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## Spatiotemporal patterns of catch and discards of the Israeli Mediterranean trawl fishery in the early 1990s: ecological and conservation perspectives

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**SUMMARY:** The spatiotemporal patterns of discards and catch composition of Israeli trawlers were examined using a 4-year (1990-1994), 324 haul dataset. Haul depth was found to be the main grouping variable for hauls, although significant seasonal differences were also found. 28.3% of the total catch was discarded, and there was a 40.1% discard percentage in shallow hauls. According to these figures, annual discards for the Israeli trawl fleet for the study period are estimated at ca. 440 to 700 t. Both the biomass and the number of discarded specimens peaked in summer, as well as the percentage of juvenile fish of commercial species. These findings suggest that a summer moratorium on trawling would reduce discards. The percentage of specimens of Indo-Pacific origin decreased from 51% in depths shallower than 37 m to 24% between 38 and 73 m, and 8% in deeper strata. Discards along the Israeli coast were comparable to those observed elsewhere in the Mediterranean. The findings presented here are the first quantitative account of fish community assemblages in the nearshore waters of the easternmost part of the Mediterranean, and thus provide valuable information for comparisons with more current datasets that are currently being assembled.

**Keywords:** bottom-trawl, Israel, discards, catch composition, Lessepsian migration, fishery management.

**RESUMEN:** PATRONES ESPACIO-TEMPORALES DE LA CAPTURA Y LOS DESCARTES DE PESQUERÍA DE ARRASTRE MEDITERRÁNEA ISRAELÍ AL INICIO DE LA DÉCADA DE LOS NOVENTA: PERSPECTIVAS ECOLÓGICAS Y DE CONSERVACIÓN. – Se analizaron los patrones espacio-temporales de los descartes y la composición de la captura de la flota de arrastre de Israel utilizando datos de 4 años (1990-1994), 324 caladas. La profundidad resultó ser el principal factor en la agrupación de las caladas, si bien se encontraron asimismo diferencias significativas entre estaciones. Se descartó el 28.3% de la captura total, alcanzándose el 40.1% en las caladas realizadas en las aguas más someras. Según estos porcentajes, se estimó una captura anual descartada por la flota de Israel en ese período de 440-700 t. La biomasa, el número de ejemplares descartados, así como el porcentaje de juveniles de especies comerciales fue mayor en verano. Estos resultados sugieren que una veda de arrastre en verano favorecería la disminución de la captura descartada. El porcentaje de ejemplares de origen indo-pacífico descendió desde 51% en aguas de una profundidad inferior a 37 m, al 24% entre 38-73 m y al 8% en el estrato más profundo. Los descartes en la costa israelí fueron similares a los observados en otras zonas del Mediterráneo. Se presentan por primera vez resultados cuantitativos relativos a comunidades de las aguas costeras del extremo oriental del Mediterráneo, aportándose información para su comparación con datos más recientes que en la actualidad están siendo obtenidos.

**Palabras clave:** arrastre de fondo, Israel, descartes, composición de la captura, migración lessepsiana, gestión de pesquerías.

## INTRODUCTION

It is considered that marine communities have been altered by multiple human stressors. One of the most influential of these stressors is fishing, specifically bottom trawling (Alverson *et al.*, 1994, Hall *et al.*, 2000, Jackson *et al.*, 2001, Pauli *et al.*, 2002). Trawling was criticized for its low selectivity and damaging effects on the benthic habitat as early as the 18th century (Sacchi, 2008). Low selectivity leads to large portions of the catch being discarded at sea due to the species being unmarketable or too small. These discards are an important measure of the impacts of fishing on marine stocks (Alverson *et al.*, 1994). The present study deals with discards, rather than bycatch. It argues that bycatch may be a misleading term for the spatially and temporally heterogeneous multi-species Mediterranean trawl fishery. Whereas bycatch is a loosely defined term, discards are unanimously defined as the part of the catch which is brought onto the deck and then thrown back into the sea (Alverson *et al.*, 1994, Hall *et al.*, 2000, Tsagarakis *et al.*, 2008).

Alverson *et al.* (1994) did not specifically address discards in the Mediterranean; however, Kelleher (2005) assigned the Mediterranean and Black Sea fisheries (excluding the Levant) a mere 4.9% discard ratio based on an analysis of 24% of the total catch. Davies *et al.* (2009) took a more thorough approach and estimated Mediterranean discards at 306000 tons, or 21.1% of the total catch. 85% of these discards originated in the trawl fisheries, which were estimated to have a 45-50% discard ratio. Various other studies (Stergiou *et al.*, 1998, Machias *et al.*, 2001, D'Onghia *et al.*, 2003, Sánchez *et al.*, 2004, 2007) have assigned discard ratios of 20-50% to various trawl fisheries in the western and central Mediterranean. El-Mor *et al.* (2002) and Alsayes *et al.* (2009), however, found that only 15-25% of the catch was discarded in Egypt. Recently, in two extreme cases, local discards were found to exceed 70% in Portugal (Esmeralda Costa *et al.*, 2008) and Turkey (Soykan and Kincigil, 2006). Discard practices vary annually and seasonally throughout the Mediterranean (Machias *et al.*, 2001, Leonart and Maynou, 2003, Sánchez *et al.*, 2004). For some commercial species, this is because fishermen adjust the actual minimum landing size to match market demand rather than to comply with the Minimum Landing Size (MLS) regulations. For other species (most notably goatfishes) this means that juvenile specimens are consistently landed and marketed. MLS regulations in Israel have been arbitrarily set for several prominent commercial species but are not enforced.

Depth and fishing season were found to be the major factors contributing to the discard rate and catch composition in many Mediterranean trawl fisheries (Stergiou *et al.*, 1998, Machias *et al.*, 2001, D'Onghia *et al.*, 2003, Sánchez *et al.*, 2004, 2007). These findings have been used to justify and manage seasonal

trawl closures and minimal trawling depth limitations. The time of day was also shown to have significant effects on catch composition, but mostly as a confounding factor with depth (Wassenberg *et al.*, 1997). There are also spatial differences between different trawling zones. In order to understand these, it is important to determine the characteristics of and variation in local fishing practices (Sánchez *et al.*, 2007).

The Levantine ecosystem differs from the rest of the Mediterranean in phenomena such as Levantine Nanism, in which organisms are smaller and reproduce earlier. This phenomenon was hypothesized by Por (1989) and demonstrated by Sonin *et al.*, 2007 for the red mullet *Mullus barbatus*. The Levant is also consistently invaded by Indo-Pacific species (e.g. Spanier and Galil, 1991, Rilov and Galil, 2009). This bioinvasion is particularly reshaping the shallow shelf fauna, mainly due to the shallowness of the main invasion vector – the Suez Canal (Rilov and Galil, 2009).

The present study analyzes catch, discard and assemblage composition data for the Israeli trawl fishery for the years 1990-1994. This analysis is the first quantitative study of Israeli trawl catches and the first to describe the spatio-temporal patterns of the demersal fish community in the Levant. It focuses on the proportion of discarded specimens, a measure which has thus far been overlooked in Mediterranean trawl catch studies, most of which focus on discarded biomass alone. From a conservation perspective, these data are vital for an understanding of the rates of change vectors and how they are reflected through the fishery. They can serve as a baseline for future comparisons of the status of fish and fisheries in the rapidly changing eastern Mediterranean, and as such assist in ecosystem-based management of the trawl fishery.

## MATERIALS AND METHODS

### Description of the fishing fleet, study area and typical catch and effort

Israeli trawling fleets operate along 170 km of coastline, up to 20 km offshore. Some additional, small-scale activity took place near the coast of northern Sinai until the mid 1990s. Trawling occurs in two main geographic areas (Fig. 1), and the same fishing gear is used in both areas. South of Haifa, trawling lanes run parallel to the shore and maintain the haul depth along the isobaths. The wide, shallow continental shelf of southern Israel means that more shrimp trawling, generally performed between 20 and 40 m, is carried out than in the northern fields. The narrower northern shelf and curvature of Haifa Bay often dictate curved or semi-circular trawling lanes. The primary target fish species have traditionally included high priced species such as prawns, mullids and groupers, common sea breams (such as bouge and pandoras) and lizard fish. Hake are also targeted, but at greater depths (Snovsky and Shapiro, 1997).

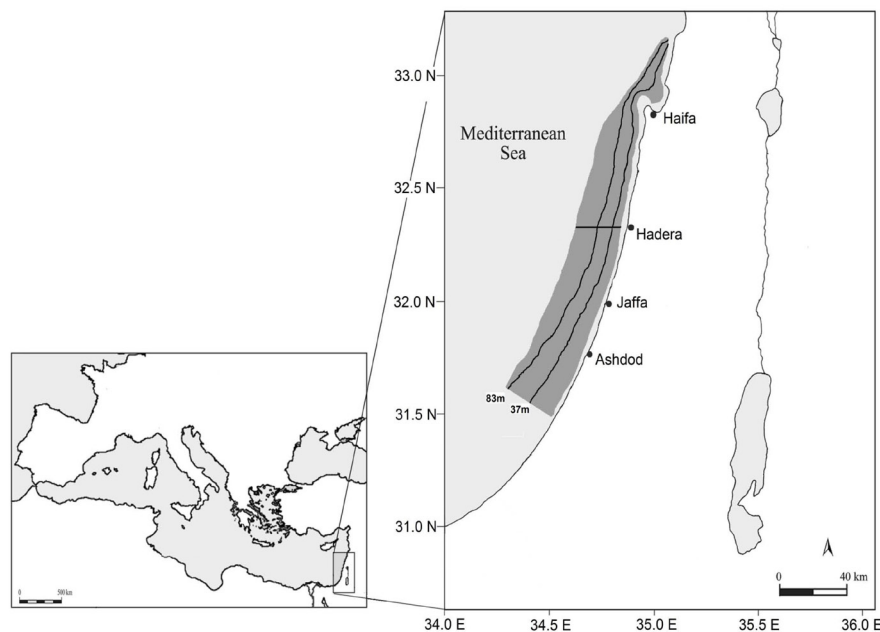


FIG. 1. – Map of the study site, with the main locations and isobaths mentioned in the text. The dark grey area represents the study area, covering all the trawling grounds on the Israeli coast in the study period.

The present study refers to data collected in the early 1990s, when 30–34 vessels, each with a mean engine power of 214–228 hp, were spending a total of 5152–6214 days at sea each year (Snovsky and Shapiro, 1997). The fleet size was frozen at 30 licenses in 1995 and today only 23 out of the 30 vessels are active, possibly due to rising fuel prices and declining catches. This fleet size limit has not proven effective in halting declines in CPUE (catch per unit effort; Fig. 2). A 45-day summer trawling moratorium was established in 1998–99, but the policy was discontinued the following year despite encouraging interim results, including increasing catches and larger specimens of commercial species (Pisanty *et al.*, 2000). Currently, the fleet trawls all year round, spending only ca. 4000 days/year at sea. It is important to note that this reduction in fishing effort is mitigated by an increase in mean engine power (currently 294 hp), which allows increased effort per sea-day. Before 2004–5, the fleet trawled for hake in the spring, and also for rose shrimps *Parapenaeus longirostris* and red shrimps *Aristeus antennatus* and *Aristeomorpha foliacea*. In recent years stocks have dwindled, and now the fleet operates almost exclusively on the continental shelf between 15 m (the minimum depth allowed by law) and 150 m. This trend towards shallower trawls is in opposition to the efforts in other Mediterranean fisheries, for which regulation of shallow trawling has led to the development of deep-sea trawl fisheries (D’Onghia *et al.*, 2003, Esmeralda-Costa *et al.*, 2008). Such spatial changes in fishing effort alter species compositions, and therefore more Lessepsian migrants are caught by trawlers fishing in the shallows (see Results). The gear has changed very little since 1990, and 40–48mm (at the cod end) diamond-mesh nets

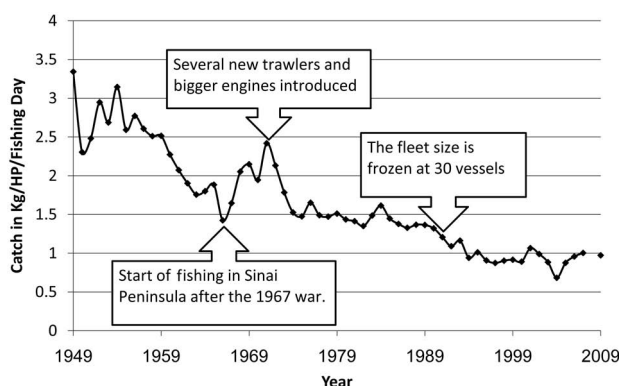


FIG. 2. – Declines in CPUE (catch per unit effort) of Israeli trawlers based on data collected by the Department of Fisheries in the Ministry of Agriculture since 1948. The effort unit used was engine horsepower per day at sea, as used by Garcia and Demetropoulos (1986).

are still used by all trawlers. Annual catches in the early 1990s fluctuated between 1107 and 1757 t, with a mean of 1409 t; in the last 3 years, catches did not exceed 1227 t per year. While catches of hake, grouper, goatfish and meagre have sharply declined in recent decades (Scheinin, 2010), increases were noted for Chondrichthyes and for the invasive tiger prawn *Marsupenaeus japonicus*. Since shrimp trawling is more fuel efficient, today almost all vessels target *M. japonicus* in the shallows (15–40 m) at night.

### Data collection

Data were collected from 324 commercial trawl hauls carried out between April 1990 and December 1994 by the Israel Fishery Department. These surveys

took place onboard trawlers fishing the Israeli continental shelf, between latitudes 31°20' N and 33°05' N. Depths ranged between 15 and 300 m. The gross, discarded and landed catch weights were estimated for 173 out of the 324 hauls in which two or more of these variables were recorded, and therefore total catch analysis was possible. A sample of ca. 5% of the biomass (2.7–12.5 kg with a mean of  $5.5 \pm 2.4$  kg per haul) was extracted from each haul. While this partial-sampling method may miss rare species, it allows nearly all the fauna in the nets to be properly sampled and the time-consuming length measurements to be carried out onboard. Fish were taxonomically identified to species level, except for several cases in which only the genus was noted. Fish Total Length (TL), cephalopod Mantle Length (ML) and crustacean Carapace Length (CL for crabs, eye to telson length for shrimps) were measured to the closest 0.5 cm interval. The discard lengths defined in the present study are described in Table 1 and were subsequently used to differentiate between the two discarded fractions: non-commercial species and juveniles of commercial species. These lengths were determined empirically, i.e. they were estimated based on observations of onboard sorting practices, fishermen's experience and minimum landing size (MLS), rather than on the actual onboard sorting of specimens, which may vary considerably due to factors such as season, abundance, and market considerations (Machias *et al.*, 2001, Demestre *et al.*, 2008).

### Data analysis

Four factors (season, depth, time of the day and geographical trawling area) were tested for their effects (Wilcoxon signed rank test,  $P < 0.05$ ) on discard proportions of both the biomass (expressed in kg per hour) and number of discarded fish, which were classified as either undersized commercial specimens or non-commercial species. Other variables examined included mean species richness (S), Shannon (H') and Simpson diversity and evenness (Pielou's J) as well as the mean proportion of Lessepsian migrants in hauls.

Seasons were defined as four equal three-month periods. The time of day was defined as either day or night. Depths of hauls were divided into 3 depth strata. The 37 m isobath was chosen to separate the shallow from medium depth due to bottom type: sandy to 37 m and muddy in deeper strata. This depth is the median point of the 25–50 m sand-mud transition zone described by Sandler and Herut (2000). The 83 m isobath was chosen as the transition point between medium and deep strata because it approximates the median depth for hauls deeper than 37 m. The two study areas, north of Hadera vs. south of Hadera, span the entire trawling range of the Israeli fleet. Though the two areas are adjacent, they were analyzed independently in this study because they are trawled by two different groups of trawlers (which use similar fishing techniques). Haifa-based trawlers operate north of Hadera, while

fields south of Hadera are mostly fished by trawlers that dock in Jaffa and Ashdod (see Fig. 1). We compare the northern and southern areas to test our hypothesis of a higher Lessepsian migrant abundance in the south.

Catch composition analysis was performed using the PRIMER-E v6 statistical software package (Clarke and Warwick, 2001) as follows: For clustering of hauls and Multi Dimensional Scaling analysis (MDS), data was  $\log x+1$  transformed (to allow for the expression of less common species in the assemblage) and then ordered in a Bray-Curtis similarity matrix. The PERMANOVA routine in PRIMER was used to test the significance of differences and the interactions between factors. This application tests the simultaneous response of variables to factors in an ANOVA design using permutations. The SIMPER routine in PRIMER was used to identify the most dominant species in each stratum, defined as the species which contributed most to the Bray-Curtis similarity. To this end, sample data was square-root transformed in order to weight the more abundant species (e.g. Clarke and Warwick, 2001).

### RESULTS

A total of 145 species (or genera, where specific identification was uncertain) belonging to 75 families was identified in surveys (Table 1). Of 124 bony fish species, Sparidae (17 species) and Carangidae (8 species) were the most dominant families. Seven cartilaginous fish species, 10 crustacean species and 6 species/genera of cephalopods were recorded. Sixty-two species were consistently discarded, 52 were commercial, and 40 were assigned a minor commercial value due to their scarcity, low price or both (Table 1). Bony fish accounted for 69.4% of the total number of specimens. Crustaceans, despite being represented by only 10 species, accounted for 28.3% of all specimens. The total landed biomass harvest rate was  $19.7 \text{ kg h}^{-1}$ , while  $7.74 \text{ kg h}^{-1}$  were discarded, culminating in a total discard mean per-haul of 28.2% of the biomass. Of all the sampled specimens, 46.7% were discarded. For bony fishes only, this figure was slightly higher at 52.3% (Table 1).

All four factors were found to have significant effects (Wilcoxon,  $P < 0.05$ ) on the discarded proportion of the catch, and the factors 'depth' and 'season' generally had lower p values. Depth and season also had significant effects on Shannon's H', Pielou's J and Simpson's D, as well as species richness. The time of day and geographic area did not however have significant effects on evenness.

The highest seasonal biomass discard ratio was recorded in summer (38.6%; Fig. 3a) and almost doubled that of spring or winter. It coincided with a very high summer proportion of discarded specimens (61% of bony fish; Fig. 4a). Furthermore, during summer 74% of these were undersized juveniles of commercial species. In no other season did any of the last two parameters exceed 52%. Shannon's diversity and species richness significantly decreased from means of

TABLE 1. – List of species recorded in surveys, their origin, commercial value and abundance in 324 trawl samples, as well as their landed and discarded fractions in the catch. N, number of specimens; Minor, minor commercial value; Com., commercial; Disc., discarded; \* Lessepsian migrant; \*\* discard size was set according to MLS regulations; \*\*\* species were not separated in samples and were recorded as one taxa.

Species	Family	Value	N	Discard Size in mm	No. Landed	Discard %
<b>Bony Fishes</b>						
<i>Pagellus erythrinus</i>	Sparidae	Com.	7284	110**	1918	73.6
<i>Upeneus moluccensis</i> *	Mullidae	Com.	6230	90	4524	27.3
<i>Boops boops</i>	Sparidae	Com.	5469	130	1979	63.8
<i>Mullus barbatus</i>	Mullidae	Com.	4774	90	3624	24.1
<i>Callionymus filamentosus</i> *	Callionymidae	Disc.	3631	-	0	100
<i>Leiognathus kluzingeri</i> *	Leiognathidae	Disc.	3569	-	0	100
<i>Mullus surmuletus</i>	Mullidae	Com.	3501	90	2525	27.9
<i>Spicara smaris</i>	Centracanthidae	Minor	2491	130	139	94.4
<i>Pagellus acarne</i>	Sparidae	Com.	2483	120	1402	43.5
<i>Dentex macrophthalmus</i>	Sparidae	Com.	2093	110	328	84.3
<i>Saurida undosquamis</i> *	Synodontidae	Com.	1796	160**	1289	28.2
<i>Trachurus mediterraneus</i>	Carangidae	Com.	1795	130	833	53.5
<i>Engraulis encrasicolus</i>	Engraulidae	Minor	1573	110	25	98.4
<i>Lepidotrigla cavillone</i>	Triglidae	-	1525	-	0	100
<i>Merluccius merluccius</i>	Merlucciidae	Com.	1090	140	849	22.1
<i>Macrorhamphosus scolopax</i>	Macrorhamphosidae	Disc.	838	-	0	100
<i>Sardina pilchardus</i>	Clupeidae	Minor	764	110	200	73.8
<i>Lithognathus mormyrus</i>	Sparidae	Com.	763	110**	546	28.4
<i>Citharus linguatula</i>	Citharidae	Minor	731	150	86	88.2
<i>Alepes djedaba</i> *	Carangidae	Com.	729	110**	547	24.9
<i>Serranus hepatus</i>	Serranidae	Disc.	600	-	0	100
<i>Upeneus pori</i> *	Mullidae	Com.	583	90	481	17.5
<i>Sphyræna chrysaena</i> *	Sphyrænidae	Com.	515	150	494	4.1
<i>Trachinus draco</i>	Trachinidae	Disc.	453	-	0	100
<i>Stephanolepis diaspros</i> *	Monacanthidae	Disc.	450	-	0	100
<i>Bothus podas</i>	Bothidae	Disc.	427	-	0	100
<i>Spicara maena</i>	Centracanthidae	Minor	406	130	42	89.6
<i>Trachurus picturatus</i>	Carangidae	Com.	342	130	186	45.6
<i>Trachurus trachurus</i>	Carangidae	Com.	332	130	240	27.7
<i>Capros aper</i>	Caproidae	Disc.	325	-	0	100
<i>Sardinella aurita</i>	Clupeidae	Com.	319	110**	217	32.0
<i>Sphyræna sphyraena</i>	Sphyrænidae	Com.	286	150	268	6.3
<i>Arnoglossus sp.</i>	Bothidae	Disc.	213	-	0	100
<i>Uranoscopus scaber</i>	Uranoscopidae	Disc.	203	-	0	100
<i>Scomber japonicus</i>	Scombridae	Com.	197	110	172	12.7
<i>Pagrus coeruleostictus</i>	Sparidae	Com.	186	110	116	37.6
<i>Diplodus sargus</i>	Sparidae	Com.	165	110**	144	12.7
<i>Synodus saurus</i>	Synodontidae	Com.	159	160**	108	32.0
<i>Ariosoma balearicum</i>	Congridae	Disc.	152	-	0	100
<i>Trigloporus lastoviza</i>	Triglidae	Disc.	149	-	0	100
<i>Diplodus annularis</i>	Sparidae	Com.	138	110**	87	36.9
<i>Trigla lyra</i>	Triglidae	Disc.	130	-	0	100
<i>Caranx rhonchus</i>	Carangidae	Minor	123	130	110	10.5
<i>Serranus cabrilla</i>	Serranidae	Disc.	113	-	0	100
<i>Gobius niger</i>	Gobiidae	Disc.	110	-	0	100
<i>Sillago sihama</i> *	Sillaginidae	Com.	90	130	73	18.8
<i>Spicara flexuosa</i>	Centracanthidae	Minor	86	130	16	81.4
<i>Helicolenus dactylopterus</i>	Scorpaenidae	Disc.	85	-	0	100
<i>Epinephelus aeneus</i>	Serranidae	Com.	79	150	53	32.9
<i>Lagocephalus suezensis</i> *	Tetraodontidae	Disc.	78	-	0	100
<i>Seriola dumerili</i>	Carangidae	Com.	76	130	70	7.9
<i>Scomberomorus commerson</i> *	Scombridae	Com.	73	140	67	8.2
<i>Lepidorhombus whiffiagonis</i>	Scophthalmidae	Minor	71	150	0	100
<i>Trichiurus lepturus</i>	Trichiuridae	Minor	64	300	47	26.6
<i>Solea spp.</i>	Soleidae	Minor	60	150	24	0.6
<i>Diplodus vulgaris</i>	Sparidae	Com.	57	110**	48	15.8
<i>Chlorophthalmus agasizii</i>	Chlorophthalmidae	Disc.	56	-	0	100
<i>Pomadasys incisus</i>	Haemulidae	Minor	55	130	45	18.2
<i>Atherina spp.</i>	Atherinidae	Disc.	49	-	0	100
<i>Trachinus araneus</i>	Trachinidae	Disc.	48	-	0	100
<i>Apogon imberbis</i>	Apogonidae	Disc.	44	-	0	100
<i>Gnatholepis mystax</i>	Congridae	Disc.	38	-	0	100
<i>Phycis phycis</i>	Gadidae	Disc.	37	-	0	100
<i>Dussumieria elopsoides</i> *	Clupeidae	Minor	36	110**	36	0
<i>Herklotsichthys punctatus</i> *	Clupeidae	Minor	34	110	0	100
<i>Pagrus pagrus</i>	Sparidae	Minor	33	110	1	96.9
<i>Coelorhynchus Coelorhynchus</i>	Macrouridae	Disc.	25	-	0	100
<i>Zeus faber</i>	Zeidae	Minor	25	120	4	84.0
<i>Oxyurichthys petersi</i> *	Gobiidae	Disc.	24	-	0	100
<i>Caranx crysos</i>	Carangidae	Com.	21	130	15	28.6
<i>Lagocephalus spadiceus</i> *	Tetraodontidae	Disc.	21	-	0	100
<i>Siganus rivulatus</i> *	Siganidae	Minor	20	130	5	0.75
<i>Sargocentron rubrum</i> *	Holocentridae	Minor	18	140	17	5.5

TABLE 1 (cont.). – List of species recorded in surveys, their origin, commercial value and abundance in 324 trawl samples, as well as their landed and discarded fractions in the catch. N, number of specimens; Minor, minor commercial value; Com., commercial; Disc., discarded; \* Lessepsian migrant; \*\* discard size was set according to MLS regulations; \*\*\* species were not separated into samples and were recorded as one taxa.

Species	Family	Value	N	Discard Size in mm	No. Landed	Discard %
<i>Diplodus puntazzo</i>	Sparidae	Com.	17	110**	17	0
<i>Ophiodon barbatum</i>	Ophidiidae	Disc.	17	-	0	100
<i>Balistes capriscus</i>	Balistidae	Com.	16	130	14	12.5
<i>Microchirus ocellatus</i>	Soleidae	Disc.	14	-	0	100
<i>Dactylopterus volitans</i>	Dactylopteridae	Minor	13	130	2	84.6
<i>Oblada melanura</i>	Sparidae	Com.	13	110**	12	7.7
<i>Cynoglossus sinusarabici</i> *	Cynoglossidae	Disc.	11	-	0	100
<i>Terapon puta</i> *	Terapontidae	Disc.	10	-	0	100
<i>Liza aurata</i>	Mugilidae	Com.	9	200**	5	4.44
<i>Dentex gibbosus</i>	Sparidae	Minor	8	110	8	0
<i>Aspitrigla cuculus</i>	Triglidae	Disc.	7	-	0	100
<i>Conger conger</i>	Congridae	Disc.	7	-	0	100
<i>Dentex dentex</i>	Sparidae	Minor	7	110	2	71.4
<i>Dentex maroccanus</i>	Sparidae	Minor	7	110	1	85.7
<i>Hoplostethus mediterraneus</i>	Trachichthyidae	Disc.	6	-	0	100
<i>Sparus aurata</i>	Sparidae	Com.	6	110	6	0
<i>Xyrichtys novacula</i>	Labridae	Disc.	6	-	0	100
<i>Blennius ocellaris</i>	Blenniidae	Disc.	5	-	0	100
<i>Epinephelus haifensis</i>	Serranidae	Minor	5	150	4	0.2
<i>Alectis alexandrinae</i>	Carangidae	Minor	4	150	0	100
<i>Apogon pharonis</i> *	Apogonidae	Disc.	4	-	0	100
<i>Pempheris vanicolensis</i> *	Pempheridae	Disc.	4	-	0	100
<i>Siganus luridus</i> *	Siganidae	Minor	4	130	0	100
<i>Trachinus radiatus</i>	Trachinidae	Disc.	4	-	0	100
<i>Trigla lucerna</i>	Triglidae	Disc.	4	-	0	100
<i>Dicentrarchus punctatus</i>	Moronidae	Minor	3	150	3	0
<i>Hyporhamphus affinis</i> *	Hemiramphidae	Minor	3	160	3	0
<i>Lepidopus caudatus</i>	Trichiuridae	Minor	3	300	3	100
<i>Liza ramada</i>	Mugilidae	Minor	3	200	2	33.3
<i>Lophius budegassa</i>	Lophiidae	Minor	3	200	3	100
<i>Torquigener flavimaculosus</i> *	Tetraodontidae	Disc.	3	-	0	100
<i>Anguilla Anguilla</i>	Anguillidae	Disc.	2	-	0	100
<i>Argyrosomus regius</i>	Sciaenidae	Com.	2	150	2	0
<i>Etrumeus teres</i> *	Clupeidae	Com.	2	150	2	0
<i>Hemiramphus far</i> *	Hemiramphidae	Minor	2	160	2	0
<i>Muraena Helena</i>	Muraenidae	Minor	2	-	0	100
<i>Phycis blenoides</i>	Gadidae	Disc.	2	-	0	100
<i>Pomatomus saltator</i>	Pomatomidae	Com.	2	150	2	0
<i>Argentina sphyraena</i>	Argentinidae	Minor	1	-	0	100
<i>Echelus myrus</i>	Ophichthidae	Disc.	1	-	0	100
<i>Echeneis naucrates</i>	Echeneididae	Disc.	1	-	0	1
<i>Epinephelus costae</i>	Serranidae	Minor	1	150	1	0
<i>Lepidotrigla dieuzeidei</i>	Triglidae	Disc.	1	-	0	100
<i>Microchirus variegatus</i>	Soleidae	Disc.	1	-	0	100
<i>Mugil cephalus</i>	Mugilidae	Com.	1	200	1	0
<i>Pagrus auriga</i>	Sparidae	Com.	1	110	1	0
<i>Panturichthys fowleri</i>	Heterochelyidae	Disc.	1	-	0	100
<i>Scorpaena notata</i>	Scorpaenidae	Disc.	1	-	0	100
<i>Scorpaena scrofa</i>	Scorpaenidae	Disc.	1	-	0	100
<i>Symphurus nigrescens</i>	Cynoglossidae	Disc.	1	-	0	100
<b>Cartilagenous Fishes</b>						
<i>Torpedo torpedo</i>	Torpedinidae	Minor	30	170	14	53.3
<i>Rhinobatos rhinobatos</i>	Rhinobatidae	Com.	8	300	3	62.5
<i>Raja miraletus</i>	Rajidae	Com.	7	250	0	100
<i>Squalus blainvillei</i>	Squalidae	Minor	3	500	2	33.3
<i>Torpedo marmorata</i>	Torpedinidae	Minor	3	170	2	33.3
<i>Dasyatis pastinaca</i>	Dasyatidae	Com.	2	250	1	50
<i>Mustelus mustelus</i>	Triakidae	Minor	1	500	0	100
<b>Cephalopods</b>						
<i>Loligo vulgaris</i>	Loliginidae	Com.	1481	100	233	84.3
<i>Sepia officinalis</i>	Sepiidae	Com.	242	60	189	21.9
<i>Octopus/Eledone sp.</i>	Octopodidae	Com.	134	20	100	25.4
<i>Illex coindetii</i>	Ommastrephidae	Com.	63	100	20	68.2
<b>Crustaceans</b>						
<i>Parapenaeus longirostris</i>	Penaeidae	Com.	14773	60	4253	71.5
<i>Marsupenaeus japonicus</i> *	Penaeidae	Com.	3707	60	3637	1.9
<i>Charybdis longicollis</i> *	Portunidae	Disc.	3595	-	0	100
<i>Aristeomorpha foliacea</i> / <i>Aristeus antennatus</i> ***	Aristeidae	Com.	2940	60	2270	22.8
<i>Erugosquilla massavensis</i> */ <i>Squilla mantis</i> ***	Squillidae	Disc.	252	-	0	100
<i>Portunus pelagicus</i> *	Portunidae	Com.	30	70	30	0
<i>Penaeus semisulcatus</i> *	Penaeidae	Com.	41	60	41	0
<i>Pontocaris cataphracta</i>	Crangonidae	Disc.	12	-	0	100
<i>Metapenaeus monoceros</i> *	Penaeidae	Minor	8	60	8	0

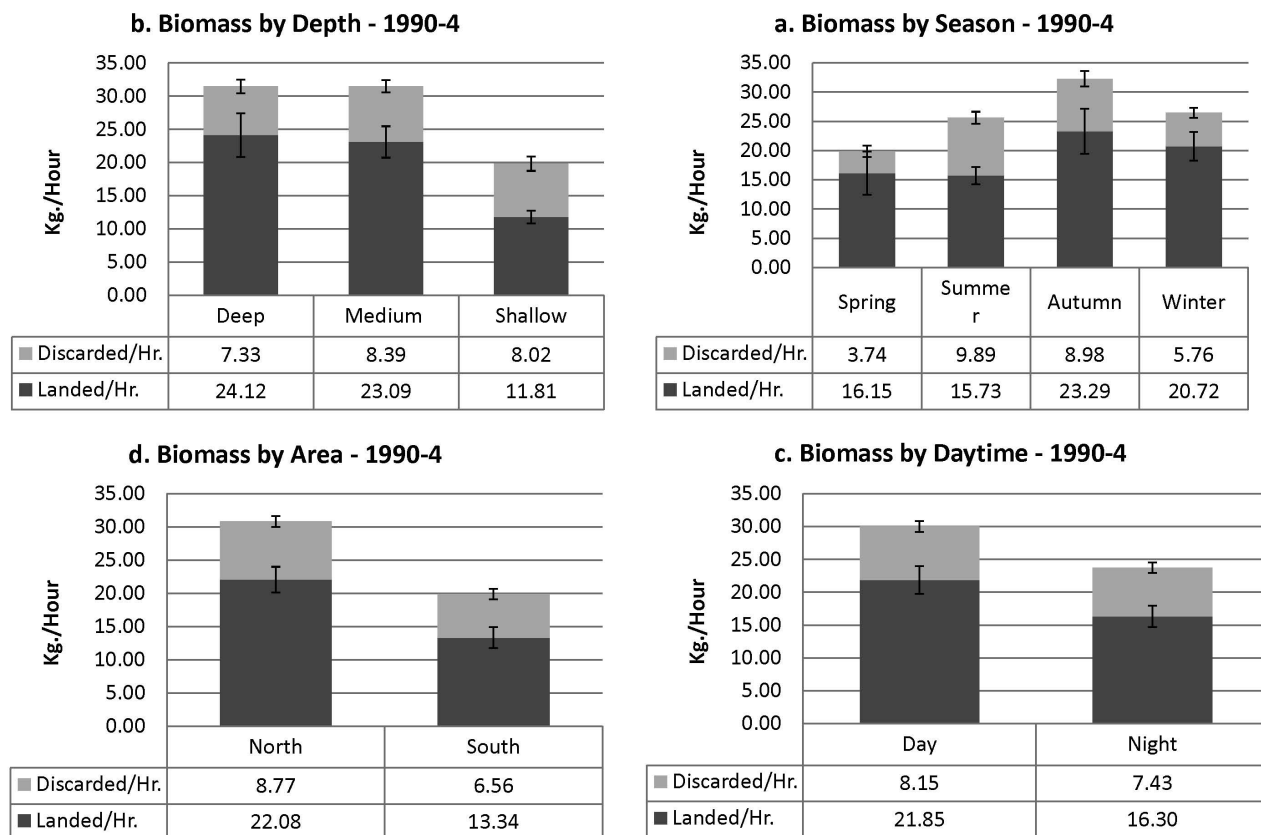


FIG. 3. – Mean landed and discarded biomass ± standard error, recorded in 173 trawl hauls for the 4 study factors: a, season; b, depth; c, time of day; and d, area.

TABLE 2. – Number of hauls used for the analysis of sample data (total n=324) and biomass (recorded in 173 hauls). Note that several hauls may have exceeded a single time of day, depth or area and were thus omitted from the respective analysis.

Sample analysis (Total n=324)	Biomass analysis (Total n=173)	Details	Factor
78	40	Oct.-Dec.	Autumn
100	53	Jan.-Mar.	Winter
40	17	Apr.-Jun.	Spring
106	63	Jul.-Sep.	Summer
55	38	>84m	Deep
147	72	38-83m	Medium
114	57	<37m	Shallow
162	90	Daylight	Day
158	82	Darkness	Night
199	106	North of Hadera	North
116	60	South of Hadera	South

H'=1.96 and S=18.17 species per haul in the summer to values of 1.77 and 15.72 respectively in winter.

The discard ratio was also found to be highest in shallow fishing fields (Fig. 3b; 40.1%) and discards were comprised mostly of unwanted species (Fig. 4b). In deeper strata, discard proportions were lower but were comprised mostly of juveniles of commercial species. Diversity and richness were negatively correlated with depth, and decreased from 1.92 and 17.94 for shallow hauls (<37 m deep) to 1.56 and 14.98 species per haul in deep hauls respectively.

TABLE 3. – A permutation analysis of variance (PERMANOVA) designed to test interactions of the study factors - depth, time of day (nested in depth), area and season, and their interactions. P(permutation) indicates the statistical significance of the interaction. \*P<0.05 \*\*P<0.005

Factor	df	Pseudo-F	P(permutation)	perms
Depth	2	4.1055	0.018*	999
Area	2	1.5092	0.145	998
Season	3	2.8254	0.102	997
Time of day (Depth)	3	4.3359	0.001**	999
Depth×Area	3	1.4737	0.134	999
Depth×Season	6	2.0571	0.079	999
Area×Season	5	1.5973	0.219	998
Area×Time of day(Depth)	4	1.5736	0.008**	999
Season×Time of day(Depth)	7	1.7061	0.001**	996
Depth×Area×Season	5	1.3105	0.302	999
Area×Season×Time of day (Depth)	3	1.4126	0.04*	997
Residual	274	4.1967E5		
Total	324	8.1654E5		

The predominance of night hauls in shallow waters (80 out of 114 shallow hauls were nocturnal; Fig. 5) caused the depth and time of day to be confounding. The time of day factor was therefore nested within the depth factor in the permutational analysis of variance (PERMANOVA) design, which tested for interactions between factors. The PERMANOVA model results (Table 3) indicate that depth and time of day nested within depth had the most significant effects on catch

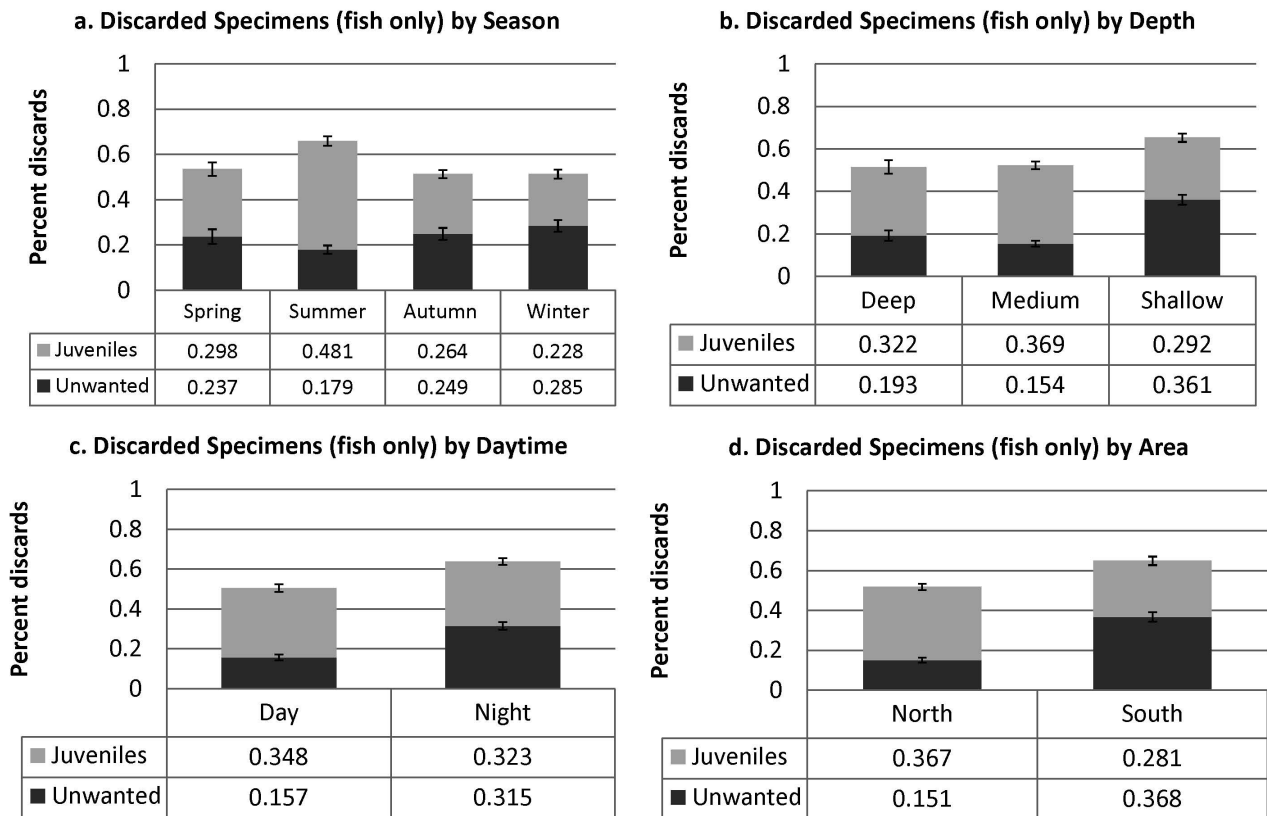


FIG. 4. – Mean proportion of the two fractions comprised in the discarded portion of the fish in 324 haul samples: undersized juveniles of commercial species and specimens of unwanted, non-commercial species ± standard error, for the 4 study factors: a, season; b, depth; c, time of day; and d, area.

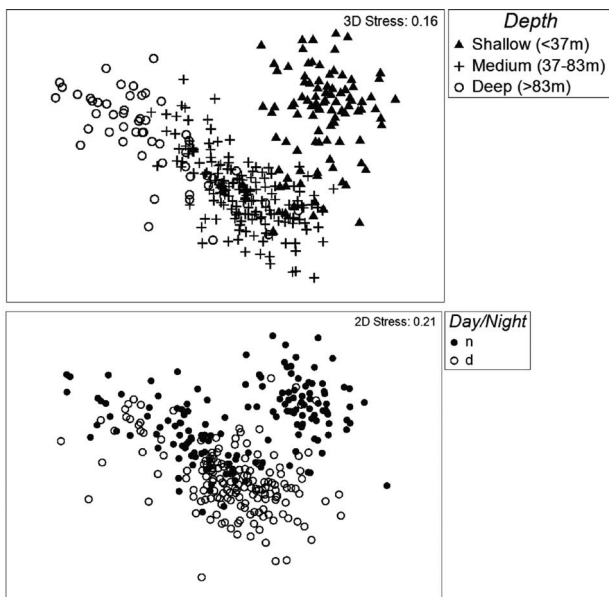


FIG. 5. – MDS of the species composition of 324 haul samples according to haul depth (top) and time of day (bottom); n, night; d, day.

species composition. Towing area and season had no significant effects on composition, except when they interacted with the time of day nested in depth, which

suggests a complex set of influences on species compositions. After it was determined that depth was the dominant factor affecting catch composition, a SIMPER analysis was performed separately for each of the 3 depth strata. Higher similarity (Table 4) was recorded for hauls in deep and medium strata than in shallow hauls. The porgy *Pagellus erythrinus* was found to be the most dominant species in shallow and medium depths. Commercial penaeid prawns were among the dominant species in both shallow and deep hauls, with *P. longirostris* and *M. japonicus* ranking first and third respectively in these strata.

Several trends were found to differentiate between trawling areas: northern hauls showed higher landed catches (by 9 kg h<sup>-1</sup>; Fig. 3d) and lower biomass discard percentages (by 6%) than southern hauls. However, these discards were comprised mainly of juveniles of commercial species (Fig. 4d).

Migrants accounted for 29.2% of the total landed biomass in surveys. Out of 26 Lessepsian bony fish species, 7 were commercial, 6 were of minor commercial value and 13 were always discarded (Table 1), whereas 4 out of the 6 Lessepsian crustacean species were of commercial value. In The SIMPER analysis, 4 out of the 7 most dominant species in the shallow stratum were Lessepsian migrants (Table 4). In depths exceeding 37 m, the dominant Lessepsian species were



TABLE 4. – Results of a nonparametric SIMPER procedure based on a square root transformed Bray-Curtis similarity index of the number of specimens per hour of trawling. The contribution of the dominant species to the similarity % (Contrib%) of the 3 depth strata is described for the 7 dominant species of each stratum. Other parameters include the average contribution to abundance, similarity, similarity/standard deviation and cumulative similarity.

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Shallow stratum (15-37 m) average similarity: 30.31					
<i>Pagellus erythrinus</i>	1.50	6.30	1.25	20.77	20.77
<i>Callionymus filamentosus</i> *	1.30	5.41	0.97	17.84	38.61
<i>Marsupenaeus japonicus</i> *	1.26	4.86	0.70	16.05	54.66
<i>Boops boops</i>	0.68	2.17	0.78	7.15	61.81
<i>Saurida undosquamis</i> *	0.52	1.33	0.66	4.39	66.19
<i>Lithognathus mormyrus</i>	0.50	1.32	0.67	4.36	70.55
<i>Upeneus pori</i> *	0.45	1.26	0.69	4.17	74.72
Medium stratum (38-83 m) average similarity: 34.06					
<i>Pagellus erythrinus</i>	1.46	6.01	1.72	17.65	17.65
<i>Upeneus moluccensis</i> *	1.51	5.21	0.98	15.28	32.93
<i>Mullus barbatus</i>	1.20	3.25	0.79	9.54	42.48
<i>Boops boops</i>	1.16	3.18	0.86	9.33	51.81
<i>Mullus surmuletus</i>	0.99	2.27	0.64	6.68	58.49
<i>Pagellus acarne</i>	0.88	1.60	0.50	4.70	63.19
<i>Saurida undosquamis</i> *	0.62	1.51	0.59	4.43	67.62
Deep stratum (>84 m) average similarity: 33.09					
<i>Parapenaeus longirostris</i>	2.77	12.63	1.13	38.18	38.18
<i>Merluccius merluccius</i>	1.09	4.33	1.01	13.07	51.25
<i>Dentex macrophthalmus</i>	1.23	3.54	0.66	10.69	61.93
<i>Boops boops</i>	0.85	1.94	0.60	5.87	67.80
<i>Mullus barbatus</i>	0.62	1.77	0.75	5.35	73.15
<i>Macrohamphosus scolopax</i>	0.77	1.48	0.53	4.47	77.62
<i>Aristeomorpha foliacea</i>	0.77	1.24	0.28	3.73	81.35

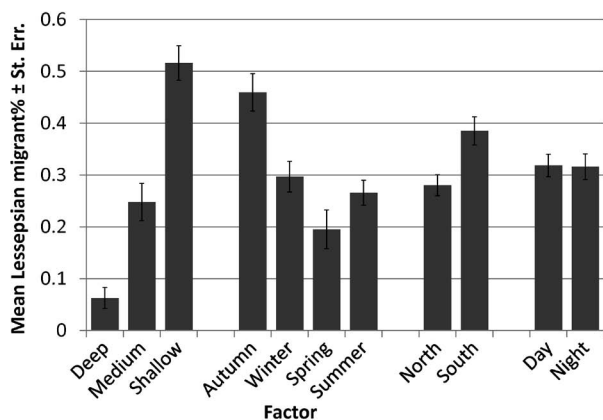


FIG. 6. – Mean Lessepsian migrant proportion ± S.E. for the 4 study factors in the 324 haul samples.

the goatfish *U. moluccensis* and the lizardfish *S. undosquamis* (Table 4). In shallower waters, where migrants proliferate, the penaeid prawn *M. japonicus* was the prominent commercial species. It also accounted for the bulk of shallow landings. Other common migrants were mostly non-commercial species such as the in-shore pelagic pony fish *L. klunzingeri*, the shallow water dragonet *C. filamentosus* and the swimming crab *C. longicollis*. Proportions of migrants in the catch varied significantly (Wilcoxon,  $P < 0.05$ ) with season, depth and area, peaking in the autumn, shallows and south respectively (Fig. 6). No statistically significant differences were found for the time of day. In total, 43.9% of all Indo-Pacific specimens were discarded; slightly less than the 47.3% noted for indigenous specimens.

## DISCUSSION

### Discards and catch composition

This is the first fully quantitative study of demersal fish communities in the Levant. Despite its delayed publication, this dataset provides a crucial reference point for the assessment of change vectors. It also demonstrates the magnitude of the effects of trawling on the Levantine ecosystem via discards, which is a prime conservation issue. Discards in the present study amounted to 28.2% of the total catch, or 330-550 t of the 1107-1757 t  $y^{-1}$  caught by Israeli trawlers during the study period (Snovsky and Shapiro, 1997). It is estimated, however, that >90% of trawling in Israel is performed at depths shallower than 83m, where discard rates are closer to 40% (Fig. 3b). This leads to a total discards estimate of 440-700 t per annum for the Israeli fleet. The 28.2% figure for total discards in the present study is considerably lower than the 40-45% figure used by Davies *et al.* (2009) for the entire Mediterranean, but higher than the 15-25% values suggested by El-Mor *et al.* (2002) and Alsayes *et al.* (2009) for Egyptian trawlers. The high discard ratios described here clearly support the use of more selective trawl nets, such as the 40mm square mesh nets mandated by the General Fisheries Commission for the Mediterranean (GFCM) for Mediterranean fleets by 2012. Mesh size regulations in Israel today are still similar to those used during the study period. We therefore recommend making further changes, as well as establishing MPAs and a summer moratorium on trawling as precautionary measures.

Israeli gross catch rates fluctuated seasonally between 19.9 and 32.2 kg h<sup>-1</sup>, while discards varied between 3.7 and 9.9 kg h<sup>-1</sup> (Fig. 3). Despite the poor Levantine fishery suppositions made in various studies (Por, 1989, Sonin *et al.*, 2007), these values are comparable to catch and discard rates reported for the central Mediterranean (Machias *et al.*, 2001, D'Onghia *et al.*, 2003, Sánchez *et al.*, 2007). Discarded biomass alone, however, cannot represent the full extent of the impact of trawling on future year classes. The spatiotemporal variance in discards, as shown in Fig. 4, reveals the motive for discarding and also the potential commercial losses incurred. We suggest that these datasets may compensate slightly for the absence of proper stock assessments in the region. Nearly 60% of all fish were discarded in the present study, with juveniles of commercially exploited species representing >60% of these discards.

97 species appeared in both Machias *et al.* (2001) and the present study. Out of these, 30 taxa were marketed in Greece but discarded in Israel. An example of these taxa (which abound in catches but are seldom sold) is the genus *Spicara* (n=2978 in Table 1). Members of this genus comprise up to 50% of the commercial catch of trawls in Cyprus (Garcia and Demetropoulos, 1986), while they are normally discarded in every size in Israel, and only acquire a minor commercial value when catches are especially poor. Other such species include congers, ophiidons and other eels, gurnards, some flatfishes, such as *B. podas* or *C. linguatula*, scorpion fishes, weavers and stargazers. Some crustaceans with commercial potential are also discarded in Israel, most notably the stomatopod *Squilla mantis*, which is landed consistently, and seldom discarded in Balearic and Adriatic trawl fisheries (Sánchez *et al.*, 2007, Demestre *et al.*, 2008). The Israeli fishing fleet is thus wasting a potentially valuable resource, as these species can be landed and sold if a suitable market can be found. However, when this issue is addressed the smaller size of Levantine organisms (i.e. Nanism), may limit the commercial potential of these genera. This dwarfing phenomenon has been suggested to be the result of lower productivity in the region (Sonin *et al.*, 2007) and is speculated to affect most of the Levantine fauna (Por, 1989, Sonin *et al.*, 2007).

For several species, most noticeably goatfishes, the observed discard length differed greatly from MLS. The MLS of goatfish is 11 cm; however, due to the high prices obtained for goatfish regardless of size, specimens as small as 9 cm were consistently landed and this was the length actually used as the maximum discard size. This led to fairly low discard rates of 17.5-27.3% for the 4 mullid species. An examination of the most commonly caught commercial and minor-commercial species in Table 1 reveals two distinct subgroups. One subgroup includes species which exhibit low discard rates (less than 30%) such as the 4 mullid species, lizardfish and hake (due to their high commercial value and small discard sizes), rock-dwelling

sea breams (most of which are adults caught foraging slightly off their rocky habitat) and pelagic or semi-pelagic families such as Scombridae, Clupeidae or Carangidae. The second subgroup is made up of species for which 60-98% of the specimens were discarded. This includes some of the most common species, such as porgies, bouge, picarels, dentex and flatfishes. The landing size for these species is substantially larger than the mean size of caught specimens, which leads to high discard rates. Esmeralda Costa *et al.* (2009) found a similar trend as far west as Portugal, with less than 30% discards for sardines, carangids, scombrids and *Diplodus* spp., as opposed to >70% for porgies and hake. It is evident from the small size of the fish caught by Levantine trawlers (Table 1) that most individuals have not reached reproductive maturity. This seriously jeopardizes the sustainability of the fishery regardless of whether juveniles are landed or discarded.

### Spatial and temporal trends

Depth was found to be the main explanatory factor for both catch composition and discard percentage. Higher landed and lower discarded biomass was found deeper than 37 m (Fig. 3b). However, the proportion of juveniles of commercial species within discards in these deep strata was significantly higher (Fig. 4). Shallow stratum discard proportions were higher (Fig. 3b); however, they were dominated by non-commercial species, rather than commercial juveniles (Fig. 4b). This finding may present a dilemma for fishery managers seeking to minimize discards via spatial exclusion: although closing shallow waters to trawling will lead to a richer and more diverse environment, shifting the effort into deeper grounds will harm more commercial juveniles. A trawl ban shallower than 50m (as described by Sweeting *et al.*, 2009) may not be suitable for Israeli fishing fields, as it may displace trawling effort into deeper grounds, where juvenile recruits make up a larger portion of the assemblage. In addition, a 50 m minimum trawl depth would eliminate the entire *M. japonicus* catch, the most valuable commercial resource harvested by trawlers.

High summer discard proportions were accompanied by increases in Shannon's H' and species richness. As in shallow depths, summer discards were comprised mostly of non-commercial species (Fig. 4a). A summer trawling moratorium, as practiced in other Mediterranean countries (Machias *et al.*, 2001, D'Onghia *et al.*, 2003, Sánchez *et al.*, 2004, Demestre *et al.*, 2008) may prove effective in raising CPUE and reducing discards. An effective moratorium requires that fishing pressure is not merely shifted to other seasons and that discard practices remain consistent throughout the fishing season (Machias *et al.*, 2001, Sánchez *et al.*, 2007).

As in the present study, Sánchez *et al.* (2004) reported that discarded biomass decreased with depth on the shelf. Machias *et al.* (2001) and D'Onghia *et al.* (2003), working on the slope, found that discard

percentages increased with depth. This may attest to a spatial discarding pattern for the Mediterranean, where discards are highest on the deep shelf and decrease towards the shallower shelf from one end and the deeper slope on the other.

Juveniles of the European squid *L. vulgaris* and the rose shrimp *P. longirostris* were dominant among deep strata discards. Whereas squids are consistently landed when of size, rose shrimps are often discarded even at legal sizes, mostly due to low market prices. Despite the high abundance of rose shrimp, the high costs of deep sea trawling often stop trawlers from targeting it. Conversely, discarded crustaceans in shallow waters included mostly the non-commercial swimming crab *C. longicollis*. Along with several other species, this crab was responsible for a high crustacean discard rate in Levantine shallow waters (>5 kg h<sup>-1</sup>), which is unlike the low ca. 1 kg h<sup>-1</sup> crustacean discard rate noted by Machias *et al.* (2001) in Greece.

### Lessepsian migrants

The percent of Lessepsian migrant specimens in trawl catches decreased from 51% in the shallows to 24% and 8% in the medium and deep strata respectively. *S. undosquamis* and *U. moluccensis* were the dominant Indo-Pacific species in the deeper grounds; perhaps outlining the maximum bathymetric boundary of migration. The niche partitioning pattern, (Golani, 1993) which suggests that native goatfishes dominate deeper strata than migrants, is also evident in the present data (Table 4).

While Lessepsian migrants remain poorly established in the rocky littoral (Golani *et al.*, 2007), this study has found that they proliferate in highly (and often) disturbed trawl grounds. This heavily exploited environment only allows resilient species with rapid population recovery rates and recolonization abilities to persist. We therefore hypothesize that Lessepsian migrants display good adaptive characteristics, which have enabled them to migrate and colonize a new ecosystem, and which have given them a selective advantage in a scheme of recurring and rapid exploitation and recolonization like that imposed by trawling.

Lessepsian migrants were a significant and valuable portion of the Israeli trawl catch in the past (Ben-Yami, 1955), and remain so today (Sonin *et al.*, 2007). Still, some studies argue that the cumulative effect of migration is harmful (Galil, 2007). Ben-Tuvia (1973) estimated that migrants constitute 21% of trawl yields, slightly less than the landed migrant biomass proportion found in the present study (29%). As expected, migrants were most common in shallow grounds (Fig. 6). No substantial diurnal differences in migrant proportions were observed; however, their composition in catches varied between night and day. The SIMPER analysis showed that typical nighttime migrants were the dragonet *C. filamentosus* and the prawn *M. japonicus* in the shallows. The main migrants contributing to

daytime assemblages in all strata were *U. moluccensis*, *S. undosquamis* and *L. klunzingeri*. The first two species were also responsible for high migrant percentages in autumn and winter (Fig. 6). These species, along with the indigenous *B. boops* and *P. erythrinus*, also accounted for the high landings in autumn (Fig. 3a). The present study has also found a significantly higher proportion of Lessepsian migrants in the southern trawling area (Fig. 6). We suggest that this is either the result of its proximity to the Suez Canal or of the wider continental shelf of southern Israel.

Today, the migrant prawn *M. japonicus* is a central target species of the Egyptian, Turkish and Israeli trawl fisheries (Galil, 2007). Its high market value and near-shore habitat have reshaped local trawling and turned the shallow strata into the most intensively trawled habitat off the Israeli coast. Since its acceptance in the local market in the 1970s, it has comprised more than a fifth of the income of Israeli trawlers (Snovsky and Shapiro, 1997). With increasing migration rates, soaring oil prices and declines in deep fisheries, it stands to reason that the market value and overall biomass of migrant species will continue to rise in the future. More research and time are required to determine whether migrants can compensate for the loss of landings of local species or the declines in CPUE shown in Fig. 2.

New trawl surveys are currently being conducted along the Israeli coast. The present study serves as an important spatial and temporal baseline for a detailed comparison of the status of fish and fisheries over the last two decades in the dynamic, quickly evolving habitats of the Mediterranean.

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### REFERENCES

- Alsayes, A., S. Fattouh and S. Abu-Enin. – 2009. By-catch and discarding of trawl fisheries at the Mediterranean coast of Egypt. *World J. Fish. Mar. Sci.*, 1: 199-205
- Alverson, D.L., M.H. Freeberg, S.A. Murawski and J.G. Pope. – 1994. A global assessment of fisheries bycatch and discards. *FAO Fish. Tech. Paper*, 339: 233.
- Ben-Tuvia, A. – 1973. Man-made changes in the eastern Mediterranean Sea and their effect on the fishery resources. *Mar. Biol.*, 19: 197-203.
- Ben-Yami, M. – 1955. 1954 – 1955: over-fishing or bad season? *Fisher. Bull.*, Haifa 6: 10-14 [in Hebrew]
- Clarke, K.R. and R.M. Warwick. – 2001. Change in marine communities: an approach to statistical analysis and interpretation, 2<sup>nd</sup> edition. PRIMER-E: Plymouth
- Davies, R.W.D., S.J. Cripps, A. Nickson and G. Porter. – 2009. Defining and estimating global marine fisheries bycatch. *Mar. Policy*, 33: 661-672.
- Demestre, M.S. de Juan, P. Sartor and A. Ligas. – 2008. Seasonal

- closures as a measure of trawling effort control in two Mediterranean trawling grounds: Effects on epibenthic communities. *Mar. Pollut. Bull.*, 56: 1765-1773.
- D'Onghia G., R. Carlucci, P. Maiorano and M. Panza. – 2003. Discards from deep-water bottom trawling in the eastern-central Mediterranean Sea and effects of mesh size changes. *J. Northwest Atl. Fish. Soc.*, 31: 245-261.
- El-Mor, M., J.S. El-Etreby, S. Mohammad and M.R. Sapota. – 2002. A study on trash catch of the bottom trawl along Port-Said coast, Egypt. *Oceanolog. Stud.*, 31: 45-55.
- Esmeralda Costa, M., K. Erzini and T. Cerveira Borges. – 2008. Bycatch of crustacean and fish bottom trawl fisheries from southern Portugal (Algarve). *Sci. Mar.*, 72(4): 801-814.
- Galil, B.S. – 2007. Seeing red: alien species along the Mediterranean coast of Israel. *Aquat. Invas.*, 2: 281-312.
- Garcia, S. and A. Demetropoulos. – 1986. Management of Cyprus fisheries. *FAO Fisheries Technical Paper*, (250): 40 pp.
- Golani, D. – 1993. The sandy shore of the Red Sea - launching pad for Lessepsian (Suez Canal) migrant fish colonizers of the eastern Mediterranean. *J. Biogeog.*, 20(6): 579-585.
- Golani, D., R. Reef-Motro, S. Ekshtein, A. Baranes and A. Diamant. – 2007. Ichthyofauna of the rocky coastal littoral of the Israeli Mediterranean, with reference to the paucity of Red Sea (Lessepsian) migrants in this habitat. *Mar. Biol. Res.*, 3: 333-341.
- Hall, M.A., D. L. Alverson and K. I. Metuzals. – 2000. By-Catch: problems and solutions. *Mar. Pollut. Bull.*, 41(1-6): 204-219.
- Jackson, J.B.C., M.X. Kirby, W.H. Berger, K.A. Bjorndal, L.W. Botsford, B.J. Bourque, R.H. Bradbury, R. Cooke, J. Erlandson, J.A. Estes, T.P. Hughes, S. Kidwell, C.B. Lange, H.S. Lenihan, J.M. Pandolfi, C.H. Peterson, R.S. Steneck, M.J. Tegner and R.R. Warner. – 2001. Historical overfishing and the recent collapse of coastal ecosystems. *Science*, 293: 629-637.
- Kelleher, K. – 2005. Discards in the world's marine fisheries: an update. Rome: Food and Agriculture Organization of the United Nations, FAO; 2005. 131 pp.
- Leonart, J. and F. Maynou. – 2003. Fish stock assessments in the Mediterranean: state of the art. *Sci. Mar.*, 67(Suppl. 1): 37-49.
- Machias A., V. Vassilopoulou, D. Vatsos, P. Bekas, A. Kallianiotis, C. Papaconstantinou and N. Tsimenides. – 2001. Bottom trawl discards in the northeastern Mediterranean Sea. *Fish. Res.*, 53: 181-195.
- Pauli, D., V. Christensen, S. Guénette, T.J. Pitcher, U.R. Sumaila, C.J. Walters, R. Watson and D. Zeller. – 2002. Towards sustainability in world fisheries. *Nature*, 418: 689-695.
- Pisanty, S., O. Sonin and A. Alperovic. – 2000. Assessment of the influence of a summer trawling ban on the catch of the fishery. Technical Paper (in Hebrew). State of Israel, Ministry of Agriculture and Rural Development, Department of Fisheries. 17 pp.
- Por, F.D. – 1989. The legacy of Tethys - an aquatic biogeography of the Levant. Dordrech, Kluwer 216 pp.
- Rilov, G. and B.S. Galil. – 2009. Marine bioinvasions in the Mediterranean Sea - history, distribution and ecology. In: G. Rilov and J.A. Crooks (eds.), *Biological invasions in marine ecosystems: ecological management and geographic perspectives*, 3-11 pp. Springer-Verlag, Heidelberg.
- Sacchi, J. 2008. The use of trawling nets in the Mediterranean. Problems and selectivity options. *Options Mediterranennes*, B62: 87-96.
- Sánchez P., M. Demestre and P. Martín. – 2004. Characterization of the discards generated by bottom trawling in the northwestern Mediterranean. *Fish. Res.*, 67: 71-80.
- Sánchez P., P. Sartor, L. Recasens, A. Ligas, J. Martín, S. de Ranieri and M. Demestre. – 2007. Trawl catch composition during different fishing intensity periods in two Mediterranean demersal fishing grounds. *Sci. Mar.*, 71(4): 765-773.
- Sandler, A. and B. Herut. – 2000. Composition of clays along the continental shelf off Israel: contribution of the Nile versus local sources. *Mar. Geol.*, 167: 339-354.
- Scheinin, A.P. – 2010. *The population of bottlenose dolphins (Tursiops truncatus), bottom trawl catch trends and the interaction between the two along the Mediterranean continental shelf of Israel*. Ph.D. dissertation, Univ. Haifa, Israel.
- Snovsky, G. and J. Shapiro – 1997. *The fishery and aquaculture of Israel 1996 in figures*. The state of Israel, Ministry of Agriculture – Department of Fisheries. 37pp.
- Sonin O., E. Spanier, D. Levi, B. Patti, P. Rizzo and M.G. Andreoli. – 2007. Nanism (dwarfism) in fish: a comparison between red mullet *Mullus barbatus* from the southeastern and the central Mediterranean. *Mar. Ecol. Prog. Ser.*, 343: 221-228.
- Soykan H. and T. Kinacıgil. – 2006. Bycatch associated with shrimp trawling in the Eastern Mediterranean (Taşucu Bay) In: *Report of the ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB)*. Izmir, Turkey. 16.3: 50p.
- Spanier E. and B.S. Galil. – 1991. Lessepsian migration a continuous biogeographical process. *Endeavour*, 15 (3): 102-106.
- Stergiou, K.I., E. Christou and G. Petrakis. – 1997. Modelling and forecasting monthly fisheries catches: comparison of regression, univariate and multivariate time series methods. *Fish. Res.*, 29: 55-95.
- Sweeting C.J., F. Badalamenti, G. D'Anna, C. Pipitone and N.V. C. Polunin. – 2009. Steeper biomass spectra of demersal fish communities after trawler exclusion in Sicily. *ICES. J. Mar. Sci.*, 66: 195-202.
- Tsagarakis K., A. Machias, M. Giannoulaki, S. Somarakis and I. Karakassis. – 2008. Seasonal and temporal trends in metrics of fish community for otter-trawl discards in a Mediterranean ecosystem. *ICES. J. Mar. Sci.*, 65(4): 539-550.
- Wassenberg T.J., S. J. M. Blaber, C. Y. Burrige, D. T. Brewer, J. P. Salini and N. Grible. – 1997. The effectiveness of fish and shrimp trawls for the sampling of fish communities in tropical Australia. *Fish. Res.*, 30: 241-251.

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