Review

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The seaweed resources of Israel in the Eastern Mediterranean Sea

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Abstract: In spite of the natural harsh marine environments and continuous global change stressors affecting the Levant basin, the Israeli marine flora in the Eastern Mediterranean Sea is quite diverse, with about 300 recognized species. Such high seaweed biodiversity for a small maritime area is remarkable compared to the ca. 1200 species described for the entire Eastern Mediterranean Sea. Since about the year 1890, the Levant basin has been hosting over 115 seaweeds species that migrated from the Indo-Pacific through the Suez Canal. Indeed, approximately 16% of the marine flora is regarded as invasive or exotic to the Israeli shores, in a process that constantly reshapes seaweed populations and their biodiversity. In spite of significant contributions by Israeli scientists to the general biology and technologies for seaweed cultivation worldwide, Israel has little historical and cultural tradition of commercial seaweed cultivation, or use. At present, only two commercial companies are engaged in land-based seaweed cultivation (*Ulva* sp. and *Gracilaria* sp.) with a number of products marketed locally and abroad. Recently, offshore cultivation and biorefinery approaches have been explored, but not yet commercialized.

Keywords: invasive seaweeds; land-based cultivation; offshore cultivation; seaweed industry.

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Introduction

The Israeli marine flora biodiversity in the Eastern Mediterranean Sea (EMEDS) is significant, around 300 species (Table 1) compared to 1200 species estimated to exist in the entire EMEDS. While studies from the Israeli Mediterranean Sea (IMEDS) have been generally extensive, the economic potential as well as the contribution and ecological roles of seaweeds to local marine ecosystems are yet to be assessed (Lipkin and Friedlander 1998, Israel and Einav 2017, Badreddine et al. 2018). In general, intertidal algal communities are abundant with high standing stocks developing on abrasion platforms during short growing seasons (Figure 1), usually in spring and fall (Einav and Israel 2007). These platforms are, however, periodically exposed during low tides and, although tidal fluctuations are limited (ca. 30 cm), seaweeds become exposed to extreme conditions of temperature, irradiance and dehydration (Lipkin and Safriel 1971). Over the years, Israel has contributed significantly to the research and development of seaweed aquaculture in land-based settings and more recently offshore cultivation has been investigated. Current commercial ventures involve two companies that grow *Gracilaria* and *Ulva* producing a number of processed products that sell both locally and abroad (Figure 2).

The EMEDS and the Levant basin

The Mediterranean Sea (MEDS) has been exposed to long-term environmental pressures of an anthropogenic nature and on-going global changes such as increasing temperatures, salinities and seawater levels (Kress et al. 2014). As one moves east, nutrients become depleted and seawater heats up and evaporates, hence, making the EMEDS largely oligotrophic, saltier and hotter than the Western basin. The EMEDS is divided into four sub-basins; the so-called Adriatic, Ionian, Aegean and Levant Seas. The Israeli Mediterranean shoreline is situated in the Levant basin. Here, the bottom is primarily

Table 1: Benthic seaweeds from the Israeli Mediterranean Sea with current or potential applications.

	Ecology	Species/uses/comments
Phyllum Ochrophyta (total described 52 species)		
Colpomenia sinuosa (Mertens *ex* Roth) Derbès *et* Solier	Subtidal	Active compounds, starch
Cystoseira spp. C. Agardh	Intertidal (tide pools) and subtidal to 30 m	*C. rayssiae* Ramon, *C. compressa* (Esper) Gerloff *et* Nizamuddin, *C. schiffneri* Hamel Active compounds
Dictyopteris membranacea Batters	Intertidal/subtidal	Active compounds
Dictyota spp. J.V. Lamouroux	Intertidal/subtidal to 25 m	*D. dichotoma* (Hudson) J.V. Lamouroux, *D. linearis* (C. Agardh) Greville, *D. fasciola* (Roth) J.V. Lamouroux, *D. spiralis* Montagne, and other varieties that need confirmation
Halopteris scoparia (Linnaeus) Sauvageau	Subtidal	Active compounds
Hydroclathrus clathratus (C. Agardh) M. Howe	Intertidal/subtidal	Active compounds
Lobophora schneideri C.W. Vieira	Subtidal to 30 m	Active compounds
Padina spp. Adanson	Intertidal/subtidal to 20 m	*P. gymnospora* (Kützing) Sonder, *P. pavonica* (Linnaeus) Thivy. Active compounds
Rosenvingea intricata (J. Agardh) Børgesen	Subtidal to15 m	Active compounds
Sargassum spp. C. Agardh	Intertidal/subtidal to 20 m	*S. acinarium* (Linnaeus) Setchell, S. *vulgare* C. Agardh, *S. trichocarpum* C. Agardh Active compounds
Scytosiphon lomentaria (Lyngbye) Link	Intertidal 0–1 m	Food, active compounds
Spatoglossum spp. Kützing	Subtidal to 20 m	*S. asperum* J. Agardh, *S. solieri* (Chauvin *ex* Montagne) Kützing Active compounds
Stypopodium schimperi (Kützing) Verlaque *et* Boudouresque	Subtidal to 25 m	Active compounds
Taonia atomaria (Woodward) J. Agardh	Subtidal to 20 m	Active compounds
Phyllum Chlorophyta (total described 76 species)		
Bryopsis spp. J.V. Lamouroux	Intertidal	*B. plumosa* (Hudson) C. Agardh, *B. hypnoides* J.V. Lamouroux Active compounds
Caulerpa spp. J.V. Lamouroux	Intertidal/subtidal	*C. prolifera* (Forsskål) J.V. Lamouroux, *C. mexicana* Sonder *ex* Kützing, *C. scalpelliformis* (R. Brown *ex* Turner) C. Agardh, Active compounds
Cladophora spp. Kützing	Intertidal	*C. pellucida* (Hudson) Kützing, *C. prolifera* (Roth) Kützing, additional species need verification Active compounds
Cladophoropsis spp. Børgesen	Intertidal	*C. membranacea* (Hofman Bang *ex* C. Agardh) Børgesen, *C. zollingeri* (Kützing) Reinbold Active compounds
Codium spp. Stackhouse	Intertidal (tide pools) and subtidal to 20 m	*C. parvulum* (Bory *ex* Audouin) P.C. Silva *C. decorticatum* (Woodward) M.Howe, *C. taylorii* P.C. Silva, *C. tomentosum* Stackhouse, *C. vermilara* (Olivi) Delle Chiaje Food
Ulva spp. Linnaeus	Intertidal	*U. onhoi* M. Hiraoka *et* S. Shimada, *U. compressa* Linnaeus, *U. rigida* C. Agardh, *U. fasciata* Delile, *U. tepida* Masakiyo *et* S. Shimada, *U. chaugulii* M.G. Kavale *et* M.A. Kazi, *U. mediterranea/californica* Alongi, Cormaci *et* G. Furnari Food and biorefinery
Valonia utricularis (Roth) C. Agardh	Intertidal	Ornamental

Table 1 (continued)

	Ecology	Species/uses/comments
Phyllum Rhodophyta (total described 177 species)		
Asparagopsis spp. Montagne	Intertidal/subtidal to 15 m	*A. armata* Harvey, *A. taxiformis* (Delile) Trevisan Medicinal
Botryocladia botryoides (Wulfen) Feldmann	Intertidal/subtidal	Shade habitats Ornamental
Chondracanthus acicularis (Roth) Fredericq	Intertidal	Agar
Corallina spp. Linnaeus	Intertidal/subtidal to 10 m	*C. granifera* J. Ellis *et* Solander, *C. officinalis* Linnaeus, *C. elongata* J. Ellis *et* Solander Active compounds
Dasya spp. C. Agardh	Subtidal	*D. corymbifera* J. Agardh, *D. elegans* (G. Martens) C. Agardh, *D. ocellata* (Grateloup) Harvey, *D. punicea* (Zanardini) Meneghini Active compounds
Digenea simplex (Wulfen) C. Agardh	Subtidal, tide pools	Active compounds
Galaxaura rugosa (J. Ellis *et* Solander) J.V. Lamouroux	Intertidal (tide pool)/ subtidal to 25 m	Extensive and rapid proliferate in recent years. Invasive
Gelidium spp. J.V. Lamouroux	Intertidal	*G. crinale* (Hare *ex* Turner) Gaillon, *G. latifollium* Bornet *ex* Hauck Agarose
Gracilaria spp. Greville	Intertidal, tide pools	*G. bursa-pastoris* (S.G. Gmelin) P.C. Silva, *G. dura* (C. Agardh) J. Agardh (= *G. conferta*) Agar, protein
Halymenia spp. C. Agardh	Subtidal to 20 m	*H. dichotoma* (J. Agardh) J. Agardh, *H. floresii* (Clemente) C. Agardh Ornamental
Hypnea spp. J.V. Lamouroux	Intertidal to 1 m	*H. musciformis* (Wulfen) J.V. Lamouroux, *H. cervicornis* J. Agardh, *H. cornuta* (Kützing) J. Agardh Carrageenan
Jania rubens (Linnaeus) J.V. Lamouroux	Intertidal/subtidal to 20 m	Active compounds
Laurencia spp. J.V. Lamouroux	Intertidal/subtidal to 5 m	Suggested species *L. obtusa, L. papillosa, L. truncata, L. pinntifida, L. paniculata*, need verification Active compounds
Laurenciella marilzae (Gil-Rodríguez, Sentíes, Díaz-Larrea, Cassano *et* M.T. Fujii) Gil-Rodríguez, Sentíes, Díaz-Larrea, Cassano *et* M.T. Fujii	Subtidal to 15 m	Blooms year around, invasive from the Atlantic Ocean Active compounds
Lithothamnion sonderi Hauck	Subtidal to 25 m	Ornamental
Nemalion helminthoides (Velley) Batters	Intertidal	Food
Peyssonnelia squamaria (S.G. Gmelin) Decaisne *ex* J. Agardh	Intertidal/subtidal to 1 m	Dark habitats Ornamental
Porphyra rosengurttii J. Coll *et* J. Cox	Intertidal	Needs taxonomic verification Food
Pterocladiella capillacea (S.G. Gmelin) Santelices *et* Hommersand	Intertidal/subtidal to 2 m	Agar
Rhodymenia spp. Greville	Subtidal	*R. corallicola* (Zanardini) Ardissone *R. pseudopalmata* (J.V. Lamouroux) P.C. Silva Ornamental, gels
Rytiphlaea tinctoria (Clemente) C. Agardh	Intertidal	Pigments
Solieria filiformis (Kützing) P.W. Gabrielson	Intertidal	Strongly seasonal Agar

Species given after Lipkin and Friedlander (1998), Einav and Israel (2008), Israel and Einav (2017), and references therein.

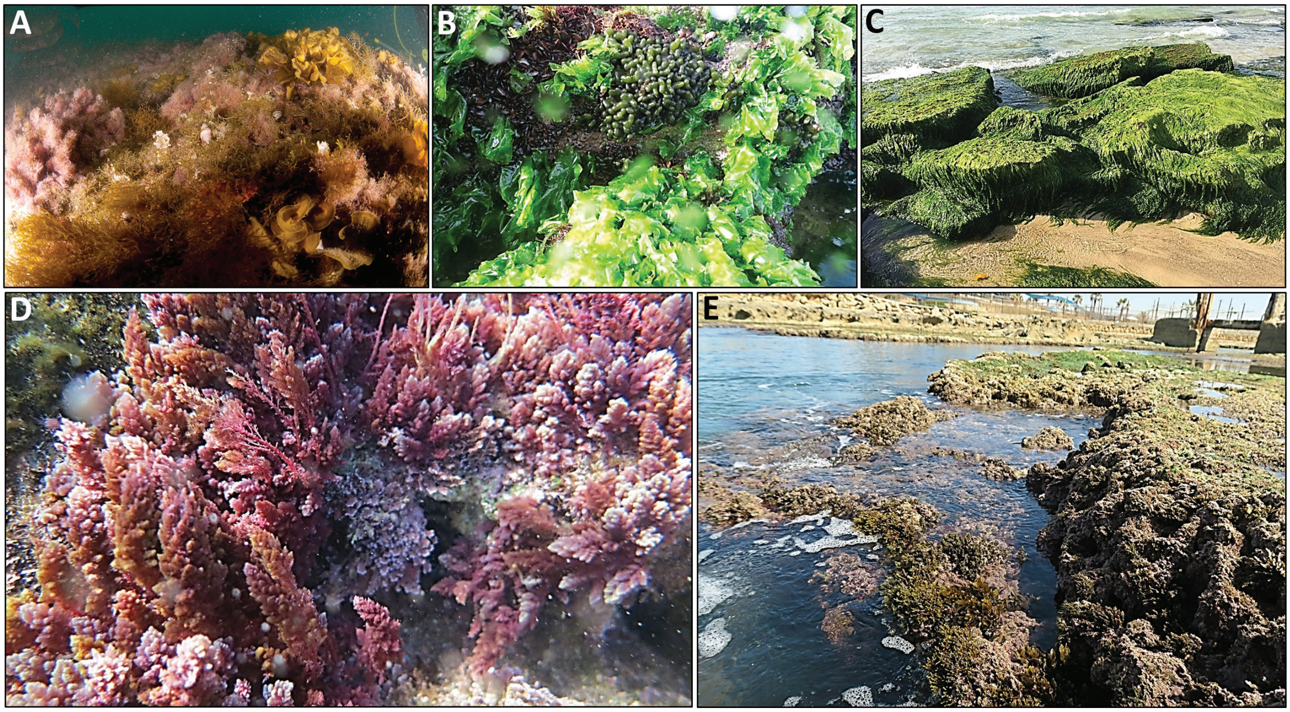

Figure 1: Characteristic seaweed communities from the Israeli Mediterranean Sea.
(A) An assemblage of macroalgae at 10 m depth in Haifa Bay composed of *Jania rubens*, *Padina* spp., *Lobophora schneideri*, *Dictyota* spp. and others (photo credit: G. Rilov). (B) Intertidal *Volonia utricularis* and *Ulva* spp. (C) Abrasion platforms in the intertidal covered by *Ulva* spp. during March 2019 in Hertzlyia. (D) Populations of *Asparagopsis taxiformis* thriving in intertidal rock pools in Rosh Hanikra. (E) Algal diversity during high growth season on the intertidal shores of Atlit in February 2018.

sandy and exposed to the open sea, with biogenic abrasion platforms in some parts (Lipkin and Safriel 1971). The opening of the Suez Canal in 1869 permitted the in-flow of marine organisms from the Red Sea and Indo-Pacific Ocean straight into the Levant basin. These migrations are collectively called the “Lessepsian invasion” (Por 1978, Galil 2007). There is a consensus that the major vector of introduction of seaweeds into the EMEDS is via the Suez Canal (Verlaque and Boudouresque 2005, Zenetos et al. 2010, 2012, Romero 2015, Verlaque et al. 2015), with additional alien species originating from mariculture and shipping activities (primarily ballast waters and hull fouling), for example, seaweeds entering the Western Mediterranean from the Atlantic Ocean, on their way into the Eastern basin (Katsanevakis and Crocetta 2014, Aragay et al. 2016, Sghaier et al. 2016). Seaweed biodiversity is larger in the Western basin than in the Eastern basin (ca. 60% vs. 40% of an approximate 1500 species suggested for the whole MEDS; Hoffman 2014), yet the arrival of alien marine macroalgae is more intense in the EMEDS. Indeed, there are almost four times as many alien seaweed species in the EMEDS (409) as in the Westernmost Mediterranean (110) (Galil 2007, Verlaque et al. 2015).

In the last decades the IMEDS witnessed a number of alien macroalgae proliferating in subtidal areas such as *Codium parvulum* (Israel et al. 2010), *Stypopodium schimperi* (Verlaque and Boudouresque 1991, Einav and Israel 2009) and *Galaxaura rugosa* (Hoffman et al. 2008), and recently species of *Dictyota* (unpublished observations) and *Lobophora* (Vieira et al. 2019), and many others which are unaccounted for. Offshore drifts of these species can be intense (Israel et al. 2010), with biomass amounts decreasing following relatively short time-periods (e.g. 2–5 years), with the invaders integrating thereafter with existing seaweed assemblages. In another example, *Asparagopsis taxiformis* (Delile) Trevisan, allegedly introduced into the MEDS in 1831 (Verlaque et al. 2015) was hardly noticeable in the Israeli intertidal zone until a decade ago. This seaweed now covers significant areas in both the rocky intertidal and shallow subtidal (Einav 2007). Other genera, such as *Fucus* Linnaeus and *Laminaria* J.V. Lamouroux, as well as the seagrass *Posidonia oceanica*, reported to proliferate in Cyprus (Kletou et al. 2018), have never been spotted in the IMEDS coasts. Worth mentioning is the presence of *Caulerpa racemosa* var. *turbinata* J. Agardh (Durand et al. 2002) which bloomed on Turkish, Greek and Cypriot

Figure 2: From fresh biomass to final products.
Wild type (B) and a green mutant (A) of *Gracilaria* sp. produced by Sealaria Ltd. (with permission) and dried powder (C) used as raw material for the production of cosmetic products for human (D) and animal (E) use. A view of Seakura Ltd. cultivation grounds (F) for tank cultivation of *Ulva* species (G, with permission) and some of their products (H) (from https://www.seakura.co.il).

shores (Tsiamis et al. 2014) yet never established on the Israeli Mediterranean shores (Einav 1998a,b, Ukabi et al. 2013, 2014).

Seaweed flora of Israel

The population biology and biodiversity of seaweeds have been studied irregularly for the IMEDS. From the estimated 300 species counted so far (Einav and Israel 2008, Israel and Einav 2017), about 60% were reds, 23% greens and 17% browns. Only two seaweed taxonomic keys with general descriptions have been published for local seaweeds (Nemlich and Danin 1964, Einav 2007), and one, extensive eco-taxonomic review article (Einav and Israel 2008). For the Israeli coast only one endemic species has been suggested, the brown alga *Cystoseira rayssiae* Ramon (Ramon 2000), while the red algae *Gracilaria* "*dura*" (formerly described as *Gracilaria conferta* Schousboe *ex* Montagne in Weinberger et al. 2010) and *Porphyra* sp. (*Pyropia* J. Agardh), as well as many others, are all in need of taxonomic confirmation (Israel et al. 1999, 2008, Israel and Einav 2017). The largest and the oldest seaweed collection in Israel is to be found at the Botanical Herbarium of The Hebrew University in Jerusalem. Another collection is preserved at the Museum of Natural History, Tel Aviv University, and is based on decades of field collections by Yaacov Lipkin. A third, newly established seaweed herbarium is found at Israel Oceanographic & Limnological Research, Haifa, with more than 1500 records and about 100 species identified so far. It includes anonymous dry samples from the 1950s. These seaweed assortments have been inspired by the pioneering work of phycologists. Notable among them is the agronomist Aharon Aharonson (Kellerman 1993) who compiled a seaweed collection from Atlit coast, Israel, in 1907, and Joseph Carmin, the first to publish lists of marine macroalgae from the Eastern Mediterranean (Carmin 1934, 1957). Tscharna Rayss also published comprehensive taxonomic revisions of local seaweeds (Rayss 1941, 1954, 1955), and Tikva Edelstein conducted a unique and valuable work on deep-water seaweeds in the Haifa area, north of Israel (Edelstein 1960, 1962). Additional contributors on seaweed taxonomy were Inka Dor (Dor 1961) for Rhodophyta, and Edith Ramon (Ramon and Fridmann 1966) for Ochrophyta as well as the studies of Yaakov Lipkin on the ecology and taxonomy of seaweeds from the Israeli coasts of both the Mediterranean and Red Seas (Lipkin 1962, 1972, Lipkin and Safriel 1971, Lipkin and Silva 2002). Barbro Lundberg provided data on algal communities compiled over 25 years mostly by means of surveys of intertidal habitats (Lundberg 1996).

At present, insufficient knowledge of the physiological tolerance ranges of native and exotic seaweeds, the attributes of their life histories, and the genetic makeup of their populations, hampers the prediction of the impact of invasion and climate change on seaweeds from the IMEDS (Guy-Haim et al. 2016). In this context, explaining the disappearance of species is much more difficult than their appearance as invasive ones. Nevertheless, the resilience capacity within the IMEDS is outstanding. For example, *Halymenia dichotoma* (J. Agardh) J. Agardh and *Halymenia floresii* (Clemente) C. Agardh had been abundant in the shallow subtidal hard bottoms (Nemlich and Danin 1964), then were unseen for several years, and are now observed thriving again at deeper depths of about 18 m (A. Israel, unpublished observations). A similar phenomenon accounts for species of *Naccaria* Endlicher and *Scinaia furcellata* J. Agardh, as well as *Pyropia* sp. J. Agardh and species of *Laurencia* J.V. Lamouroux (A. Israel, unpublished observations). In contrast, the green seaweed *Halimeda tuna* (J. Ellis & Solander) J.V. Lamouroux has virtually disappeared from the intertidal region, at least for the last 10–15 years (A. Israel, unpublished observations). By feeding on coarse seaweeds, Lessepsian herbivorous fishes, typically *Siganus* spp. have contributed (in a yet unquantified degree) to the changes observed in the IMEDS seaweed population dynamics (Lundberg 1981).

The composition of *Ulva* species has also shifted over the last couple of decades, from populations then composed of usually three species to populations now composed of six dominant species, including two aliens (Krupnik et al. 2017). Years of rapid environmental change in the Israeli MEDS, particularly rising sea temperatures (Gertman et al. 2013, Shaltout and Omstedt 2014, Raveh et al. 2015, Ozer et al. 2016) combined with local effects of thermal pollution from power plants and brines from desalination plants (Titelboim et al. 2016) have all contributed to a gradual environmental shift and an unknown impact on the seaweed populations. There are 86 seaweeds currently regarded as alien on IMEDS shores (Israel and Einav 2017) and new ones are detected regularly (Hoffman and Wynne 2016). *Ulva ohnoi* M. Hiraoka *et* S. Shimada is an invasive species originally described from southern and western temperate regions of Japan where it forms green tides (Hiraoka et al. 2004). It was first spotted in 2002 from natural habitats in the IMEDS (Krupnik et al. 2017). Probably, earlier records of *Ulva rigida* C. Agardh and *Ulva lactuca* Linnaeus from Israel were misidentifications of this species (Einav and Israel 2008). *Ulva ohnoi* is very closely related to, and can interbreed with, *Ulva fasciata* S.F. Gray (Hiraoka et al. 2004), which has often been found in Israel (Beer et al. 1990). *Ulva* species all grow at high rates in aquaculture tanks (Neori et al. 2004, Ashkenazi et al. 2019).

Due to the geographic-oceanographic patterns of Lessepsian introductions, newly-introduced species are often reported first in Israel (Nunes et al. 2014). A positive aspect of detecting alien species relies on the opportunity to incorporate them into local industries and aquaculture. For example, *Ulva* species may be valuable for the local bioeconomy (Chemodanov et al. 2017). The results are especially important given the growing interest in using *Ulva* biomass for various food applications, for example protein (Kazir et al. 2018) and starch (Prabhu et al. 2019), in bioremediation, or as a source for bioethanol production. Any future industrial-scale cultivation of *Ulva* will rely initially on collections of material from the wild. Given that sustainable food supplies, renewable energy and water treatment are major challenges for the near future, *Ulva* species could be a viable answer to many of these challenges. With respect to the clear impact of invasive marine organisms, which are evidently changing the seaweed diversity of the Levant area, the future contribution of critical natural seaweed resources to the Israeli coast and economy remains to be seen.

Seaweed cultivation approaches

In Israel, seaweed cultivation methodologies have been under constant study, as have development and commercialization aspects during the last 40 years, and some of these have been adopted by emerging local seaweed companies. Detailed culture techniques and approaches were published by Friedlander and Lipkin (1982), Israel et al. (2006) and Friedlander (2008) for the known profitable seaweeds. Due to the generally exposed Israeli coastline, implementing long-line rope or raft methods as in SE Asia is problematic, hence, making on-land (in tanks and ponds) the preferable, or perhaps the only practical alternative for seaweed culture here (Neori et al. 2017). In recent years, there has been a number of undocumented attempts to cultivate algae in land-based settings using salty or brackish water of underground origin, or brine derived from desalination plants (Israel et al. 2005). The commercial maturation of these trials has been limited in Israel to several small enterprises, as described below. However, Israeli cultivation technology has been deployed abroad, for instance in South Africa (reviewed in Amosu et al. 2013), Australia (Winberg et al. 2011, Lawton et al. 2013) and China (Wang et al. 2007). With appropriate technological advancements, however, offshore seaweed biomass production as part of the IMTA approach could play a significant role in the development of the local economy (Fernand et al. 2017). Elsewhere, outside SE Asia, technologies for massive offshore seaweed culture are limited in scale and include farm concepts for kelp growth, tidal flat farms, floating cultivation, ring cultivation, wind-farm integrated systems, and bottom plantations (Buschmann et al. 2017). However, future expansion of biomass production in the open sea will require shifting the cultivation infrastructure to more exposed environments, where operation with current technologies would require complex logistics and high costs. While Israel has been for years a pioneer in land-based seaweed cultivation (Friedlander 2008, Neori et al. 2017), there have been only two local reports of macroalgal culture in sea-based settings, yet none in strictly offshore settings. Friedlander and Lipkin (1982) first cultivated a number of polysaccharides producing seaweeds in a shallow field site in south Israel. *Ulva* sp. and *Gracilaria* sp. were more recently tested in nets or single layer lines as reported by Korzen et al. (2016) and Chemodanov et al. (2017). Korzen et al. (2016) reported a series of short-term experiments in which *Ulva rigida* C. Agardh and *Gracilaria bursa-pastoris* (S.G. Gmelin) P.C. Silva were cultivated downstream of fish cages (ca. 3 miles offshore) yielding encouraging perspectives on their nutrient uptake, growth and chemical constituents as related to the nutrients derived from the fish. Chemodanov et al. (2017), tested the productivity of *Ulva* sp. during a full year in one-layered reactors set within the proximity of a power plant, a concept that underlined the possibility of long-term cultivation. The generally rough offshore conditions for the IMEDS as presented above, have precluded further experimental or pilot efforts to cultivate seaweeds in the sea. Nevertheless, the high natural irradiance and relatively warm seawater temperatures year round, in addition to emerging techniques for offshore settings, could encourage these types of activities.

Commercialization of seaweeds

A limited number of initiatives to exploit or cultivate seaweeds have taken place in Israel. During the late 1990s, SeaOr Marine Enterprises Ltd. established a 2-ha pilot, land-based seaweed farm using tanks and ponds. The farm operated for several years in the location of Michmoret, north of Tel Aviv on the IMEDS coast. The company adopted an IMTA approach culturing marine fish, abalone, sea urchins and also bivalves and shrimps, all integrated with the seaweeds *Ulva* sp. and *Gracilaria* sp. and occasionally also *Pyropia*. It leveraged local climate and recycled fish waste products into macroalgal biomass, which was fed to the abalone. It also effectively purified the water sufficiently to allow the water to be recycled to the fishponds and to meet point-source effluent environmental regulations. The farm was a pilot that operated technically well but was too small to be profitable (Neori et al. 2017). Under a new management, and for the last 10 years or so, and using the same infrastructure grounds, Seakura Ltd. (www.seakura.co.il) has engaged quite successfully in the cultivation of *Ulva* spp. intended for high-value foods (Figure 2F,G,H). In recent years, this same company has also produced important amounts of *Gracilaria* sp. biomass for human consumption, and a number of products of both species have been available in local and international markets. Another active seaweed company is Sealaria Ltd. (www.sealaria.co.il), based in the northern Kibbutz Rosh Hanikra. This company produces a few tonnes of fresh *Ulva* sp. and *Gracilaria* sp. intended for cosmetics and for veterinarian products based on hydrogels extracted from these seaweeds (Figure 2D,E).

Future trends

The prevailing harsh natural conditions within the IMEDS with its exposed coastline and various usage conflicts have largely discouraged the development of seaweed cultivation projects in the sea. As the demands grow, land-based seaweed aquaculture in Israel can develop on extensive abandoned fish farms along the Carmel coast. Furthermore, with appropriate advances in infrastructure and engineering, offshore cultivation may take place within the Exclusive Economic Zone (EEZ) set for the IMEDS. The economic potential of the EEZ has been fully recognized in the last decade, triggering the possibility of aquaculture activities including seaweed cultivation. Producing sustainable algal biomass offshore for commodities and bioenergy is promising because of its sustainability, but is an extremely challenging endeavor. Although the concept of Ocean Farms has been introduced decades ago, current commercial seaweed cultivation is mostly practiced in protected, near shore areas. In most cases offshore cultivation means the movement of farm installations from near shore, sheltered environments and facilities to more exposed environments, where frequent harvests may have additional logistical and cost implications. New original ideas for the physical cultivation technology, nutrient supply and biomass processing, such as in biorefineries, will be needed (Neori and Guttman 2017, Kazir et al. 2018, Prabhu et al. 2019). Key aspects when evaluating the potential value of seaweeds in Israel include also solidifying past taxonomic identifications and long-term records and descriptions of local seaweeds, both particularly troublesome for the Levant basin.

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Graphical abstract

Alvaro Israel, Alexander Golberg and Amir Neori

The seaweed resources of Israel in the Eastern Mediterranean Sea

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Review: The seaweed biodiversity in the Israeli Mediterranean Sea shores is significant and could be utilized for the benefit of humans.

Keywords: invasive seaweeds; land-based cultivation; offshore cultivation; seaweed industry.