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# Non-indigenous ascidians (Chordata: Tunicata) along the Mediterranean coast of Israel

NOA SHENKAR[1] AND YOSSI LOYA[2]

[1]Biology Department, University of Washington, Seattle, Washington, [2]Department of Zoology, The George S. Wise Faculty of Life Sciences, Tel Aviv University, Tel Aviv, Israel

*One of the most extensively documented marine bioinvasion phenomena is the invasion of Red Sea species to the Mediterranean Sea through the Suez Canal. The present study reports the occurrence of seven non-indigenous ascidian species along the Mediterranean coast of Israel:* Ecteinascidia thurstoni, Ascidia cannelata, Phallusia nigra, Rhodosoma turcicum, Symplegma brakenhielmi, Microcosmus exasperatus *and* Herdmania momus. *Five of these species (excluding* P. nigra, *and* R. turcicum*) probably reached the Mediterranean via the Suez Canal, since they have an extra-tropical Indo-Pacific distribution and a restricted distribution in the eastern Mediterranean. This is the first record of* E. thurstoni *in the Mediterranean. The accumulating evidence for the negative impact of non-indigenous ascidians on local species and habitats raises the necessity for long-term studies and monitoring of this group.*

**Keywords:** non-indigenous ascidians, Chordata, Tunicata, Mediterranean coast of Israel

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## INTRODUCTION

One of the most pervasive, seemingly irreversible and devastating impacts of human activity on natural ecosystems is that of introduction of non-indigenous species. In the past few decades there has been a rapid increase in the number of reports of introductions of non-indigenous ascidians (NIAs) into many parts of the world (Lambert & Lambert, 1998, 2003; Coles *et al.*, 1999; Lambert, 2002). Ascidians (phylum: Chordata: sub-phylum: Tunicata) are sessile marine filter feeders with a short lived non-feeding motile larva (Berrill, 1950; Millar, 1971). There are several possible modes of introductions into new regions by NIAs: (1) in ballast water, as the ascidian larvae are able to postpone settlement and survive for several days (Marshall *et al.*, 2003); (2) in sea chests (Coutts *et al.*, 2003; Coutts & Dodgshun, 2007); (3) on the hulls of barges, pleasure craft and other boats; and (4) as epifauna on shells and shellfish transported between mariculture operations (Lambert, 2002). Hence, first records of appearance of the NIAs are usually from harbours and marinas where the species flourish on artificial surfaces probably due to the fewer species present and thus lower competition for space. Moreover, the harbour ecosystem, with its protected and eutrophic waters, is an ideal habitat for sessile suspension-feeders such as ascidians (Lambert & Lambert, 1998; Lambert, 2002; Mastrototaro *et al.*, 2004). Most of the non-indigenous species are able to tolerate wide fluctuations in temperature, salinity and pollution (Sims, 1984; Naranjo *et al.*, 1996; Nomaguchi *et al.*, 1997; Stachowicz *et al.*, 2002; reviewed in Lambert, 2005). In addition, NIAs have a rapid growth rate, a usually short life span of a few months, reach sexual maturity when only a few weeks old, and produce large numbers of short-lived non-feeding planktonic larvae (Lambert, 2001, 2002). These characters, combined with the lack of significant predators, make the ascidians very successful invaders and result in the establishment of huge populations that can significantly change the benthic community of a region (Castilla *et al.*, 2004; Valentine *et al.*, 2007; Bullard *et al.*, 2007; Dijkstra *et al.*, 2007a) and economically affect commercially important activities, such as fishing and aquaculture (Bourque *et al.*, 2007).

Since the opening of the Suez Canal in 1869, more than 200 Red Sea species of algae, invertebrates and fish have dispersed through the canal to the Mediterranean coasts (lessepsian migration, Por, 1978; also referred to as erythrean invasion, Galil, 2000). But while introductions of taxa such as molluscs and fish have been studied extensively (Safriel & Ritte, 1986; Spanier & Galil, 1991; Barash & Denin, 1992; Lotan *et al.*, 1994; Golani, 1998; Galil, 2000), little is known on lessepsian migration of ascidians. Recently, an overview of the metazoan alien biota recorded from the Mediterranean coast of Israel (Galil, 2007) indicated that of the 296 alien species listed, 284 have been introduced through the Suez Canal. Nevertheless, only two ascidian species (*Herdmania momus* and *Phallusia nigra*) appear in the list of alien species reported from the coastal waters of Israel and as the editor indicates this group needs 'critical reevaluation' (Galil, 2007).

The current study provides a review of the available literature concerning NIAs along the Mediterranean coast of Israel and an updated list based on extensive field surveys in the region during the past few years.

**Corresponding author:**
N. Shenkar
Email: nshenkar@u.washington.edu

## MATERIALS AND METHODS

Ascidian samples were collected from eleven sites along the Israeli Mediterranean coast using SCUBA and snorkelling (Figure 1; Table 1). Upon sampling, the ascidians were narcotized with menthol crystals in a closed jar in order to prevent evaporation of the menthol. Only after the samples were fully relaxed (determined by inserting a sharp probe into an open siphon and getting no response), the samples were transferred to a jar with seawater/formalin fixative after rinsing the menthol crystals from the animals' body. The fixative was prepared according to the following formula for 1 l of fixative use: 100 ml of full-strength formaldehyde, 850 ml of seawater, and 50 ml of distilled water. One gram of sodium borate was added to the mixture and the solution was then mixed with a magnetic stirrer. In order to allow DNA analysis a small portion of each sample was directly preserved in absolute ethanol.

Dissections were stained with haemalum and mounted on permanent slides. Taxonomic identification was carried out using authoritative keys and texts (e.g. Van Name, 1921, 1931, 1945; Kott, 1985, 1990, 1992, 2001; Monniot *et al.*, 1991; Monniot & Monniot, 2001). The entire collection is part of the National Collections of Natural History at Tel Aviv University, Israel (specimens beginning with AS). In addition, other preserved material available from museum collections in Israel was studied (specimens beginning with NS).

## RESULTS

A survey of the available preserved material from the National Collections of Natural History at Tel Aviv University, Israel, combined with the number of non-indigenous species described from the Israeli coasts in the literature, results in an estimation of ten non-indigenous species from the Mediterranean coast of Israel (Table 2). However, the current study provides a list of seven suspected non-indigenous species that are currently found along the Mediterranean coast of Israel: *Ecteinascidia thurstoni*, *Ascidia cannelata, Phallusia nigra*, *Rhodosoma turcicum, Symplegma brakenhielmi*, *Microcosmus exasperatus* and *Herdmania momus*.

### FAMILY PEROPHORIDAE

*Ecteinascidia thurstoni* (Herdman, 1890)

Material examined: AS25263–AS25266, AS25275, compared to NS 8362 (Ras Sudar, Gulf of Suez 25 October 1971 identified by C. Monniot, Figure 2a).

Literature for identification: Kott, 1985.

External appearance: colonies of small rounded zooids joined by stolons from the postero-ventral part of the body. The test is thin and glassy with a distinct yellow-orange ring around the rim of the apertures.

Distribution along the Mediterranean coast of Israel: found on both artificial and natural substrate at shallow depth (<5 m) along the northern shores of Israel (Achziv and 'Akko). It is usually present during the summer months and gradually disappears during autumn. Colonies with larvae were found in July (AS25265) and September (AS25275). The larvae are present in the right peribranchial cavity. The samples were compared with *E. thurstoni* collected in Ras Sudar, Gulf of Suez 1971 (NS 8362). *Ecteinascidia thurstoni* has recently been reported along the Red Sea, Gulf of Suez and Port Said on the Mediterranean coast of Egypt (Gab-Alla, 2008).

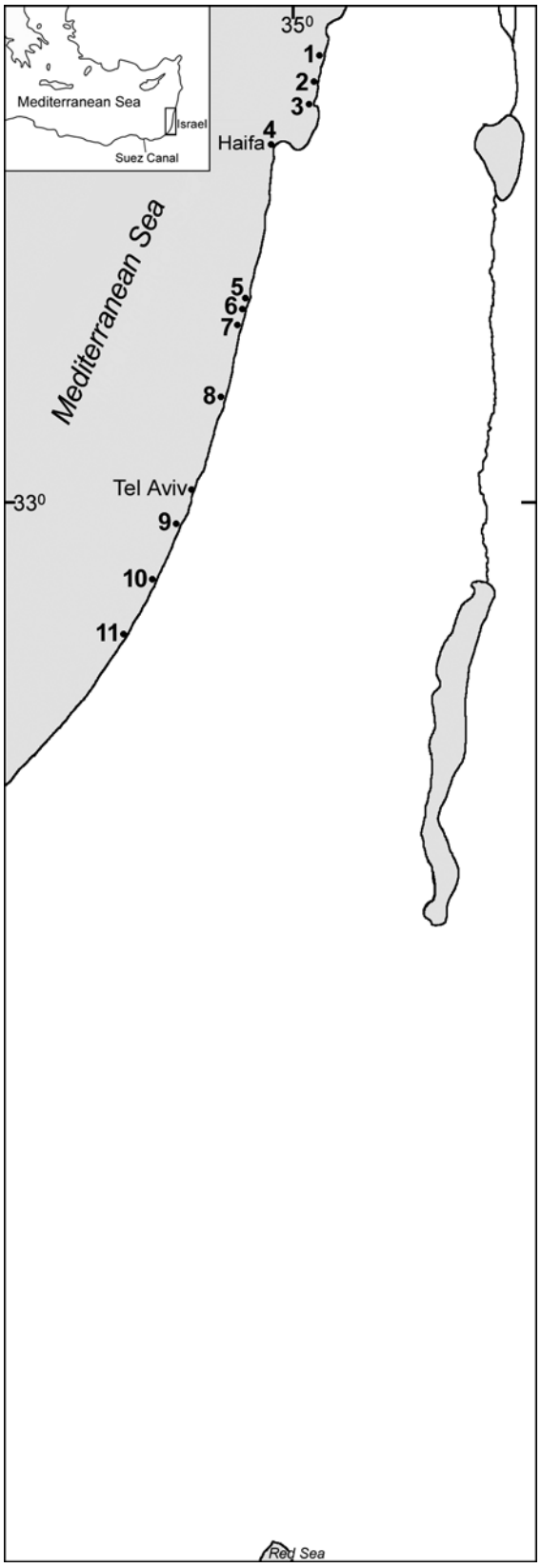


**Fig. 1.** Map of the investigated area with the location of sampling sites.

**Table 1.** The sites surveyed along the Mediterranean coast of Israel, GPS position, and substrate type.

| No. | Site | Position | Substrate type | Remarks |
|---|---|---|---|---|
| 1 | Achziv | 33°02′33″N<br>35°05′49″E | Natural rocky shore | |
| 2 | Shave- Ziyyon | 32°58′47″N<br>35°04′48″E | Artificial substrate | Plastic nets |
| 3 | ‘Akko | 32°55′15″N<br>35°04′22″E | Artificial substrate<br>Natural rocky shore | Wood pillars, metal pilings |
| 4 | Shiqmona | 32°55′15″N<br>35°04′22″E | Artificial substrate | |
| 5 | Sedot-yam | 32°29′50″N<br>34°51′31″E | Natural rocky shore | |
| 6 | Hadera | 32°28′13″N<br>34°52 ′05″E | Artificial substrate | Electric Company pier (iron) |
| 7 | Mikhmoret | 32°24′17″N<br>34°51′31″E | Natural rocky shore | |
| 8 | Ga’ash | 32°135′2″N<br>34°49′05″E | Natural rocky shore | |
| 9 | Palmahim | 31°55′27″N<br>34°413′2″E | Natural rocky shore | |
| 10 | Ashdod | 31°50′32″N<br>34°39′13″E | Artificial substrate | Electric Company |
| 11 | Ashqelon | 31°37′58″N<br>34°30′02″E | Artificial substrate | Oil Company pier (iron) |

FAMILY ASCIDIIDAE

*Ascidia cannelata* (Oken, 1820)

Material examined: AS25296–AS25300, AS25306 and compared with AS25229 (Gulf of Aqaba, identified by F. Monniot).

Literature for identification: Oken, 1820; Pérès, 1958b.

External appearance: solitary species with a transparent-gelatinous tunic. The body is oval with siphons parallel and darker than the rest of the tunic. One side of the body is completely attached to the substrate.

Distribution along the Mediterranean coast of Israel: found on both artificial (Hadera) and natural substrate (Achziv, Mikhmoret and Palmahim) up to 15 m depth. All samples were found with gonads.

*Phallusia nigra* (Savigny, 1816)

Material examined: AS25289–AS25295; Figure 2b.

Literature for identification: Van Name, 1921.

External appearance: individuals are easily recognized by the shiny black dark-blue tunic and smooth surface. The body is oval with elongated siphons separated by a third to half the body length. Specimens can reach 10 cm in length.

Distribution along the Mediterranean coast of Israel: widely distributed at all sites and common in shallow to 30 m depth overgrowing both natural and artificial substrates. All samples were found with well developed gonads.

FAMILY CORELLIDAE

*Rhodosoma turcicum* (Savigny, 1816)

Material examined: AS25267–AS25274, and compared with AS25233 from the Gulf of Aqaba identified by F. Monniot, Figure 2c.

Literature for identification: Kott, 1985.

External appearance: this species is characterized by the remarkable horizontal fold of the body that acts as a lid over the apertures. It is operated by the highly adapted body musculature. Individuals are upright, oval in section, slightly laterally flattened. The test is firm, gelatinous and translucent. Individuals are up to 5 cm high and 2 cm wide. Well developed gonads appeared in samples taken in December 2004 (AS25271), March (AS25272) and September 2005 (AS25273), and November 2007 (AS25274).

**Table 2.** Literature review of non-indigenous ascidians from the Mediterranean coast of Israel.

| Species name | Reference |
|---|---|
| *Ascidia cannelata* | Pérès, 1958a,b; Steinitz, 1967, 1970; Por, 1978; Koukouras *et al.*, 1995 |
| *Ascidia cf. sydneiensis* | Izquierdo-Muñoz *et al.*, 2007 |
| *Phallusia nigra* | Pérès, 1958; Steinitz, 1967, 1970; Por, 1978; Koukouras *et al.*, 1995; Galil, 2007; Izquierdo-Muñoz *et al.*, 2007 |
| *Rhodosoma turcicum* | Izquierdo-Muñoz *et al.*, 2007 |
| *Ecteinascidia turbinata (=moorei)* | Por, 1978; Steinitz, 1967, 1970; Koukouras *et al.*, 1995 |
| *Botryllus niger = Metrocarpa nigra* | Pérès, 1958; Steinitz, 1967, 1970; Por, 1978; Koukouras *et al.*, 1995; Fishelson, 2000 |
| *Eusynstyela hartmeyeri* | Por, 1978; Steinitz 1970; Koukouras *et al.*, 1995 |
| *Symplegma viride* * | Pérès, 1958; Steinitz, 1967, 1970; Por, 1978; Koukouras *et al.*, 1995 |
| *Microcosmus exasperatus* | Izquierdo-Muñoz *et al.*, 2007 |
| *Herdmania momus* | Pérès, 1958; Steinitz, 1967, 1970; Por, 1978; Koukouras *et al.*, 1995; Galil, 2007; Izquierdo-Muñoz *et al.*, 2007 |

*, possible misidentification of *S. brakenhielmi* (see text).

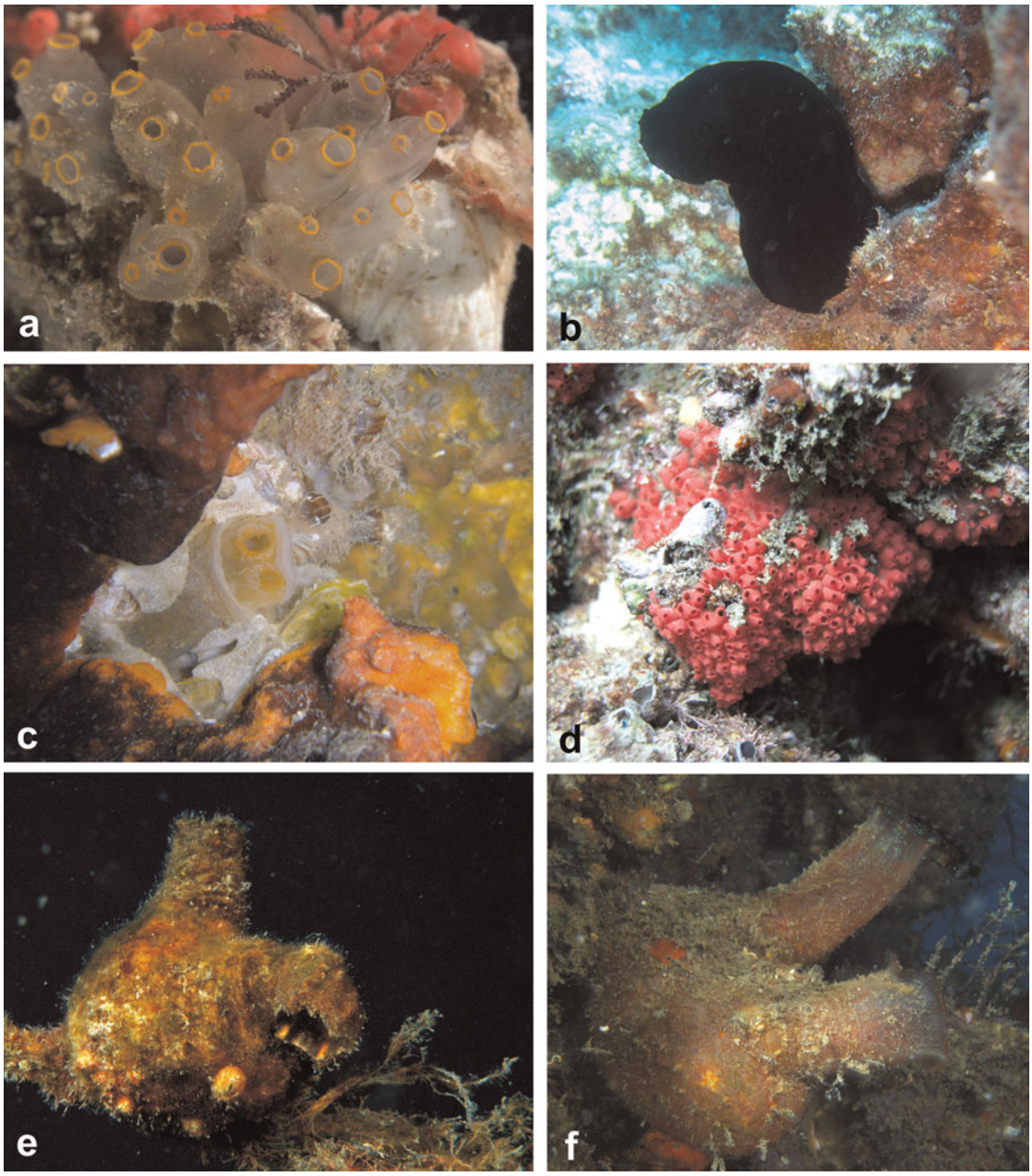


**Fig. 2.** (a) *Ecteinascidia thurstoni*; (b) *Phallusia nigra*; (c) *Rhodosoma turcicum*; (d) *Symplegma brakenhielmi*; (e) *Microcosmus exasperatus*; (f) *Herdmania momus*.

Distribution along the Mediterranean coast of Israel: although this species is generally rare due to its cryptic nature, it may be found all along the Mediterranean coast of Israel from Ashqelon in the south to Achziv in the north on both artificial and natural substrates.

FAMILY STYELIDAE

*Symplegma brakenhielmi* (Michaelsen, 1904)

Material examined: AS25251, AS25252, AS25259–AS25262, NS 15430, 15449 (*Symplegma viride* Haifa bay 13 February 1975 identified by R.H Millar) Figure 2d.

Literature for identification: Monniot & Monniot, 1997, 2001; Kott, 2004.

External appearance: red colonies about 5 cm in diameter. The zooids are embedded in a common tunic, with the two very short siphons opening for each zooid creating a beehive appearance.

Distribution along the Mediterranean coast of Israel: common on artificial substrate at the Electric Company pier at Hadera and on wood pillars in ʻAkko and also in the natural environment at shallow depth (<5 m) along the northern shores of Israel (Achziv) and in the south (Palmahim). Colonies with larvae were found in June (AS25259, AS25260). The larva is characterized by its one sense organ and three papillae (Kott, 1985). The samples were compared with *S. viride* collected in Haifa bay 1975 (NS 15430, 15449) and found both corresponding to the morphological description of *S. brakenhielmi* (Monniot & Monniot, 1997).

Therefore, the previous records of *S. viride* (Table 2) may be a misidentification of *S. brakenhielmi*. It was previously reported from the Lebanon coast (Bitar & Kouli-Bitar, 2001) and the Levantine coast of Turkey (Çinar *et al.*, 2006).

FAMILY PYURIDAE

*Microcosmus exasperatus* (Heller, 1878)

Material examined: AS25237 (identified by X. Turon) AS25301–AS25306, Figure 2e.

Literature for identification: Kott, 1985; Turon *et al.*, 2007.

External appearance: solitary globular species with long siphons and leathery bright orange tunic with a few encrustations around the base. Characterized by unique siphonal spines.

Distribution along the Mediterranean coast of Israel: typical to artificial substrates, forming dense aggregations at the Electric Company pier at Hadera, Shiqmona and 'Akko. May also be found in the natural reef in Mikhmoret and Achziv. Samples containing well-developed gonads were found throughout the year.

*Herdmania momus* (Savigny, 1816)

Material examined: AS25276–AS25286, AS25455 and compared with AS25253 (Gulf of Aqaba), Figure 2f.

Literature for identification: Nishikawa, 2002.

External appearance: individuals are almost spherical with cylindrical or trumpet-shaped siphons that are lined with red-pink and white bands in living specimens. The test is smooth, rosy-peach in colour. The siphons are turned away from each other.

Distribution along the Mediterranean coast of Israel: extensive field surveys reveal that *H. momus* on the Mediterranean coast of Israel is restricted to artificial substrates (sites number shavey tsion, shikmona, hadera) and only few individuals were found on the natural rocky substrate (AS25455). A previous study revealed that the *H. momus* Mediterranean population reproduces twice a year, when the water temperature conditions are similar to those measured in the Red Sea (~May and November; Shenkar & Loya, 2008).

## DISCUSSION

The current study is the first attempt to compile an up-to-date species list of the non-indigenous ascidians (NIAs) found along the Mediterranean coasts of Israel. Seven species from five families were currently identified. These include: *Ecteinascidia thurstoni*, *Ascidia cannelata, Phallusia nigra*, *Rhodosoma turcicum, Symplegma brakenhielmi*, *Microcosmus exasperatus* and *Herdmania momus*. This list corresponds to studies of NIAs elsewhere in the Mediterranean Sea (Streftaris *et al.*, 2005; Çinar et al., 2006; Izquierdo-Muñoz et al., 2007; Turon *et al.*, 2007), and partly corresponds to Por's (1978) original description of 'lessepsian ascidians' (based on Pérès, 1958a, b). Only those species listed as 'High probability lessepsian migrants' (*P. nigra*, *H. momus*, *A. cannelata* and *S. brakenhielmi* probably misidentified as *S. viride*) were also recently collected.

Interestingly, the solitary species *H. momus* and *M. exasperatus* were recorded from the Mediterranean coast mainly on artificial substrates, which supports the hypothesis that NIAs thrive on artificial substrates but often fail to establish communities on natural substrates (Lambert, 2002). Records of *M. exasperatus* in the Mediterranean have been recently revised by Turon *et al.* (2007), revealing a very restricted distribution in the eastern Mediterranean of this species, suggesting that it may be also considered as a lessepsian migrant. *Microcosmus exasperatus* was recorded in the Mediterranean only from the coasts of Lebanon and Tunisia and has been found in Suez and the Gulf of Aden (Monniot, 2002). *Herdmania momus* most likely has also been introduced through the Suez Canal (originally suggested by Por, 1978, but later claimed by Koukouras *et al.*, 1995 as a tropical cosmopolitan species), since it was found along the Mediterranean coast only on artificial substrates (Shenkar & Loya, 2008), it has an Indo-Pacific origin (Kott, 2002), it is recorded through the Suez Canal (Ghobashy & Adbel Messeih, 1991), and so far has been recorded in the Mediterranean only from the Levant basin (Nishikawa, 2002). *Ascidia cannelata* should also be considered as a lessepsian species according to these criteria (Koukouras *et al.*, 1995) although it may be found in the natural environment as well.

Although both *Phallusia nigra* and *Rhodosoma turcicum* have been originally described from the Red Sea (Savigny, 1816), it is difficult to determine if they have been introduced to the Mediterranean via the Suez Canal due to their wide distribution in the Mediterranean and the Atlantic Ocean (Van Name, 1921, 1945; Kott, 1985).

The current study provides the first record of the colonial ascidian *Ecteinascidia thurstoni* in the Mediterranean. There is a high probability that this species has been introduced through the Suez Canal since it is recorded from the Red Sea and along the Suez Canal (Gab-Alla, 2008). Similarly to what was found in the other locations, along the Mediterranean coast of Israel it is found only during the spring–autumn months when seawater temperatures are above 22°C (N. Shenkar, personal observations). Another non-indigenous colonial species found during the study is *Symplegma brakenhielmi*. This species is known from the Indian Ocean (Monniot & Monniot, 1997) and is distributed worldwide in warmer seas, especially in harbours where it grows on man-made structures (Lambert & Lambert, 1998). In the Levantine basin it was reported from the Lebanon coast (Bitar & Bitar-Kouli, 1995), Turkey (Çinar *et al.*, 2006) and Israel (Izquierdo-Muñoz *et al.*, 2007; Shenkar, 2008). The fact that only two non-indigenous species are colonial species is intriguing. Since in solitary ascidians fertilization and larval development usually occur in the water column (in contrast to colonial species which are brooders), it is possible that they have a higher potential for dispersal to more distant locations. Nevertheless, it has been suggested that several colonial species have been introduced worldwide by hull fouling and aquaculture (Lambert, 2002; Dijkstra *et al.*, 2007b).

Increased recreational sailing and the proliferation of marinas and artificial marine structures in recent decades, provide additional sites for colonization of NIAs, even those with low dispersal abilities (Wasson *et al.*, 2001). The accumulating evidence for the negative impact of NIAs on local species and habitats (Cohen *et al.*, 2005; Blum *et al.*, 2007; Dijkstra *et al.*, 2007a; Lambert, 2007) raises the necessity for long-term studies that will combine regular monitoring of natural versus artificial habitats, and the use of molecular genetic tools that will allow the identification of sources, patterns of dispersal, and degree of gene flow with local forms.

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**Correspondence should be addressed to:**
N. Shenkar
Biology Department
University of Washington
Seattle, Washington
email: nshenkar@u.washington.edu