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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, Lleonart 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).

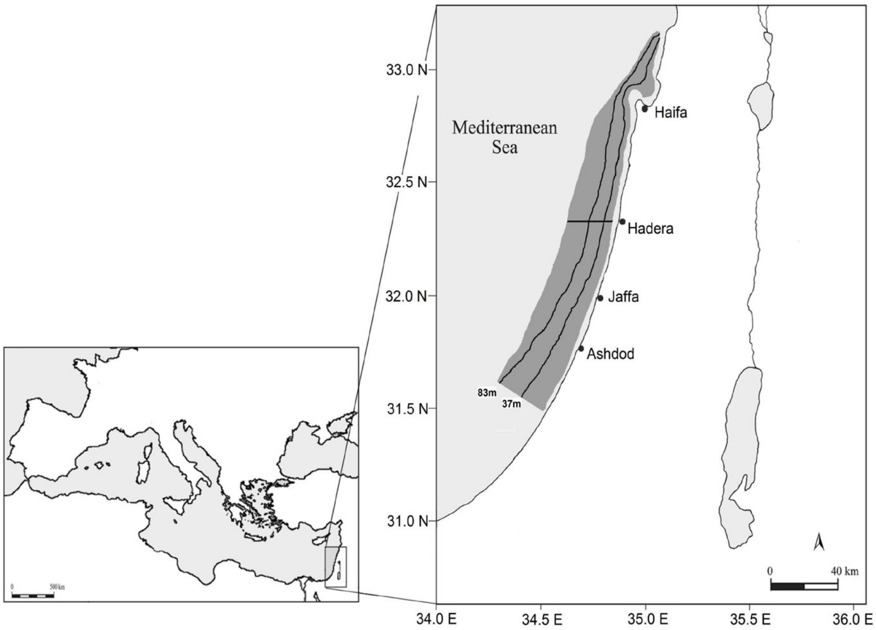

FIG. 1. – Map of the study site, with the main locations and isobaths mentioned in the text. The dark grey area represents the study area, covering all the trawling grounds on the Israeli coast in the study period.

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 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.

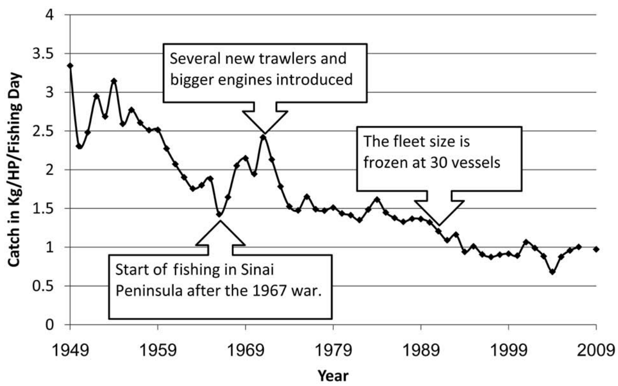

FIG. 2. – Declines in CPUE (catch per unit effort) of Israeli trawlers based on data collected by the Department of Fisheries in the Ministry of Agriculture since 1948. The effort unit used was engine horsepower per day at sea, as used by Garcia and Demetropoulos (1986).

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 31º20' N and 33º05' 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±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 kg h^{-1}, while 7.74 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 %
Bony Fishes						
Pagellus erythrinus	Sparidae	Com.	7284	110**	1918	73.6
*Upeneus moluccensis**	Mullidae	Com.	6230	90	4524	27.3
Boops boops	Sparidae	Com.	5469	130	1979	63.8
Mullus barbatus	Mullidae	Com.	4774	90	3624	24.1
*Callionymus filamentosus**	Callionymidae	Disc.	3631	-	0	100
*Leiognathus kluzingeri**	Leiognathidae	Disc.	3569	-	0	100
Mullus surmuletus	Mullidae	Com.	3501	90	2525	27.9
Spicara smaris	Centracanthidae	Minor	2491	130	139	94.4
Pagellus acarne	Sparidae	Com.	2483	120	1402	43.5
Dentex macrophthalmus	Sparidae	Com.	2093	110	328	84.3
*Saurida undosquamis**	Synodontidae	Com.	1796	160**	1289	28.2
Trachurus mediterraneus	Carangidae	Com.	1795	130	833	53.5
Engraulis encrasicolus	Engraulidae	Minor	1573	110	25	98.4
Lepidotrigla cavillone	Triglidae	Disc.	1525	-	0	100
Merluccius merluccius	Merlucciidae	Com.	1090	140	849	22.1
Macrorhamphosus scolopax	Macrorhamphosidae	Disc.	838	-	0	100
Sardina pilchardus	Clupeidae	Minor	764	110	200	73.8
Lithognathus mormyrus	Sparidae	Com.	763	110**	546	28.4
Citharus linguatula	Citharidae	Minor	731	150	86	88.2
*Alepes djedaba**	Carangidae	Com.	729	110**	547	24.9
Serranus hepatus	Serranidae	Disc.	600	-	0	100
*Upeneus pori**	Mullidae	Com.	583	90	481	17.5
*Sphyraena chrysotaenia**	Sphyraenidae	Com.	515	150	494	4.1
Trachinus draco	Trachinidae	Disc.	453	-	0	100
*Stephanolepis diaspros**	Monacanthidae	Disc.	450	-	0	100
Bothus podas	Bothidae	Disc.	427	-	0	100
Spicara maena	Centracanthidae	Minor	406	130	42	89.6
Trachurus picturatus	Carangidae	Com.	342	130	186	45.6
Trachurus trachurus	Carangidae	Com.	332	130	240	27.7
Capros aper	Caproidae	Disc.	325	-	0	100
Sardinella aurita	Clupeidae	Com.	319	110**	217	32.0
Sphyraena sphyraena	Sphyraenidae	Com.	286	150	268	6.3
Arnoglossus sp.	Bothidae	Disc.	213	-	0	100
Uranoscopus scaber	Uranoscopidae	Disc.	203	-	0	100
Scomber japonicus	Scombridae	Com.	197	110	172	12.7
Pagrus coeruleostictus	Sparidae	Com.	186	110	116	37.6
Diplodus sargus	Sparidae	Com.	165	110**	144	12.7
Synodus saurus	Synodontidae	Com.	159	160**	108	32.0
Ariosoma balearicum	Congridae	Disc.	152	-	0	100
Trigloporus lastoviza	Triglidae	Disc.	149	-	0	100
Diplodus annularis	Sparidae	Com.	138	110**	87	36.9
Trigla lyra	Triglidae	Disc.	130	-	0	100
Caranx rhonchus	Carangidae	Minor	123	130	110	10.5
Serranus cabrilla	Serranidae	Disc.	113	-	0	100
Gobius niger	Gobiidae	Disc.	110	-	0	100
*Sillago sihama**	Sillaginidae	Com.	90	130	73	18.8
Spicara flexuosa	Centracanthidae	Minor	86	130	16	81.4
Helicolenus dactylopterus	Scorpaenidae	Disc.	85	-	0	100
Epinephelus aeneus	Serranidae	Com.	79	150	53	32.9
*Lagocephalus suezensis**	Tetraodontidae	Disc.	78	-	0	100
Seriola dumerili	Carangidae	Com.	76	130	70	7.9
*Scomberomorus commerson**	Scombridae	Com.	73	140	67	8.2
Lepidorhombus whiffiagonis	Scophthalmidae	Minor	71	150	0	100
Trichiurus lepturus	Trichiuridae	Minor	64	300	47	26.6
Solea spp.	Soleidae	Minor	60	150	24	0.6
Diplodus vulgaris	Sparidae	Com.	57	110**	48	15.8
Chlorophthalmus agassizii	Chlorophthalmidae	Disc.	56	-	0	100
Pomadasys incisus	Haemulidea	Minor	55	130	45	18.2
Atherina spp.	Atherinidae	Disc.	49	-	0	100
Trachinus araneus	Trachinidae	Disc.	48	-	0	100
Apogon imberbis	Apogonidae	Disc.	44	-	0	100
Gnatholepis mystax	Congridae	Disc.	38	-	0	100
Phycis phycis	Gadidae	Disc.	37	-	0	100
*Dussumieria elopsoides**	Clupeidae	Minor	36	110**	36	0
*Herklotsichthys punctatus**	Clupeidae	Minor	34	110	0	100
Pagrus pagrus	Sparidae	Minor	33	110	1	96.9
Coelorhynchus Coelorhynchus	Macrouridae	Disc.	25	-	0	100
Zeus faber	Zeidae	Minor	25	120	4	84.0
*Oxyuirichthys petersi**	Gobiidae	Disc.	24	-	0	100
Caranx crysos	Carangidae	Com.	21	130	15	28.6
*Lagocephalus spadiceus**	Tetraodontidae	Disc.	21	-	0	100
*Siganus rivulatus**	Siganidae	Minor	20	130	5	0.75
*Sargocentron rubrum**	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 %
Diplodus puntazzo	Sparidae	Com.	17	110**	17	0
Ophiodon barbatum	Ophidiidae	Disc.	17	-	0	100
Balistes capriscus	Balistidae	Com.	16	130	14	12.5
Microchirus ocellatus	Soleidae	Disc.	14	-	0	100
Dactylopterus volitans	Dactylopteridae	Minor	13	130	2	84.6
Oblada melanura	Sparidae	Com.	13	110**	12	7.7
*Cynoglossus sinusarabici**	Cynoglossidae	Disc.	11	-	0	100
*Terapon puta**	Terapontidae	Disc.	10	-	0	100
Liza aurata	Mugilidae	Com.	9	200**	5	4.44
Dentex gibbosus	Sparidae	Minor	8	110	8	0
Aspitrigla cuculus	Triglidae	Disc.	7	-	0	100
Conger conger	Congridae	Disc.	7	-	0	100
Dentex dentex	Sparidae	Minor	7	110	2	71.4
Dentex maroccanus	Sparidae	Minor	7	110	1	85.7
Hoplostethus mediterraneus	Trachichthyidae	Disc.	6	-	0	100
Sparus aurata	Sparidae	Com.	6	110	6	0
Xyrichthys novacula	Labridae	Disc.	6	-	0	100
Blennius ocellaris	Blenniidae	Disc.	5	-	0	100
Epinephelus haifensis	Serranidae	Minor	5	150	4	0.2
Alectis alexandrines	Carangidae	Minor	4	150	0	100
*Apogon pharonis**	Apogonidae	Disc.	4	-	0	100
*Pempheris vanicolensis**	Pempheridae	Disc.	4	-	0	100
*Siganus luridus**	Siganidae	Minor	4	130	0	100
Trachinus radiatus	Trachinidae	Disc.	4	-	0	100
Trigla lucerna	Triglidae	Disc.	4	-	0	100
Dicentrarchus punctatus	Moronidae	Minor	3	150	3	0
*Hyporamphus affinis**	Hemiramphidae	Minor	3	160	3	0
Lepidopus caudatus	Trichiuridae	Minor	3	300	3	100
Liza ramada	Mugilidae	Minor	3	200	2	33.3
Lophius budegassa	Lophiidae	Minor	3	200	3	100
*Torquigener flavimaculosus**	Tetraodontidae	Disc.	3	-	0	100
Anguilla Anguilla	Anguillidae	Disc.	2	-	0	100
Argyrosomus regius	Sciaenidae	Com.	2	150	2	0
*Etrumeus teres**	Clupeidae	Com.	2	150	2	0
*Hemiramphus far**	Hemiramphidae	Minor	2	160	2	0
Muraena Helena	Muraenidae	Minor	2	-	0	100
Phycis blennoides	Gadidae	Disc.	2	-	0	100
Pomatomus saltator	Pomatomidae	Com.	2	150	2	0
Argentina sphyraena	Argentinidae	Minor	1	-	0	100
Echelus myrus	Ophichthidae	Disc.	1	-	0	100
Echeneis naucrates	Echeneididae	Disc.	1	-	0	1
Epinephelus costae	Serranidae	Minor	1	150	1	0
Lepidotrigla dieuzeidei	Triglidae	Disc.	1	-	0	100
Microchirus variegates	Soleidae	Disc.	1	-	0	100
Mugil cephalus	Mugilidae	Com.	1	200	1	0
Pagrus auriga	Sparidae	Com.	1	110	1	0
Panturichthys fowleri	Heterechelyidae	Disc.	1	-	0	100
Scorpaena notate	Scorpaenidae	Disc.	1	-	0	100
Scorpaena scrofa	Scorpaenidae	Disc.	1	-	0	100
Symphurus nigrescens	Cynoglossidae	Disc.	1	-	0	100
Cartilagenous Fishes						
Torpedo torpedo	Torpedinidae	Minor	30	170	14	53.3
Rhinobatos rhinobatos	Rhinobatidae	Com.	8	300	3	62.5
Raja miraletus	Rajidae	Com.	7	250	0	100
Squalus blainvillei	Squalidae	Minor	3	500	2	33.3
Torpedo marmorata	Torpedinidae	Minor	3	170	2	33.3
Dasyatis pastinaca	Dasyatidae	Com.	2	250	1	50
Mustelus mustelus	Triakidae	Minor	1	500	0	100
Cephalopods						
Loligo vulgaris	Loliginidae	Com.	1481	100	233	84.3
Sepia officinalis	Sepiidae	Com.	242	60	189	21.9
Octopus/Eledone sp.	Octopodidae	Com.	134	20	100	25.4
Illex coindeti	Ommastrephidae	Com.	63	100	20	68.2
Crustaceans						
Parapenaeus longirostris	Penaeidae	Com.	14773	60	4253	71.5
*Marsupenaeus japonicus**	Penaeidae	Com.	3707	60	3637	1.9
*Charybdis longicollis**	Portunidae	Disc.	3595	-	0	100
*Aristeomorpha foliacea/ Aristeus antennatus****	Aristeidae	Com.	2940	60	2270	22.8
Erugosquilla massavensis/ Squilla mantis****	Squillidae	Disc.	252	-	0	100
*Portunus pelagicus**	Portunidae	Com.	30	70	30	0
*Penaeus semisulcatus**	Penaeidae	Com.	41	60	41	0
Pontocaris cataphracta	Crangonidae	Disc.	12	-	0	100
*Metapenaeus monoceros**	Penaeidae	Minor	8	60	8	0

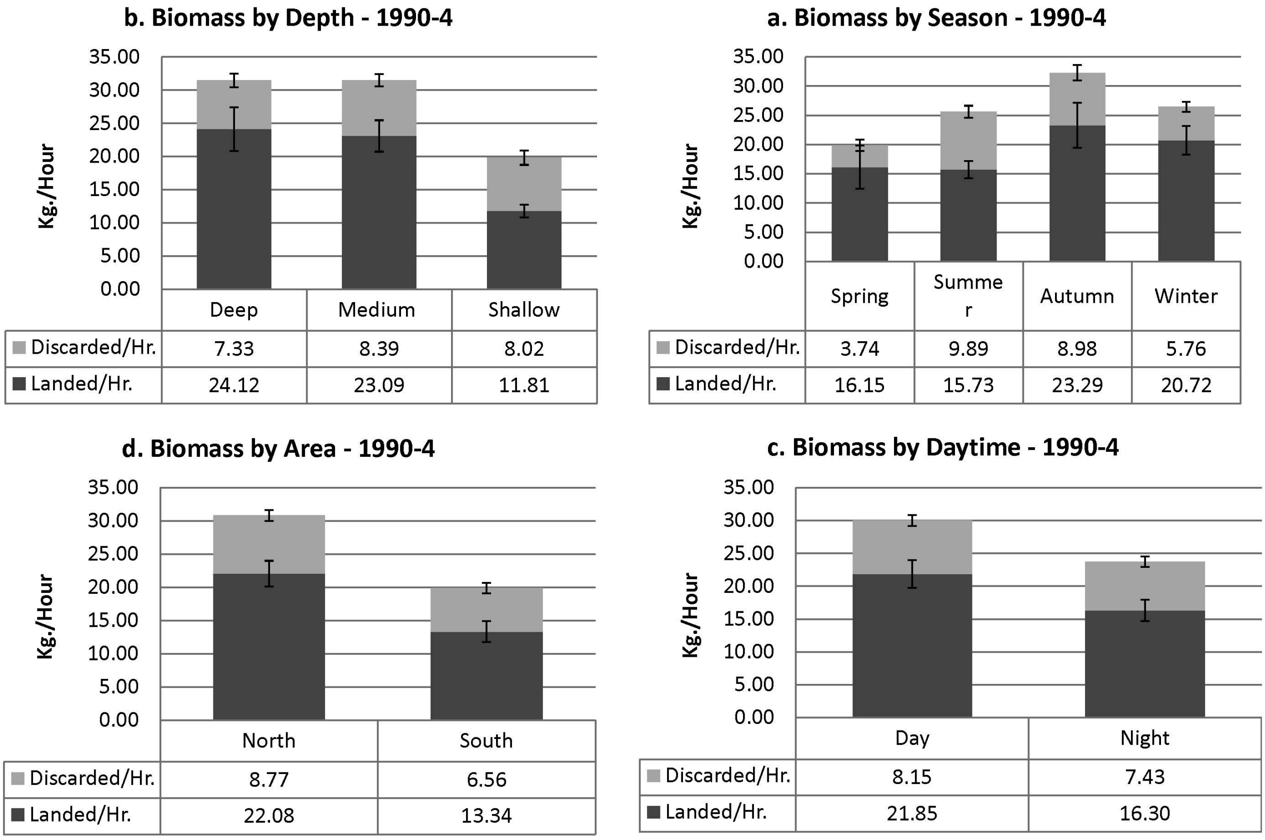

FIG. 3. – Mean landed and discarded biomass ± standard error, recorded in 173 trawl hauls for the 4 study factors: a, season; b, depth; c, time of day; and d, area.

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(perm) indicates the statistical significance of the interaction. *P<0.05 **P<0.005

Factor	df	Pseudo-F	P(perm)	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

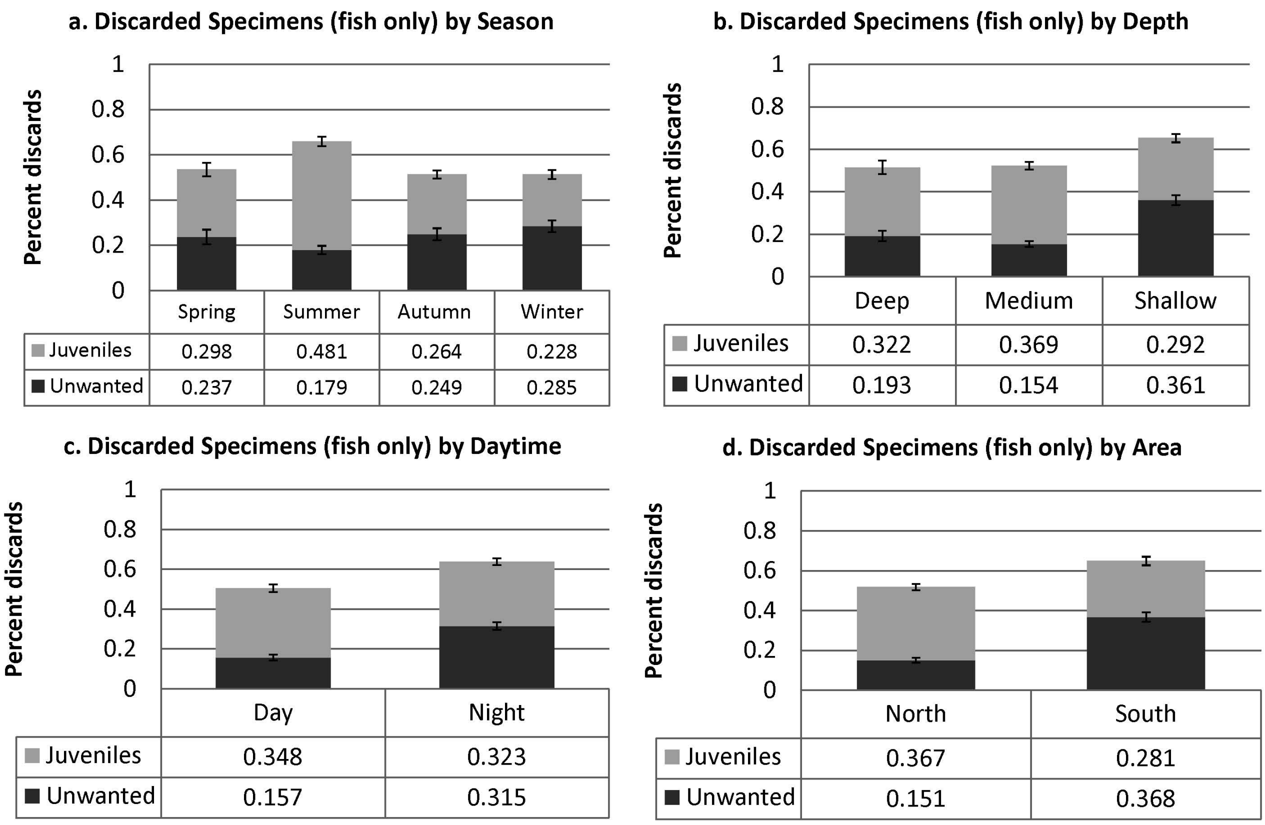

FIG. 4. – Mean proportion of the two fractions comprised in the discarded portion of the fish in 324 haul samples: undersized juveniles of commercial species and specimens of unwanted, non-commercial species ± standard error, for the 4 study factors: a, season; b, depth; c, time of day; and d, area.

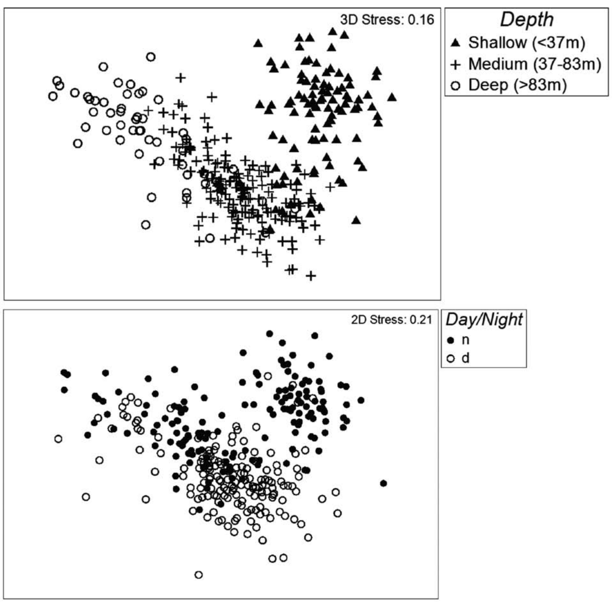

FIG. 5. – MDS of the species composition of 324 haul samples according to haul depth (top) and time of day (bottom); n, night; d, day.

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^{-1}; 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					
Pagellus erythrinus	1.50	6.30	1.25	20.77	20.77
*Callionymus filamentosus**	1.30	5.41	0.97	17.84	38.61
*Marsupenaeus japonicus**	1.26	4.86	0.70	16.05	54.66
Boops boops	0.68	2.17	0.78	7.15	61.81
*Saurida undosquamis**	0.52	1.33	0.66	4.39	66.19
Lithognathus mormyrus	0.50	1.32	0.67	4.36	70.55
*Upeneus pori**	0.45	1.26	0.69	4.17	74.72
Medium stratum (38-83 m) average similarity: 34.06					
Pagellus erythrinus	1.46	6.01	1.72	17.65	17.65
*Upeneus moluccensis**	1.51	5.21	0.98	15.28	32.93
Mullus barbatus	1.20	3.25	0.79	9.54	42.48
Boops boops	1.16	3.18	0.86	9.33	51.81
Mullus surmuletus	0.99	2.27	0.64	6.68	58.49
Pagellus acarne	0.88	1.60	0.50	4.70	63.19
*Saurida undosquamis**	0.62	1.51	0.59	4.43	67.62
Deep stratum (>84 m) average similarity: 33.09					
Parapenaeus longirostris	2.77	12.63	1.13	38.18	38.18
Merluccius merluccius	1.09	4.33	1.01	13.07	51.25
Dentex macrophthalamus	1.23	3.54	0.66	10.69	61.93
Boops boops	0.85	1.94	0.60	5.87	67.80
Mullus barbatus	0.62	1.77	0.75	5.35	73.15
Macrohamphosus scolopax	0.77	1.48	0.53	4.47	77.62
Aristeomorpha foliacea	0.77	1.24	0.28	3.73	81.35

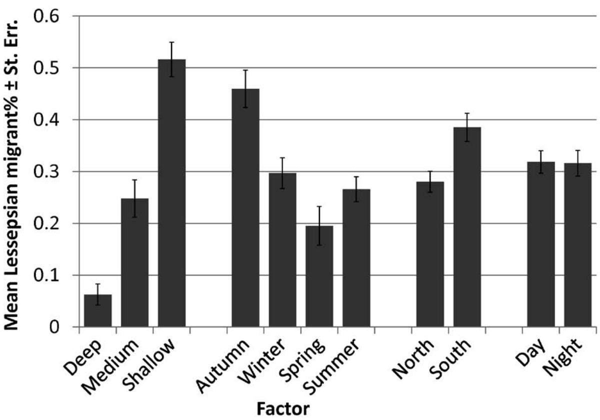

Fig. 6. – Mean Lessepsian migrant proportion ± S.E. for the 4 study factors in the 324 haul samples.

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 inshore 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^{-1}, while discards varied between 3.7 and 9.9 kg h^{-1} (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, ophiodons 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'Onoghia *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^{-1}), which is unlike the low ca. 1 kg h^{-1} 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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