BioInvasions Records (2021) Volume 10, Issue 1: 181–187

Rapid Communication

An alarming mariculture breach in a coral reef: alien barramundi *Lates calcarifer* (Bloch, 1790) at the Northern Red Sea

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Citation: Stern N, Rothman SBS (2021) An alarming mariculture breach in a coral reef: alien barramundi *Lates calcarifer* (Bloch, 1790) at the Northern Red Sea. *BioInvasions Records* 10(1): 181–187, https://doi.org/10.3391/bir.2021.10.1.19

Received: 13 October 2020
Accepted: 9 December 2020
Published: 5 January 2021

Thematic editor: Stelios Katsanevakis

Abstract

This study delivers a continuous evidence of alien barramundi *Lates calcarifer* in the Northern Red Sea, a likely outcome of fish-cage escapees from the Saudi Arabian mariculture industry, located approx. 800 km to the south. Genetic mtDNA examinations provided solid evidence for an Australian ancestral origin. Debate for the ecological implications along with emphasis on needed biosecurity practices and management regulation are provided.

Key words: Eilat, DNA barcoding, biological invasion, aquaculture escapees, aquaculture managements

Introduction

Within the aquaculture industry, almost 30 million tons of food fish production have been recorded annually from the marine and brackish environments, i.e., under the mariculture subsector industry, targeting mainly shelled molluscs, finfish, and crustaceans (FAO 2018). Considering the continuous global increase in human population and the competition for land and clean water, many mariculture industries have been transferred further into the sea, in the form of offshore marine cages installations (FAO 2018). These offer an affordable and sustainable food production while providing livelihood and employment in regions where nearshore land and freshwater supply are scarce. The Red Sea is an elongated narrow sea, formed by the divergence of the African and Arabian plates and populated mainly with a diverse Indian Ocean biota, including a high rate of endemism (Tesfamichael 2012). Historically, fishing activities have constituted a major resource in the Red Sea, providing valuable supply of protein and income to local communities. Nevertheless, despite its potential asset for the Red Sea, mariculture industries are almost absent up to date, with the exceptions of some minor shell production in Sudan, previously active fish cages installations in the Israeli Gulf of Aqaba and an active mariculture in Saudi Arabia (Hariri et al. 2002). For the last three decades, Saudi Arabia has positioned itself as the most progressing nation in the Red Sea region in aquaculture developments, specializing in inshore ponds and offshore cages (Kitto and Regunathan 2012). The Saudi Arabian enterprises target mainly the commercial shrimp industry and several finfish species such as groupers (*Epinephelus* spp.), marbled spinefoot (*Siganus rivulatus* Forsskål & Niebuhr, 1775), gilthead seabream (*Sparus aurata* Linnaeus, 1758) and Asian Seabass or barramundi (*Lates calcarifer* (Bloch, 1790)) (FAO 2015). The latter, which even received a local branding title – AKOONA™ or the Red Sea Barramundi, have been produced to a remarkable biomass of 2525 tons during 2014 alone (FAO 2015). In this study, repeated catches of large adult barramundi individuals in the Gulf of Aqaba, Northern Red Sea portent a likely escapee from the abovementioned mariculture industry. A genetic examination is hereby presented, along with a debate on its probable ecological impacts on the fragile coral reefs of the gulf and recommendation for future managements.

Materials and methods

The first catch of barramundi was reported from June 2017 by an angler at the northernmost coastline of the Gulf of Aqaba, Red Sea. Following this report, periodic searches were carried out through local fishing groups on social networks and in a citizen-science group (https://www.facebook.com/groups/FishInvasion), as well as through informal interviews with recreational fishers. Since the first report, occasional catches of barramundi were reported from the same area every few months, in particular during the winter. The exact localities of the reoccurring catches were inside the artificial marina of the touristic district of Eilat, and at the Arava drainage outflow canal, Israel (29°32′52.82″N; 34°58′04.14″E and 29°32′44.25″N; 34°58′17.53″E, respectively; Figure 1). Among these records, a single specimen was obtained from a fisher after it was kept alive in an aquarium for several days, and an additional tissue sample was obtained from another specimen. Both samples were used for the genetic analyses. The whole specimen was measured, weighted and stored for following examinations at the Steinhardt Museum of Natural History at Tel Aviv University under the voucher SMNHTAU P.15952 (Figure 2).

Genetic analyses

561 bp of the mitochondrial gene COI ("barcoding gene") were amplified using the primer set Fish F2, following the protocol of Ward et al. (2005). The contiguous sequences were uploaded to BOLD platform under the accession vouchers ALIEN004-19 and ALIEN005-19. Genetic comparisons were conducted after retrieving all previously published sequences of barramundi from both GenBank and BOLD platforms, conditioning they had a clear designated sampling localities. Pairwise comparisons were

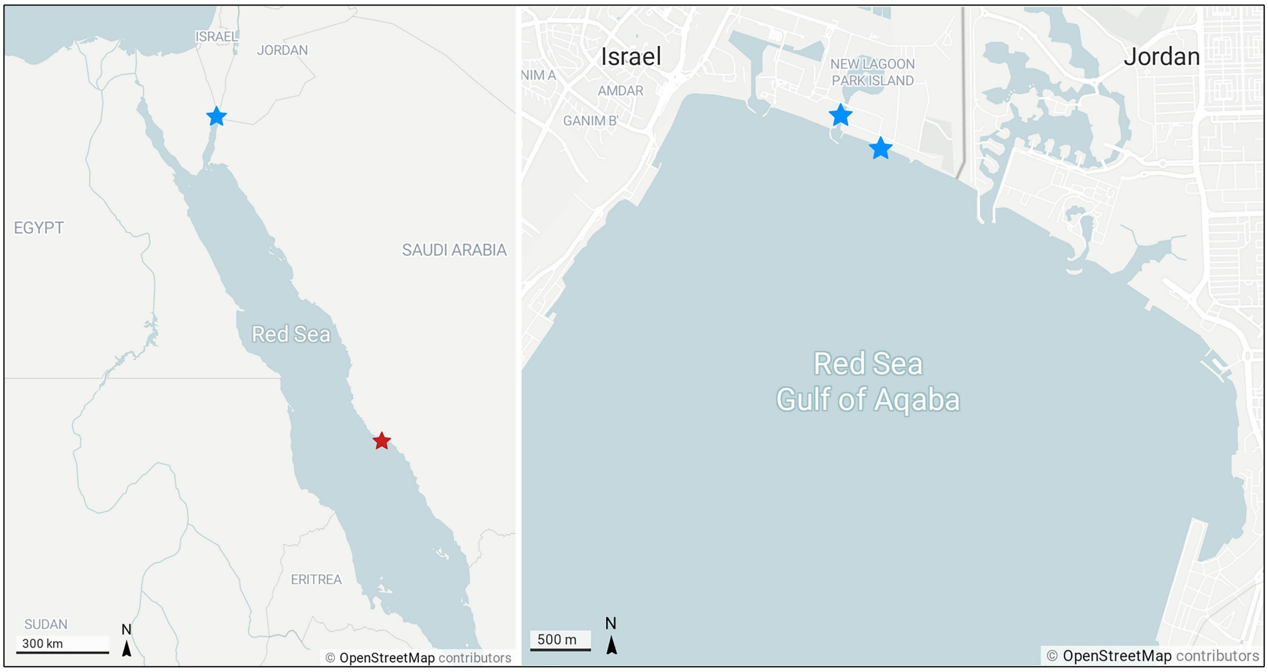

Figure 1. Left – Blue star indicates the Northern Gulf of Aqaba; Red Star indicate the Northernmost Saudi Arabian barramundi fish cage installations. Right – Northern Gulf of Aqaba, blue stars indicate the precise sites for the barramundi findings.

Figure 2. Barramundi *Lates calcarifer*, Red Sea, Gulf of Aqaba, 483 mm TL, SMNHTAU P.15952.

computed in MEGA X (Kumar et al. 2018), after finding the Kimura 2-parameter+G as the best fitted substitution model. The complete dataset, along with an outgroup individual of the Nile perch, *Lates niloticus*, was then evaluated for its haplotype diversity using the software DnaSP 6 (Rozas et al. 2017). Finally, to visualize the population structure through haplotype diversities and frequencies, a graphic median-joining un-rooted network was constructed for the genetic dataset using NETWORK version 5.0.0.3 (http://www.fluxus-engineering.com/sharenet.htm).

Results

Between the first report in the middle of 2017 to the end of 2020, more than 60 individuals of barramundi have been captured by recreational anglers in Eilat, with a max weight of 5 kg. Most of these catches however were reported only after the fish have been entirely consumed.

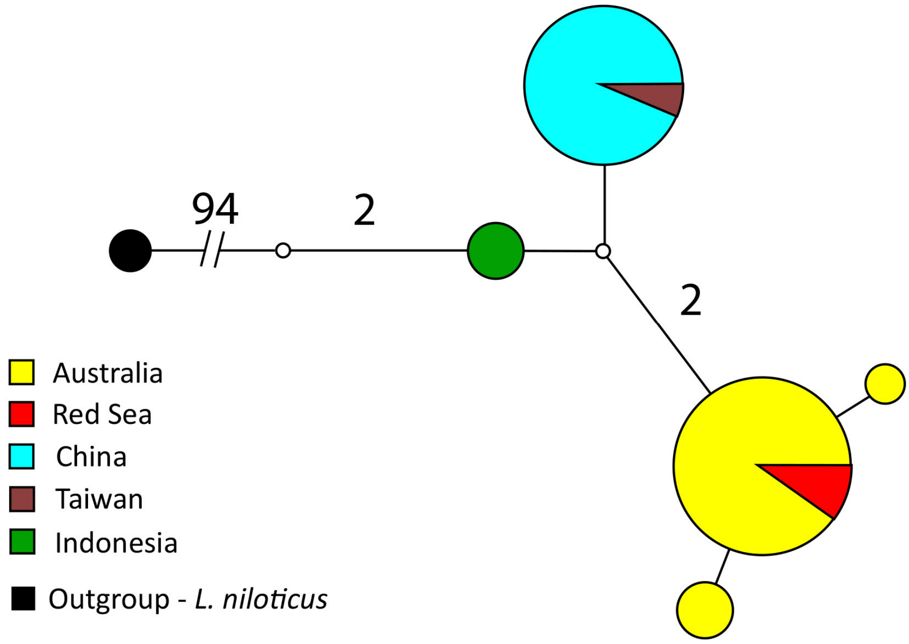

Figure 3. Median joining network for the COI haplotype of barramundi; the two invasive individuals of this study are depicted in red; numbers depict mutation steps between haplotypes above one; haplotype pies are proportionate in size to their frequencies.

Morphology

The specimen obtained for the morphological examination measured 483 mm in total length and weighted 1,473.3 g (Figure 2). It was a mature male with a gonad stage IV, according to FAO's classifications (http://www.fao.org/3/f0752e/f0752e05.htm). In addition, according to an age and growth study conducted by Stuart and McKillup (2002), this specimen is evaluated as two to three years old. Since the fish was kept in captivity for several days, it refused to eat, thus its entire digestive system was found empty.

Genetic assignment

Analyzing the mtDNA revealed a shallow genealogy within the "barcoding" COI gene over relatively wide geographic distances, with maximum genetic divergence of 0.72% between Taiwanese to Australian individuals. Outgroup congeneric species *L. niloticus*, differed by 20.4–20.7%. Out of the 43 investigated sequences, five haplotypes have been found, clustering into two geographical lineages: Australian and Chinese Sea populations that differed by 0.5–0.7% nucleotide variance. The two specimens examined in this study have been associated within the Australian lineage, thus confirming their ancestral origin (Figure 3).

Discussion

Possible impacts of invasive mariculture escapees

Along with the rapid advancement of global mariculture industries comes a great responsibility to minimize any possible negative environmental impacts (Secretariat of the Convention on Biological Diversity 2004; Diana 2009). Escapes of farmed fish to the wild, for example, may generate various undesirable impacts, such as disease transfer to wild biota (Glover et al. 2013; Girisha et al. 2019), genetically hybridize with local populations (Glover et al. 2012; Noble et al. 2014), or merely compete for local food reservoirs and ecological niches (Soto et al. 2001).

In this study, the escaped barramundis that originated from an Australian lineage, have been repeatedly observed within an artificial lagoon in Eilat, at the northern tip of the Red Sea. The semi-enclosed shape of the lagoon, along with an occasional freshwater discharge that changes local salinity levels, provides a secured shelter for the escaped barramundis at the end of their long, approx. 800 km, northward journey from the farm cage installations in Saudi Arabia (Figure 1). Such phenomenon of sheltering in artificial lagoons has been recently shown in nearby Jordanian coast in the Gulf of Aqaba, reporting a relic population of the mariculture gilthead seabream *Sparus aurata*, that are believed to reproduce in the Red Sea, although the local installation has been inactive since 2007 (Khalaf et al. 2020). In their Australian native habitat, a genetic study following an escape event has shown good survival rates for the escaped barramundi, with a concern of reproducing in the wild (Noble et al. 2014). Nevertheless, such scenario is rather unlikely in the Red Sea for the diadromous barramundi, which leave two major environmental concerns regarding its escape: (1) the risk of transferring aquaculture-related diseases and pathogens to the wild (Terlizzi et al. 2012; Girisha et al. 2019); (2) and exploiting the naïve prey of the vulnerable Red Sea coral reefs. Considering the average size of marketed barramundis, the large body sizes of the reported barramundis from Eilat and the known high trophic level of the species (3.8 ± 0.6 in Froese and Pauly 2019), it is highly probable that these escaped individuals are fully capable for predation in the wild.

Causes of farm fish escapees

Although harsh environmental events can be considered as the main cause for farmed fish escapees, they always have some relation with anthropogenic malfunction. In Norway, for example, despite that most of the escape events occurred during the autumn, where harsh weather is more frequent, the causes of these incidents were significantly dominated by structural failures (Jensen et al. 2010; Føre and Thorvaldsen 2021). The exact inappropriate maintenance of mariculture installations varies, and include untreated wear and tear of materials, an inadequate use of material to withstand possible damage to the nets by wild predators (sharks, dolphins, seals, etc.), and failure in mooring operations of the cages (Jensen et al. 2010; Arechavala-Lopez et al. 2018). Apart from the routine maintenance of the fish cages, it is also important to highlight operational failures during stock harvesting as a common agent for leakage of farmed fish to the wild (Mwanja et al. 2007; Baskett et al. 2013; Toledo-Guedes et al. 2014).

Raising biosecurity for prevention of mariculture escapees

Prevention and/or mitigation of mariculture escapees can be divided into two main actions: (1) regulations to ensure good practice in fish farms, (2) and development and enforcement of a standard of materials used in fish farming industry, minimizing the risk of escape events after harsh weather conditions. The first action includes mandatory reporting of escape incidents and meticulous training of fish farm operators (Jensen et al. 2010; Atalah and Sanchez-Jerez 2020). To best achieve this goal, it should incorporate an establishment of an escape-events commission where farmers, scientists, administration and fishermen are united to study the escapes incidents from the anthropogenic side, deduct the consequences and provide recommendations for future improvements (Jensen et al. 2010). The second action deals with the legislation of technical standards for all the equipment used in fish farms. Based on past experience, the aim of this action is to enforce the farmers to use the most adequate gear in a specific area, and should also include research & development practice to minimize escape events based on prevention (Jensen et al. 2010).

Last, although mitigation actions following reported escape events are not always achievable, local fisheries can prove valuable in recapturing the escapees. In the Western Mediterranean for example, it was shown that almost two-thirds of an escaped batch was recaptured by local artisanal fisheries (Izquierdo-Gomez and Sanchez-Jerez 2016). This suggests that after a known large-scale escape event, harnessing local fisheries can prove beneficial in mitigating the possible impacts of the event to local ecosystems. Collaborating with bordering countries, in regard to reporting such events through citizen science for example, should assist to monitor impacts of escapes at a regional scale.

To conclude, although the efficiency and productivity of the Red Sea mariculture industry should be further incentivized and developed, this industry must implement strict environmental safety actions, for the protection of the adjacent fragile and vulnerable coral reef ecosystem.

Acknowledgements

Authors thank Mati Moskovich, Shay Azulay, Oron Sharon and Kobi Tubul for providing the data of the observations, and Dor Attias for providing the specimens. Authors thank also anonymous reviewers for valuable comments.

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