster and their impacts on Mediterranean biodiversity.

3) Do nothing approach but careful monitoring by emerging technologies is required to avoid undesired consequences.

4) Monitoring Marine Protected Areas for marine healthy areas restoration.

5) Eradicating marine invasive species in novel Areas the early detection and a quick response are required.

6) Rehabilitation of endangered marine species such as marine turtles on the Mediterranean coast of Egypt.

Conflict of interest: there is no a conflict of interest. The conflict of interest "Not Applicable"

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