IMMIGRATION OF FISHES THROUGH THE SUEZ CANAL[1]

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ABSTRACT

The number of Red Sea fishes found in the eastern Mediterranean amounts to 36 species. Twelve immigrants, namely: *Spratelloides delicatulus, Herklotsichthys punctatus, Tylosurus choram, Sebastapistes nuchalis, Epinephelus tauvina, Autisthes puta, Pelates quadrilineatus, Silago sihama, Rhonsicus stridens, Crenidens crenidens, Rastrelliger kanagurta, Scomberomorus commerson,* were found in the last 12 yr. The southward migration, from the Mediterranean to the Red Sea is almost negligible. Only *Liza aurata, Dicentrarchus punctatus,* and perhaps *Carcharhinus plumbeus* can be regarded as Mediterranean immigrants.

In studying the immigration of fishes through the Suez Canal, three zooecological areas must be taken into consideration: 1) the northern Red Sea; 2) the eastern Mediterranean; and 3) the Suez Canal itself in which many marine animals from the two neighboring areas have found a permanent habitat (Steinitz 1968).

The prevailing hydrographic conditions differ in these three areas, although the salinities and summer temperatures are to some extent similar (Morcos 1967, 1970; El-Saby 1968; Oren 1970; Oren and Hornung 1972). Temperature and salinity are the main abiotic factors influencing the distribution of organisms over large zoogeographical areas. Often they also have a decisive influence on the ecological distribution of species in various biotopes of an area.

The process of immigration is highly selective. Common species of the home seas are not necessarily successful immigrants in a new region. Similar effects have been shown to occur in many forms of colonization (MacArthur and Wilson 1967). The adaptation of a species to a new area requires adjustment of its reproductive processes, especially with regard to the correct timing of spawning in order to ensure suitable physical and ecological conditions for the development and survival of the young stages.

It is evident that the direction of immigration is mainly from the Red Sea into the Mediterranean (Figure 1). The possible causes of such one way immigration have been discussed elsewhere (Aron and Smith 1971; Ben-Tuvia 1971a, 1973; Por 1971a, b).

Thirty-six Red Sea or cosmopolitan species can be regarded as Suez Canal immigrants. Twelve of them were found within the last 12 yr. Evidently, immigration is a continuous process, and over time the probability of suitable species of fishes entering the Suez Canal and colonizing the new region increases. Time also plays an essential role in the biological processes of adaptation of the species to the modified conditions of life. More resistant species, endowed with greater plasticity of genetic characters, can form local "races" within a few generations by natural selection in the new environment (Kosswig 1974). But first they need a firm foothold on the other side of the Canal, geographically close to the parental stock and in places where conditions are not drastically different from their normal habitat.

Recently I had an opportunity to collect samples from the Gulf of Suez (Ben-Tuvia and Grofit 1973), Suez Canal (Steinitz and Ben-Tuvia 1972), and Bardawil Lagoon (Ben-Tuvia 1975a) which revealed interesting data on the distribution of immigrants. Many of the species which have successfully colonized the eastern Mediterranean, such as *Saurida undosquamis, Leiognathus klunzingeri, Upeneus moluccensis,* and *U. asymmetricus,* and which are abundant there, are also dominant species on the trawling grounds of the Gulf of Suez.

High percentage of Red Sea fishes found in the hypersaline Bardawil Lagoon on the northern coast of Sinai indicates that it may serve as a stepping stone in the immigration of Red Sea fishes into the Mediterranean, especially if we regard it as a part of the system of lakes and lagoons of the Isthmus of Suez (Por 1971a). Among 55

[1]This paper was read at the 17th International Zoological Congress in Monte Carlo, 25-30 September 1972; some changes were introduced to include more recent information on immigrants.

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Manuscript accepted June 1977.
FISHERY BULLETIN: VOL. 76, NO. 1, 1978.

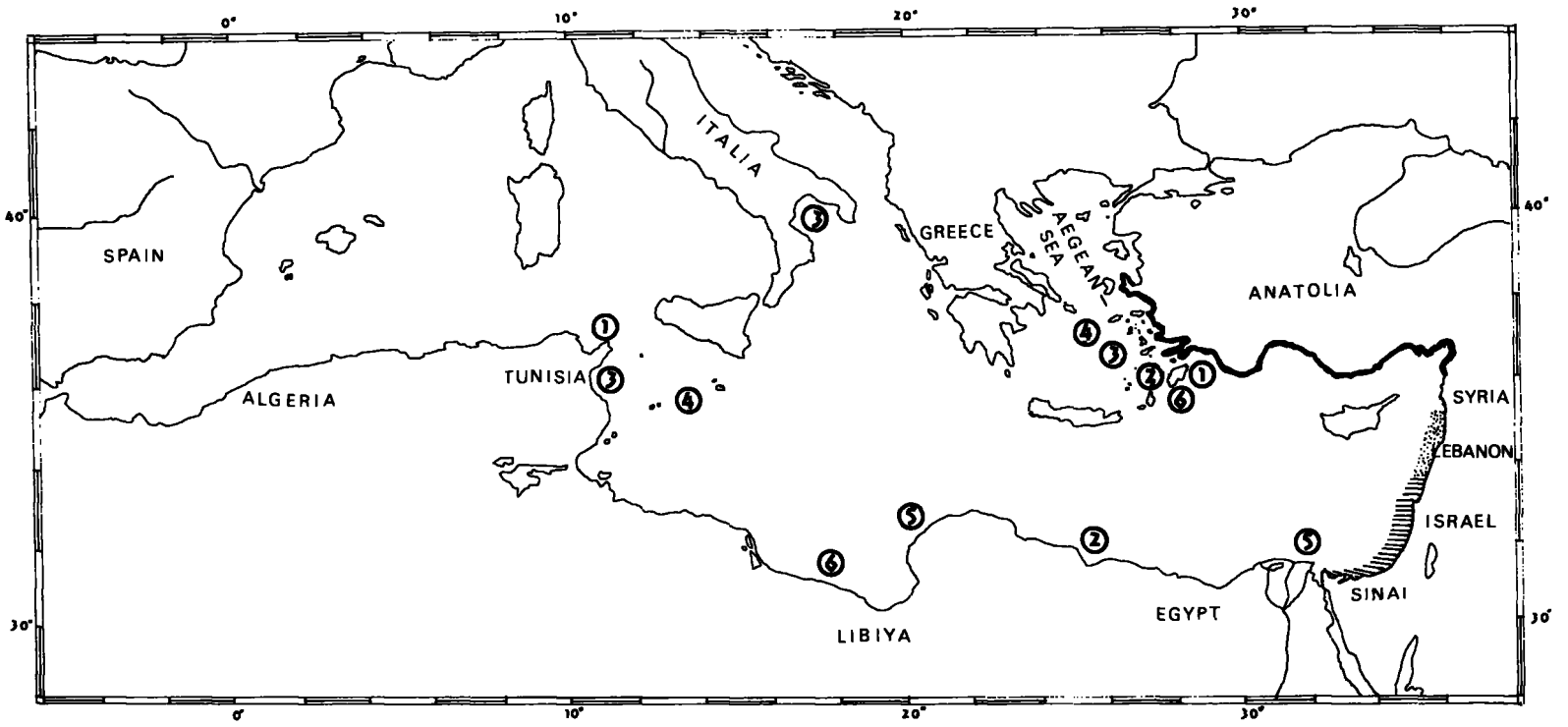

FIGURE 1.—Distribution of Red Sea fishes in the Mediterranean Sea: coast of Israel and Sinai with 34 species; coast of Lebanon with 27 species; Aegean Sea with 9 species. Numbers in circles refer to the following fishes: 1. *Signaus luridus*, 2. *S. rivulatus*, 3. *Stephanolepis diaspros*, 4. *Leiognathus klunzingeri*, 5. *Pranesus pinguis*, and 6. *Parexocoetus mento*.

species collected in Bardawil Lagoon, 14 species (25.5%) are Red Sea immigrants in comparison with about 11% estimated for all the fishes collected in the eastern Mediterranean (Ben-Tuvia 1971b).

The following Red Sea immigrants were collected in Bardawil Lagoon: *Hemiramphus far, Aphanius dispar, Atule djeddaba, Pelates quadrilineatus, Leiognathus klunzingeri, Upeneus moluccensis, Crenidens crenidens, Liza carinata, Pranesus pinguis, Siganus luridus, S. rivulatus, Sphaeroides spadiceus,* and recently *Herklotsichthys punctatus* and *Autisthes puta.*

In addition to the Red Sea immigrants, four cosmopolitan species were also found in Bardawil Lagoon: namely, *Sardinella aurita, Lobotes surinamensis, Mugil cephalus,* and *Echeneis naucrates.*

RED SEA FISHES IN THE MEDITERRANEAN SEA

In my previous summary of the immigration of Red Sea fishes into the Mediterranean (Ben-Tuvia 1966), 24 species were listed; 12 additional immigrants were since found, most of them are rare fishes at this time. Their names, distribution, and the maximum size observed in the Mediterranean Sea are given in Table 1. As yet, only one specimen of *Tylosurus choram* (Collette and Parin 1970), *Rastrelliger kanagurta* (Collette 1970), *Sebastapistes nuchalis* (Froiland 1972), and *Silago sihama* (Mouneimne 1977) have been reported from the eastern Mediterranean.

Froiland (1972), who studied scorpaenids from Cyprus in the collection of the Hebrew University Zoological Museum, reported one specimen of *Sebastapistes nuchalis* (Günther) 58 mm long. This species is known from the Indo-Pacific, including East Africa, but no records are available from the Red Sea, Suez Canal, and other localities in the eastern Mediterranean besides Cyprus. Froiland assumed that this scorpaenid "migrated through the Suez Canal."

Epinephelus tauvina (Ben-Tuvia and Lourie 1969), *Pelates quadrilineatus* (Lourie and Ben-Tuvia 1971), and *Scomberomorus commerson* (George and Athanassiou 1965) were collected on several occasions and do not seem to be very rare. *Herklotsichthys punctatus* and *Rhonciscus stridens* have been found recently in the eastern Mediterranean at several localities (Ben-Tuvia 1967, 1977; Mouneimne 1977). One specimen of *Spratelloides delicatulus* (Bennet) 51 mm long was collected with rotenone on 4 June 1973 in a shallow bay about 3 km south of Atlit (Ben-Tuvia, unpubl. data). The occurrence of *Crenidens crenidens* and *Autisthes puta* is restricted to the hypersaline Bardawil Lagoon.

It is of interest to note that some of the Red Sea immigrants have been found in recent years in new localities west of Levant (Figure 1); *Stephanolepis diaspros* in the Gulf of Taranto, south Italy and Gulf of Gabes, Tunisia (Tortonese 1967); *Siganus rivulatus* off Tobrouk, Libya (Tortonese 1970).

With the exception of perhaps two fishes, *Saurida undosquamis* and *Siganus luridus,* very little information is available on the rate of increase of the immigrant population and the ecological influence of their appearance in the new region. The first Mediterranean specimen of *Saurida undosquamis,* 145 mm standard length, was collected in Haifa Bay, by a trawler, in December 1952. Additional specimens (160-171 mm) were collected in Haifa in February 1953. According to my observations in August 1953, taken on the deck of a commercial trawler, this fish was fairly common in the Gaza-El'Arish area, and 10-20 specimens were usually caught in each haul. There is also some information on the trawling activities in the Gulf of Iskenderun and Mersin on the Anatolian coast of Turkey. In August 1952, I participated in a commercial trawling cruise to the Gulf of Mersin between Karadash-Burnuun and Bagase, during which no *Saurida undosquamis* were collected. But in 1956, this fish was common on the same trawling grounds and fished in commercial quantities. According to catch data, *S. undosquamis* started to appear in commercial quantities in the year 1955, first on the southern fishing grounds (El'Arish to Tel Aviv) and towards the end of the same year and especially during 1956 also on the northern fishing grounds such as Haifa Bay, and even in the Gulf of Iskendrun and Mersin (Ben-Yami 1955; Oren 1957).

It is worthwhile noticing that no specimens of *S. undosquamis* were found before December 1952, although Mediterranean fishes were collected in Israel during earlier years by the staff of the Sea Fisheries Research Station, Haifa, and by scientists of the Hebrew University, Jerusalem.

No less interesting is the sudden appearance of *Siganus luridus* (Ben-Tuvia 1964). Not a single specimen was found before February 1955, in spite of extensive collecting activities in Israel during

TABLE 1.—Data on Red Sea fishes found in the Mediterranean.

Species	Occurrence in eastern Mediterranean	Ecological distribution	SL[1] (mm)	Geographical distribution: Indo-Pacific	Red Sea	Suez Canal	Mediterranean[2]
Carcharhinus brevipinna	Common	Inshore-pelagic	1,200	+	+	–	Israel
Himantura uarnak	Common	Demersal	[3]1,200	+	+	+	Anatolia
Dussumieria acuta	Very common	Inshore-pelagic	155	+	+	+	Anatolia
Herklotsichthys punctatus	Rare	Inshore-pelagic	76	+	+	+	Lebanon
Etrumeus teres	Single record	Inshore-pelagic	170	+	+	–	Israel
Spratelloides delicatulus	Single record	Inshore-pelagic	51	+	+	+	Israel
Saurida undosquamis	Very common	Demersal	335	+	+	+	Anatolia
Paraexocoetus mento	Common	Pelagic	111	+	+	–	Aegean Sea; Gulf of Sidra
Hemiramphus far	Common	Inshore-pelagic	340	+	+	+	Aegean Sea
Tylosurus choram	Single record	Inshore-pelagic	—	+	+	+	Lebanon
Aphanius dispar	Common	Sublittoral	46	+[4]	+	+	Israel
Pranesus pinguis	Very common	Inshore-pelagic	120	+	+	+	Anatolia; Libya
Holocentrus ruber	Common	Inshore-pelagic	177	+	+	–	Aegean Sea
Sebastapistes nuchalis	Single record	Sublittoral	58	+	–	–	Cyprus
Platycephalus indicus	Rare	Demersal	550	+	+	+	Lebanon
Epinephelus tauvina	Rare	Demersal	790	+	+	+	Israel
Autisthes puta	Rare	Sublittoral	133	+	+	–	Bardawil Lagoon
Pelates quadrilineatus	Rare	Demersal	116	+	+	–	Lebanon
Apogonichthyoides nigripinnis	Common	Sublittoral	77	+	+	+	Lebanon
Silago sihama	Single record	Sublittoral	115	+	+	–	Lebanon
Atule djeddaba	Very common	Inshore-pelagic	230	+	+	+	Lebanon
Leiognathus klunzingeri	Very common	Demersal	77	+	+	+	Aegean Sea; Lampedusa
Rhonciscus stridens	Rare	Demersal	128	+	+	+	Lebanon
Upeneus asymmetricus	Common	Demersal	140	+	+	+	Anatolia
Upeneus moluccensis	Very common	Demersal	170	+	+	+	Aegean Sea
Crenidens crenidens	Rare	Demersal	150	+	+	+	Bardawil Lagoon
Liza carinata	Rare	Inshore-pelagic	128	+	+	+	Egypt; Israel
Sphyraena chrysotaenia	Very common	Inshore-pelagic	225	+	+	+	Anatolia
Callionymus filamentosus	Common	Demersal	110	+	+	+	Lebanon
Siganus luridus	Common	Sublittoral	215	–	+	–	Aegean Sea; Tunisia
Siganus rivulatus	Very common	Sublittoral	223	+	+	+	Aegean Sea; Libiya
Rastrelliger kanagurta	Single record	Pelagic	215	+	+	–	Israel
Scomberomorus commerson	Rare	Pelagic	460	+	+	–	Lebanon
Dollfusichthys sinusarabici	Common	Demersal	110	–	+	+	Lebanon
Stephanolepis diaspros	Common	Demersal	124	+[5]	+	+	Aegean Sea; south Italy; Tunisia
Sphaeroides spadiceus	Rare	Demersal	245	+	+	+	Aegean Sea

[1]Maximum length observed in Mediterranean.
[2]Farthest point of distribution.
[3]Length of disc.
[4]Indian Ocean only.
[5]Persian Gulf only.

the preceding years. Then the fish suddenly appeared to be fairly common along the whole Mediterranean coast of Israel, although it remained inferior in numbers to a previous Red Sea immigrant, *S. rivulatus*. Recent observations and reports show that *S. luridus* spread rapidly in the Mediterranean towards the west and north. It is common in Lebanon (George and Athanassiou 1967), Cyprus, Rhodes, and has even reached Tunisia (Ktari-Chakroun and Bouhlal 1971), a distance of more than 1,000 n.mi. from the Suez Canal.

It is a common feature of invading organisms that after an initial period of successful adaptation to the new and basically favorable environment, they may suddenly increase in number and spread to adjacent areas (Elton 1958). Various factors such as decrease in salinities of the Bitter Lakes and cessation of the Nile flood after the completion of the Aswan Dam may facilitate the passage or dispersion of Red Sea species. There is speculation that this immigration was also favored by a series of warm years (Oren 1956; Ben-Yami and Glaser 1974).

MEDITERRANEAN FISHES IN THE RED SEA

The occurrence in the Red Sea of the two Atlanto-Mediterranean and one cosmopolitan species (Table 2) is assumed to be the result of Suez Canal migration. The discovery of *Dicentrarchus punctatus* in the lagoon of El Bilaiyim, situated about 180 km south of the entrance to the Suez Canal (Ben-Tuvia 1971a), is one of the few indisputable evidences of the immigration of a Mediterranean fish into the Gulf of Suez. However, we have to bear in mind that the conditions of El Bilaiyim differ considerably from those of the Gulf proper. Salinities are much higher (50-60‰ according to measurements taken in June 1968) and most probably the seasonal and diurnal fluctuations are greater than those of surrounding waters. In this particular biotope, less competition is expected than in the open coastal waters. *Dicentrarchus punctatus* is known to inhabit the Bardawil Lagoon on the northern (Mediterranean) coast of Sinai, where salinities may reach 80‰. It was noted already by Tillier (1902) that this fish was common in the Suez Canal and reached its southern entrance. Evidently, it settled in the Canal soon after its opening.

A taxonomic study of Red Sea mugilids (Ben-Tuvia 1975b) revealed that another Mediterranean immigrant, *Liza aurata* is common in the northern Red Sea. An earlier record of its presence was made by Al-Hussaini (1947) who examined the intestine of this mullet that was captured off Ghardaqa. *Liza aurata* is known to be euryhaline and could cross the Suez Canal or an earlier freshwater connection that was established by the ancient Egyptian pharaohs and Persian kings between the Mediterranean and the Red Sea using an arm of the River Nile. This fish was reported in the Suez Canal by Tillier (1902). I found it to be common in Great Bitter Lake (Ben-Tuvia 1975a).

Recently two specimens of a sandbar shark, *Carcharhinus plumbeus*, were found in the Red Sea. One specimen, a male, 1,600 mm total length was collected on 6 August 1971 in Dahab, Gulf of Aqaba; the second specimen, a gravid female, 1,764 mm was collected on October 1975 in Ras Muhammad at the entrance to the Gulf of Suez (Baranes and Ben-Tuvia in press). Five additional specimens varying in length between 1,500 and 1,800 mm have been found very recently in the same region (unpubl. data). *Carcharhinus plumbeus* (known also under the name of *C. milberti*) is common on both sides of the Atlantic and is well known in the Mediterranean Sea (Tortonese 1956; Ben-Tuvia 1971b; Compagno 1973). The recent appearance of the sandbar shark in the northern Red Sea could be due to immigration through the Suez Canal although the possibility of penetration from the western Indian Ocean should not be excluded.

Special consideration should be given to *Serranus cabrilla*, which is common in all parts of the Mediterranean, in the Suez Canal, and also in the Red Sea. However, it cannot be regarded as an example of Suez Canal immigration, since a 17-cm long specimen was collected by Hemprich and Ehrenberg in the Red Sea before the completion of the Canal (Klunzinger 1884). According to my observations in September 1970, *S. cabrilla* is common in the northern part of the Gulf of Suez. Individuals were easily observed on sandy patches between coral heads and rocks in the shallow coastal waters off Ras Masalla and Ras Sudar. A total of 10 specimens, 52-100 mm, were collected from the Gulf of Suez plus 1 specimen, 70 mm standard length, from the Gulf of Aqaba. The abundance of *S. cabrilla* in the northern section of the Gulf of Suez indicates the possibility that the present distribution might be related to the proximity of the Suez Canal. However, further taxonomic and behavioral studies will be needed to ascertain the relationships between the Red Sea and the Mediterranean populations.

Serranus cabrilla in the Mediterranean shows great plasticity and adaptability to various ecological conditions. This fish is found in shallow coastal waters on sandy beaches and among rocks. It is

TABLE 2.—Data on Mediterranean fishes found in the Red Sea.

Scientific name	Occurrence in Red Sea	Ecological distribution	SL[1] (mm)	Geographical distribution: West Atlantic	East Atlantic	Suez Canal	Red Sea record
Carcharhinus plumbeus	Rare	Pelagic	1,764	+	+	–	Gulf of Aqaba Gulf of Suez
Dicentrarchus punctatus	Rare	Demersal	245	–	+	+	Gulf of Suez
Liza aurata	Very common	Inshore pelagic	320	–	+	+	Gulf of Aqaba Gulf of Suez

[1]Maximum length observed in Red Sea.

also occasionally found on trawling grounds in various depths, at least up to 100 m. It is common throughout the Mediterranean but rare in the Black Sea. In the eastern Atlantic, it occurs from the English Channel to Angola. Smith (1961) quoted its presence in South Africa (Natal), but it seems not to have been recorded from any other part of the Indian Ocean. Gruvel and Chabanaud (1937) reported that this fish is common throughout the Suez Canal.

CONCLUSIONS

The occurrence of large numbers of circumtropical-cosmopolitan species in the eastern Mediterranean deserves special attention. They demonstrate the distinct faunistic character of the fish population in this area. Of the 290 species of marine fishes identified from the Mediterranean coast of Israel and its immediate neighborhood, 40 species are circumtropical-cosmopolitan. Many of them are found also in the Indo-Pacific and Red Sea regions. Thus, summing up the Red Sea and cosmopolitan fishes in the eastern Mediterranean, there are 76 species which constitute about one-quarter of all fishes identified from this region. The remaining species belong to the Atlanto-Mediterranean fauna.

The Red Sea element in the eastern Mediterranean is particularly pronounced among demersal fishes. This is evident by the large number of demersal immigrants and by their common occurrence. About 17 species are bottom-living fishes, and at least 6 of them are of commercial value. I estimate that they constitute about 21% (by weight) of the Israeli trawl catches and 8% of the inshore fishery (Ben-Tuvia 1973). George and Athanassiou (1967) in their analysis of beach-seine catches of St. George Bay, Lebanon, found that among 26 commercially important fishes, 5 (19%) were Red Sea immigrants.

For a better understanding of Suez Canal immigration, additional taxonomic and biological investigations are required. Comparison of racial characteristics of immigrant fishes could help to clarify the question of the origin and relationship between the Red Sea and the Mediterranean populations. It is suspected that in some cases, exchange of fauna may have taken place before the opening of the Suez Canal as a result of the elevation of sea level and undulation of the Isthmus during the Pleistocene.

Knowledge of the comparative life histories of the immigrant fishes in the two areas is essential for understanding the selective mechanisms controlling passage through the Suez Canal and evaluating extensive ecological changes that the invading species may produce in the new areas of their distribution.

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