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 periodo 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’Ongdia 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 Alsayas 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 (Soysan 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’Ongdia 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 continental 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).
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 Aristaeus 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.

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±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>
<thead>
<tr>
<th>Species</th>
<th>Family</th>
<th>Value</th>
<th>N</th>
<th>Discard Size in mm</th>
<th>No. Landed</th>
<th>Discard %</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Pagellus erythrinus</em></td>
<td>Sparidae</td>
<td>Com.</td>
<td>7284</td>
<td>110**</td>
<td>1918</td>
<td>73.6</td>
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<td><em>Upenes mulolucensis</em></td>
<td>Mullidae</td>
<td>Com.</td>
<td>6230</td>
<td>90</td>
<td>4524</td>
<td>27.3</td>
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<td><em>Boops boops</em></td>
<td>Sparidae</td>
<td>Com.</td>
<td>5469</td>
<td>130</td>
<td>1979</td>
<td>63.8</td>
</tr>
<tr>
<td><em>Mullus barbatus</em></td>
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<td>Disc.</td>
<td>4774</td>
<td>90</td>
<td>3624</td>
<td>24.1</td>
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<td><em>Callionymus filamentosus</em></td>
<td>Callionymidae</td>
<td>Disc.</td>
<td>3631</td>
<td>-</td>
<td>0</td>
<td>100</td>
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<td><em>Leiognathus klazingeri</em></td>
<td>Leiognathidae</td>
<td>Disc.</td>
<td>3569</td>
<td>-</td>
<td>0</td>
<td>100</td>
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<td><em>Mugil cephalus</em></td>
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<td>Com.</td>
<td>3501</td>
<td>90</td>
<td>2525</td>
<td>72.9</td>
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<td><em>Spicara smaris</em></td>
<td>Gobiidae</td>
<td>Minor</td>
<td>2491</td>
<td>130</td>
<td>139</td>
<td>94.4</td>
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<td>Com.</td>
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<td>120</td>
<td>1402</td>
<td>43.5</td>
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<td>2093</td>
<td>110</td>
<td>328</td>
<td>84.3</td>
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<td>Sauridae</td>
<td>Com.</td>
<td>1796</td>
<td>160**</td>
<td>1289</td>
<td>28.2</td>
</tr>
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<td><em>Trachurus mediterraneus</em></td>
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<td>Com.</td>
<td>1795</td>
<td>130</td>
<td>833</td>
<td>53.5</td>
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<td><em>Engraulis encrasicolus</em></td>
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<td>Minor</td>
<td>1573</td>
<td>110</td>
<td>25</td>
<td>98.4</td>
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<td>Disc.</td>
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<td>-</td>
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<td>100</td>
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<td>140</td>
<td>849</td>
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<td>Disc.</td>
<td>838</td>
<td>-</td>
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<td>100</td>
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<td>764</td>
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<td>200</td>
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<td>Com.</td>
<td>763</td>
<td>110**</td>
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<td>731</td>
<td>150</td>
<td>86</td>
<td>88.2</td>
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<td><em>Alepes djejaba</em></td>
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<td>Com.</td>
<td>729</td>
<td>110**</td>
<td>547</td>
<td>24.9</td>
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<td>Disc.</td>
<td>600</td>
<td>-</td>
<td>0</td>
<td>100</td>
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<td><em>Upeneus port</em></td>
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<td>Com.</td>
<td>583</td>
<td>90</td>
<td>481</td>
<td>17.5</td>
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<td>515</td>
<td>150</td>
<td>494</td>
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<td>Disc.</td>
<td>453</td>
<td>-</td>
<td>0</td>
<td>100</td>
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<td>450</td>
<td>-</td>
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<td>100</td>
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<td>Disc.</td>
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<td>-</td>
<td>0</td>
<td>100</td>
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<tr>
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<td>Minor</td>
<td>406</td>
<td>130</td>
<td>42</td>
<td>89.6</td>
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<td>Com.</td>
<td>342</td>
<td>130</td>
<td>186</td>
<td>45.6</td>
</tr>
<tr>
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<td>Com.</td>
<td>332</td>
<td>130</td>
<td>240</td>
<td>27.7</td>
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<tr>
<td><em>Capros aper</em></td>
<td>Caproidae</td>
<td>Disc.</td>
<td>325</td>
<td>-</td>
<td>0</td>
<td>100</td>
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<td><em>Sardinella aurita</em></td>
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<td>Com.</td>
<td>319</td>
<td>110**</td>
<td>217</td>
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<td>Disc.</td>
<td>286</td>
<td>150</td>
<td>268</td>
<td>6.3</td>
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<td>Disc.</td>
<td>213</td>
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<td>Disc.</td>
<td>203</td>
<td>-</td>
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<td>100</td>
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<td>110</td>
<td>172</td>
<td>12.7</td>
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<td>Com.</td>
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<td>110</td>
<td>174</td>
<td>37.6</td>
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<td>Com.</td>
<td>165</td>
<td>110**</td>
<td>144</td>
<td>12.7</td>
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<tr>
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<td>Sparinae</td>
<td>Com.</td>
<td>159</td>
<td>160**</td>
<td>108</td>
<td>32.0</td>
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<td><em>Ilisha saliens</em></td>
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<td>87</td>
<td>130</td>
<td>70</td>
<td>7.9</td>
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<td>73</td>
<td>140</td>
<td>67</td>
<td>8.2</td>
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<td><em>Lepidochromis whiffilagonis</em></td>
<td>Scophthalmidae</td>
<td>Minor</td>
<td>71</td>
<td>150</td>
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<td>100</td>
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<tr>
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<td>Minor</td>
<td>64</td>
<td>300</td>
<td>47</td>
<td>26.6</td>
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<td><em>Solea spp.</em></td>
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<td>Minor</td>
<td>60</td>
<td>150</td>
<td>24</td>
<td>0.6</td>
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<td>Com.</td>
<td>57</td>
<td>110**</td>
<td>48</td>
<td>15.8</td>
</tr>
<tr>
<td><em>Chlorophthalmus agassizii</em></td>
<td>Chlorophthalmidae</td>
<td>Disc.</td>
<td>56</td>
<td>-</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td><em>Pomadasys incisus</em></td>
<td>Haemulidae</td>
<td>Minor</td>
<td>43</td>
<td>130</td>
<td>45</td>
<td>18.2</td>
</tr>
<tr>
<td><em>Atherina spp.</em></td>
<td>Atherinidae</td>
<td>Disc.</td>
<td>49</td>
<td>-</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td><em>Trachinus araneus</em></td>
<td>Trachinidae</td>
<td>Disc.</td>
<td>48</td>
<td>-</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td><em>Apoen orinéris</em></td>
<td>Apogonidae</td>
<td>Disc.</td>
<td>44</td>
<td>-</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td><em>Gnathodes mystax</em></td>
<td>Congridae</td>
<td>Disc.</td>
<td>38</td>
<td>-</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
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<td>Disc.</td>
<td>37</td>
<td>-</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td><em>Dussunmeria elopsoides</em></td>
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<td>Minor</td>
<td>36</td>
<td>110**</td>
<td>36</td>
<td>0</td>
</tr>
<tr>
<td><em>Herklotschthys punctatus</em></td>
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<td>Minor</td>
<td>34</td>
<td>110</td>
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<td>100</td>
</tr>
<tr>
<td><em>Pagrus pagrus</em></td>
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<td>Min.</td>
<td>33</td>
<td>110</td>
<td>1</td>
<td>96.9</td>
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<tr>
<td><em>Cetolrhynchus Cetolrhynchus</em></td>
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<td>Disc.</td>
<td>25</td>
<td>-</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td><em>Zeus faber</em></td>
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<td>25</td>
<td>120</td>
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</tr>
<tr>
<td><em>Oxyurus hystes</em></td>
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<td>Disc.</td>
<td>24</td>
<td>-</td>
<td>0</td>
<td>100</td>
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<tr>
<td><em>Carangus cryos</em></td>
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<td>Com.</td>
<td>21</td>
<td>130</td>
<td>15</td>
<td>28.6</td>
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<tr>
<td><em>Lagocephalus spadiceus</em></td>
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<td>Disc.</td>
<td>21</td>
<td>-</td>
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<td>100</td>
</tr>
<tr>
<td><em>Siganus rivulatus</em></td>
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<tr>
<td><em>Sagonocentron rubrum</em></td>
<td>Holocentridae</td>
<td>Minor</td>
<td>18</td>
<td>140</td>
<td>17</td>
<td>5.5</td>
</tr>
</tbody>
</table>

Table 1. – List of species recorded in surveys, their original, 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; * Lessporean migrant; ** discard size was set according to MLS regulations; *** species were not separated in samples and were recorded as one taxon.
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.

<table>
<thead>
<tr>
<th>Species</th>
<th>Family</th>
<th>Value</th>
<th>N</th>
<th>Discard Size in mm</th>
<th>No. Landed</th>
<th>Discard %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diplodus puntazzo</td>
<td>Sparidae</td>
<td>Com.</td>
<td>17</td>
<td>110**</td>
<td>17</td>
<td>0</td>
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<td>Ophiodon barbatum</td>
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<td>Disc.</td>
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<td>100</td>
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<td>Com.</td>
<td>16</td>
<td>130</td>
<td>14</td>
<td>12.5</td>
</tr>
<tr>
<td>Microchirus occelatus</td>
<td>Soleidae</td>
<td>Disc.</td>
<td>14</td>
<td>-</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Dactylopterus volitans</td>
<td>Dactylopteriidae</td>
<td>Minor</td>
<td>13</td>
<td>130</td>
<td>2</td>
<td>84.6</td>
</tr>
<tr>
<td>Oblada melanura</td>
<td>Sparidae</td>
<td>Com.</td>
<td>13</td>
<td>110**</td>
<td>12</td>
<td>7.7</td>
</tr>
<tr>
<td>Cynosoglossus sinarabaci*</td>
<td>Cynosoglossidae</td>
<td>Disc.</td>
<td>11</td>
<td>-</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Terapon puta*</td>
<td>Teraponitidae</td>
<td>Disc.</td>
<td>10</td>
<td>-</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Liza aurata</td>
<td>Mugilidae</td>
<td>Com.</td>
<td>9</td>
<td>200**</td>
<td>5</td>
<td>4.44</td>
</tr>
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<td>Dentex gibbosus</td>
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<td>110</td>
<td>8</td>
<td>0</td>
</tr>
<tr>
<td>Aspirtiraga cuculus</td>
<td>Triglidae</td>
<td>Disc.</td>
<td>7</td>
<td>-</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Conger conger</td>
<td>Congridae</td>
<td>Disc.</td>
<td>7</td>
<td>-</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Dentex dentex</td>
<td>Sparidae</td>
<td>Minor</td>
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<td>110</td>
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<td>71.4</td>
</tr>
<tr>
<td>Dentex macoracanus</td>
<td>Sparidae</td>
<td>Minor</td>
<td>7</td>
<td>110</td>
<td>1</td>
<td>85.7</td>
</tr>
<tr>
<td>Hoplostethus mediterraneus</td>
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<td>Disc.</td>
<td>6</td>
<td>-</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Sparus aurata</td>
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<td>Com.</td>
<td>6</td>
<td>110</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Xyrichthis novacula</td>
<td>Labridae</td>
<td>Disc.</td>
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<td>100</td>
</tr>
<tr>
<td>Blehnnus ocellaris</td>
<td>Blemnidae</td>
<td>Disc.</td>
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<td>-</td>
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<td>100</td>
</tr>
<tr>
<td>Epinephelus hainensis</td>
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<td>150</td>
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<td>Alectis alexindras</td>
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<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Apogon pharomis*</td>
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<td>Disc.</td>
<td>4</td>
<td>-</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Pempheris vanicolensis*</td>
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<td>Disc.</td>
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<td>-</td>
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<td>100</td>
</tr>
<tr>
<td>Siganus luridus*</td>
<td>Siganidae</td>
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<td>130</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Trachinus radians</td>
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<td>Disc.</td>
<td>4</td>
<td>-</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Trigla lucerna</td>
<td>Triglidae</td>
<td>Disc.</td>
<td>4</td>
<td>-</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Dicentrarchus punctatus</td>
<td>Moronidae</td>
<td>Minor</td>
<td>3</td>
<td>150</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Hyporamphus affinis*</td>
<td>Hemirhamphidae</td>
<td>Minor</td>
<td>3</td>
<td>160</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Lepidopus caudatus</td>
<td>Trichuriidae</td>
<td>Minor</td>
<td>3</td>
<td>300</td>
<td>3</td>
<td>100</td>
</tr>
<tr>
<td>Liza ramada</td>
<td>Mugilidae</td>
<td>Minor</td>
<td>3</td>
<td>200</td>
<td>2</td>
<td>33.3</td>
</tr>
<tr>
<td>Lophius budagassa</td>
<td>Lophiidae</td>
<td>Minor</td>
<td>3</td>
<td>200</td>
<td>3</td>
<td>100</td>
</tr>
<tr>
<td>Torquigener flavimaculosus*</td>
<td>Tetraodontidae</td>
<td>Disc.</td>
<td>3</td>
<td>-</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Anguilla Anguilla</td>
<td>Anguillidae</td>
<td>Disc.</td>
<td>2</td>
<td>-</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Argyrosomus regius</td>
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<td>Com.</td>
<td>2</td>
<td>150</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Erimenes teres*</td>
<td>Clupeidae</td>
<td>Disc.</td>
<td>2</td>
<td>150</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Hemirhamphus far*</td>
<td>Hemirhamphidae</td>
<td>Minor</td>
<td>2</td>
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<td>0</td>
</tr>
<tr>
<td>Muraena Helena</td>
<td>Muraenidae</td>
<td>Minor</td>
<td>2</td>
<td>-</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Physiblion bimaculata</td>
<td>Gadidae</td>
<td>Disc.</td>
<td>2</td>
<td>-</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Pomatomus saltator</td>
<td>Pomatomidae</td>
<td>Com.</td>
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<td>150</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Argentina sphyraena</td>
<td>Argentinidae</td>
<td>Minor</td>
<td>1</td>
<td>-</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Echeneius argus</td>
<td>Ophichthidae</td>
<td>Disc.</td>
<td>1</td>
<td>-</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Echeneis naucrates</td>
<td>Echeneidae</td>
<td>Disc.</td>
<td>1</td>
<td>-</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Epinephelus costae</td>
<td>Serranidae</td>
<td>Minor</td>
<td>1</td>
<td>150</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Lepidodriga diezeidei</td>
<td>Triglidae</td>
<td>Disc.</td>
<td>1</td>
<td>-</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Microchirus variegates</td>
<td>Soleidae</td>
<td>Disc.</td>
<td>1</td>
<td>-</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Mugil cephalus</td>
<td>Mugilidae</td>
<td>Com.</td>
<td>1</td>
<td>200</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Pagrus auriga</td>
<td>Sparidae</td>
<td>Com.</td>
<td>1</td>
<td>110</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Pantarichthys fowleri</td>
<td>Heterocephaliidae</td>
<td>Disc.</td>
<td>1</td>
<td>-</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Scorpaena notata</td>
<td>Scorpaenidae</td>
<td>Disc.</td>
<td>1</td>
<td>-</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Scorpaena scrofa</td>
<td>Scorpaenidae</td>
<td>Disc.</td>
<td>1</td>
<td>-</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Sympharus nigrescens</td>
<td>Cynosoglossidae</td>
<td>Disc.</td>
<td>1</td>
<td>-</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>

**Crustacean**

| Parapenaeus longirostris | Penaeidae             | Com.  | 14773 | 60          | 4253       | 84.3      |
| Marsupenaeus japonicus*  | Penaeidae             | Com.  | 3707  | 60          | 3637       | 71.5      |
| Charybdis longicollis*   | Portunidae            | Disc. | 3595  | -           | 0         | 100       |
| Aristeornora fortis/     | Aristeidae            | Com.  | 2940  | 60          | 2270       | 22.8      |
| Erigosquilla massavensis*/| Squillidae            | Disc. | 252   | -           | 0         | 100       |
| Portunus pelagicus*      | Portunidae            | Disc. | 30    | 70          | 30         | 0         |
| Penaeus monostratus      | Penaeidae             | Com.  | 41    | 60          | 41         | 0         |
| Pencottia cataphracta    | Crangonidae           | Disc. | 12    | -           | 0         | 100       |
| Metapenaeus monostratus  | Penaeidae             | Minor | 8     | 60          | 8         | 0         |

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 species per haul for shallow hauls (<37 m deep) to 1.56 and 14.98 species per haul in deep hauls respectively.

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.
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.

<table>
<thead>
<tr>
<th>Species</th>
<th>Av.Abund</th>
<th>Av.Sim</th>
<th>Sim/SD</th>
<th>Contrib%</th>
<th>Cum.%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shallow stratum (15-37 m) average similarity: 30.31</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pagellus acarne</td>
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<td>1.60</td>
<td>0.50</td>
<td>4.70</td>
<td>63.19</td>
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<tr>
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<td>0.62</td>
<td>1.51</td>
<td>0.59</td>
<td>4.43</td>
<td>67.62</td>
</tr>
<tr>
<td>Deep stratum (&gt;84 m) average similarity: 33.09</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parapenaeus longirostris</td>
<td>2.77</td>
<td>12.63</td>
<td>1.13</td>
<td>38.18</td>
<td>38.18</td>
</tr>
<tr>
<td>Merluccius merluccius</td>
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<td>4.33</td>
<td>1.01</td>
<td>13.07</td>
<td>51.25</td>
</tr>
<tr>
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<td>1.23</td>
<td>3.54</td>
<td>0.66</td>
<td>10.69</td>
<td>61.93</td>
</tr>
<tr>
<td>Boops boops</td>
<td>0.85</td>
<td>1.94</td>
<td>0.60</td>
<td>5.87</td>
<td>67.80</td>
</tr>
<tr>
<td>M. japonicus</td>
<td>0.45</td>
<td>3.01</td>
<td>1.53</td>
<td>4.87</td>
<td>70.72</td>
</tr>
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<td>Saurida undosquamis*</td>
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<td>1.51</td>
<td>0.59</td>
<td>4.43</td>
<td>67.62</td>
</tr>
<tr>
<td>Pagellus erythrinus</td>
<td>1.50</td>
<td>6.30</td>
<td>1.25</td>
<td>20.77</td>
<td>20.77</td>
</tr>
<tr>
<td>Callionymus filamentosus*</td>
<td>1.30</td>
<td>5.41</td>
<td>0.97</td>
<td>17.84</td>
<td>38.61</td>
</tr>
<tr>
<td>Marsupenaeus japonicus*</td>
<td>1.26</td>
<td>4.86</td>
<td>0.70</td>
<td>16.05</td>
<td>54.66</td>
</tr>
<tr>
<td>Boops boops</td>
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<td>0.78</td>
<td>7.15</td>
<td>61.81</td>
</tr>
<tr>
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<td>1.33</td>
<td>0.66</td>
<td>4.39</td>
<td>66.19</td>
</tr>
<tr>
<td>Lithognathus mormyrus</td>
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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 (Sno student 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 discard 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 smallest 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⁻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 goaffishes 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 environment only allows resilient species with rapid population recovery rates and recolonization abilities to persist. We therefore hypothesize that Lessepsian 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 ecosystems of the Mediterranean.

**ACKNOWLEDGEMENTS**

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