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Trends in trawl and purse seine catch rates in the north-eastern Mediterranean

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Abstract

Data on fishing effort expressed in vessel days at sea and corresponding landing/day for a large number of species have been collected by the Institute of Marine Biological Resources (IMBR) since the second half of 1995. Data were collected over a grid of 21 stations throughout the Greek seas. In the present study we analyzed the monthly days at sea as well as catch per day for trawlers and purse seiners from 1996 to 2000, by general linear models and trend analysis. The following vessel size groups per gear were considered: (a) trawlers smaller and larger than 20m; (b) purse-seiners smaller and larger than 15m. Collected data were also aggregated for five fishing sub-areas: the North Aegean, the Central Aegean, the South Aegean, Cretan waters and the Ionian Sea. Trend analysis of landing/day time series indicated that demersal and pelagic resources are declining in the main fishing grounds. Declining landing/day trends are regarded as indicators of overfishing, especially in the light of the fact that high catch rates are maintained by fishing in 'hot spots'. The results of the present analysis provide, for the first time, important information on the sustainability of the fisheries in the north-eastern Mediterranean, an area characterized by a complete lack of accurate long-term data on effort and catch per effort

Keywords: Catch rate trends; Trawlers; Purse seiners; North-east Mediterranean.

Introduction

Catches and corresponding fishing effort data are of paramount importance for stock assessment and fishery management (e.g. HILBORN & WALTERS, 1992; CHEN, 1996; PAULY & MACLEAN, 2003) as well as for studying the effects of fishing on marine ecosystems (e.g. PAULY *et al.,* 1998, 2000, 2002). One important factor affecting the quality of parameter estimation by various fishery models and thus that of stock assessment, as well as masking the identification of the fisheries-related effects on ecosystems, is the quantity and quality of landings and fishing effort data (e.g. HILBORN & WALTERS, 1992; PAULY, 1994; CHEN, 1996). This is especially true of the Mediterranean Sea, which is characterized by a poorly developed fishery data collection system, many landing sites, and the absence of reliable long time series of such data (STERGIOU & POLUNIN, 2000, LLEONART & MAYNOU 2003).

For Greece, fishery statistics are collected by four independent organisations: (a) the National Statistical Service of Greece (NSSH); (b) the Agricultural Bank of Greece; (c) the National Company for the Development of Fisheries; and (d) the Ministry of Agriculture (not routinely involved in data collection). The collected information from these organizations is overlapping, contradictory, and sometimes leads to confusion (STERGIOU *et al.,* 1997). Although NSSH statistical data may suffer from various biases, which may be higher for inshore fisheries, they are the best figures available with respect to: (a) the length of available time series (since 1964), (b) spatial and temporal resolution of collected data, (c) the consistency and degree of subjectivity in data collection, and (d) the statistical design (STERGIOU, 1997a, b; STERGIOU *et al.,* 1997, 2007a,b). In addition, NSSH records show signs of biological, ecological, oceanographic and technical relevance and are in reasonable agreement with the results of trawl and echo-surveys conducted in the Greek seas (STERGIOU, 1997a,b).

Four important drawbacks of all the above-mentioned data sources are: (a) fishing effort is not recorded on a sub area and monthly basis; (b) no data are available concerning fishing effort expressed as fishing days at sea, which has been proposed by the European Union (EU) (see European Commission Regulation 1639/2001); (c) the different small-scale fishing gear (i.e., longliners, netters, other boats) are generally grouped together under one category (e.g. NSSH statistics grouped as 'other boats'); and (d) no data is so far available concerning artisanal vessels with an engine horsepower lower than 19 HP, which represent about 2/3 of the total fishing fleet (STERGIOU *et al.,* 1997), although recently reconstructed data are available (TSIKLIRAS *et al.,* 2007).

Because of the above-mentioned drawbacks, in the second half of 1995 the Institute of Marine Biological Resources (IMBR) of the Hellenic Center for Marine Research started, to collect, within the framework of various projects funded by National and European sources, data on fishing effort (expressed as days at sea) by main fishing gear as well as the corresponding landing/day.

As the sampling scheme radically changed after 2001, in the present study we analyzed the monthly time series of fishing effort and landing/day for trawlers and purse seiners from 1996 to 2000. This is the first analysis for the eastern Mediterranean and will serve as a baseline against which future data collections could be contrasted. The time series were analyzed using General Linear Models and trend analysis in order to identify various patterns on both the spatial and temporal scale.

Material and Methods

Description of the fisheries

One important feature of the study area is the strong decrease in productivity and fishery landings along the NNW to SSE axis (STERGIOU *et al.,* 1997). This is also reflected in the fleet distribution, with the majority of vessels operating in the northern Aegean Sea, while the number of registered trawlers and purse seiners declines southwards. The Greek waters are mainly exploited by the Greek fishing fleet, with the exception of the eastern Aegean Sea where the Turkish fishing fleet also operates, exploiting a small part of the eastern shelf that contributes up to 20% of the total landings (STERGIOU *et al.,* 1997). There is a closed season for Greek trawlers from the 1st of June to the 30th of September, and for purse seiners from the 15th of December to the end of February (KAPANTAGAKIS, 2007). As a result, no effort and landing/day records exist for the corresponding time periods. Because of the small sizes of the species exploited, both the trawl cod end mesh sizes and the purse seine mesh sizes are small (14mm and 10mm bar length, respectively).

Description of existing data sets

Data on fishing effort expressed as fishing days at sea and total landing/day have been collected by the IMBR since the second half of 1995 within the framework of various projects funded by several national and EU sources. For the purposes of the present study, we analyzed the monthly data referring to the 1996-2000 period. Data were collected over a grid of 21 stations in the most important fishing ports or sites throughout the Greek seas (Fig. 1) from a sample of vessels displaying full activity. Collected data were grouped by the following vessel size categories: (a)

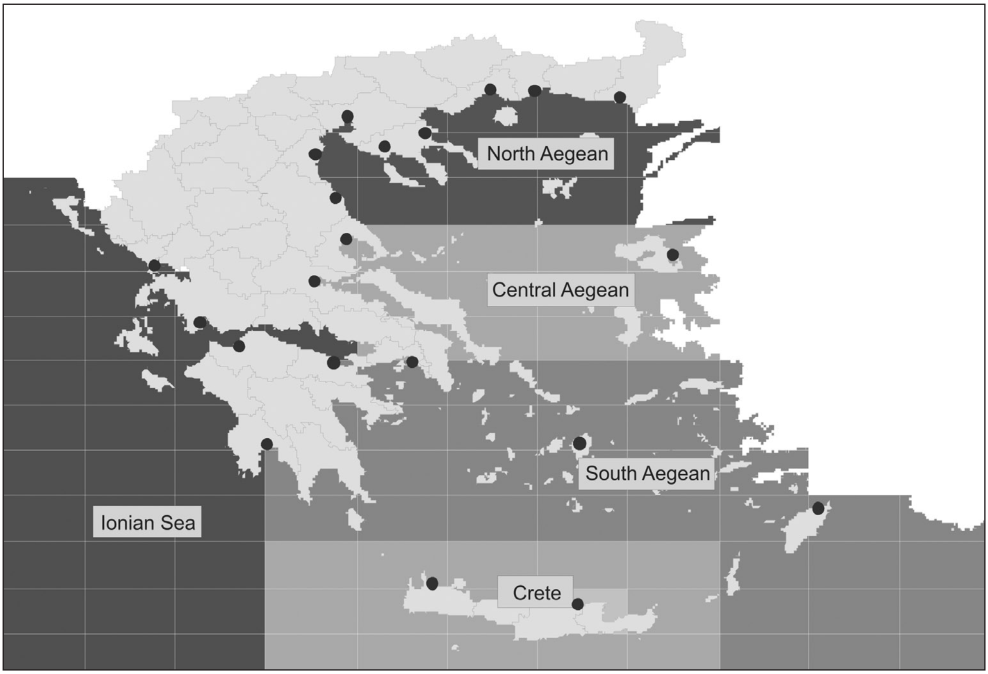

Fig. 1: The main sub-areas and sampling stations (black circles).

trawlers smaller and larger than 20m and (b) purse-seiners smaller and larger than 15m. The mean percentage of vessels sampled in each area ranged from 5.2 to 40% for trawlers and from 5.4 to 75.2% for purse seiners, whereas the mean percentage of vessels sampled for landing/day ranged from 4.1 to 40.6% for trawlers and from 6.5 to 66.4% for purse seiners (Table 1). Collected data were also aggregated for five fishing sub-areas: the N. Aegean, the Central Aegean, the S. Aegean, Cretan waters and the Ionian Sea (Fig. 1), which generally differ in terms of landed biomass, species composition and biological productivity (see detailed review by STERGIOU *et al.,* 1997).

The above-mentioned groupings resulted in 12 out of 19 (63%) complete (i.e., without any missing point) time series of landing/day and 19 out of 38 (50%) complete time series of effort in number of days at sea. In general, the incomplete time series were characterized by only a few missing data points.

Data analysis

The main features and changes among years, months, sub-areas and vessel size categories were examined using General Linear Models (GAVARIS 1980; KIMURA 1980) for each fishing gear. Landing/day (C) and effort (days at sea, E)

Table 1
Mean monthly (1996 to 2000) percentages of vessels sampled for effort (GRT) and catch/day as well as mean number (N) of vessels registered, for each sub-area and fishing gear by vessel size. CA = Central Aegean Sea; C = Cretan waters; I = Ionian Sea; NA = N. Aegean Sea; SA = S. Aegean Sea.

Gear	Area	Vessel size	GRT (%)	Catch/day (%)	N
Trawlers	CA	>20m	23.5	10.4	36.3
	CA	<20m	8.0	7.7	39.8
	C	<20m	13.6	12.8	51.7
	I	>20m	18.1	23.7	45.3
	I	<20m	5.2	4.1	37.8
	NA	>20m	40.0	40.6	50.7
	NA	<20m	6.0	6.3	45.3
	SA	>20m	29.1	32.4	47.0
	SA	<20m	8.9	9.2	37.2
Purse seiners	CA	>15m	15.9	6.8	67.7
	CA	<15m	6.1	6.5	23.3
	C	>15m	75.2	66.4	5.0
	C	<15m	19.8	19.8	6.3
	I	>15m	14.4	21.1	23.6
	I	<15m	7.3	6.8	23.8
	NA	>15m	25.5	23.2	64.3
	NA	<15m	13.7	13.1	7.7
	SA	>15m	6.0	7.5	89.8
	SA	<15m	5.4	6.7	47.7

were standardized for differences among sub-areas (A), vessel sizes (S), years (Y) and months (M). The following model was used: ln Y= A + S + Y + M + AS + AY + AM + SY +SM + YM + c, where c is a constant. In each model, only significant parameters were included, at a significance level of 0.05 using a stepwise backward method.

In addition, all time series were plotted against time for each gear type, vessel size and sub area. Consequently time-varying regressions (trend analysis) were fitted to all time series, and regressions with slopes significantly ($P<0.05$) different from 0 were identified. The mean value per month for each sub area was calculated after weighting with the registered fleet at each monitored station. Finally, comparisons of mean effort and mean landing/day between gears, gear sizes and sub-areas were undertaken using one-way analysis of variance (ANOVA) and Fisher's Least Significance Difference (LSD) test (ZAR, 1984). For all analyses the STATGRAPHICS software was used.

Results

Monthly fishing effort

The estimated General Linear Models for days at sea indicated the significant effects of sub area, year and month ($p<0.05$). Applying the estimated models the mean value for each set of parameters used could be calculated:

Trawlers:

$\mathrm{Ln(E)} = 22.437 + 0.923T_1 + 0.506T_2 - 0.742T_3 - 0.119T_4 - 1.662A_1 + 0.997A_2 - 0.976A^3 - 0.421A_4 - 1.532M_1 - 0.915M_2 - 0.272M_3 - 0.045M_4 + 2.219M_5 + 1.521M_{10} + 0.850M_{11}$ ($r^2 = 0.335$); and

Purse seiners:

$\mathrm{Ln(E)} = 17.389 - 3.099T_1 - 1.420T_2 - 0.077T_3 + 2.490T_4 - 3.559M_3 - 0.496M_4 + 3.257M_5 + 3.670M_6 + 3.660M_7 + 3.221M_8 + 2.613M_9 + 0.667M_{10} - 2.376M_{11}$ ($r^2 = 0.678$),

where E= days at sea; T_1, T_2,T_3 and T_4= 1 if Year=1996 to 1999 respectively, -1 if Year=2000 and 0 otherwise; A_1 = 1 if Area= Cretan waters, -1 if Area=S. Aegean (SA), 0 otherwise; A_2 = 1 if Area=Central Aegean (CA), -1 if Area=SA, 0 otherwise; A_3 = 1 if Area=Ionian Sea, -1 if Area=SA, 0 otherwise; A_4 = 1 if Area=N. Aegean, -1 if Area=SA, 0 otherwise; M_1, M_2, M_3, M_4, M_5, M_6, M_7, M_8, M_9, M_{10} and M_{11} = 1 if Month =1 to 11, respectively, -1 if Month=12, 0 otherwise.

The monthly days/vessel, for small- and large-sized trawlers in the five sub-areas from1996 to 2000 is shown in Figure 2. With the exception of trawlers smaller than 20m in the N. Aegean Sea for which the mean number of days/vessel decreased significantly ($P<0.05$) with time, the mean number of days/vessel did not change with time in the remaining cases.

During the study period, the mean number of days/vessel ranged from 20.8, for trawlers larger than 20m operating in Cretan waters, to 24.5 for trawlers larger than 20m operating in the S. Aegean Sea (Table 2). The effort differed significantly (ANOVA, for all $F>5.75$, $P<0.05$) among gear-size/sub area categories.

The mean number of days/vessel exhibited a clear seasonal cycle, being higher in May and October, just before and after the closing season, and lower in the winter months, December–January, ranging between 17.5 and 29 days/vessel, depending on the area and vessel size (Fig. 3).

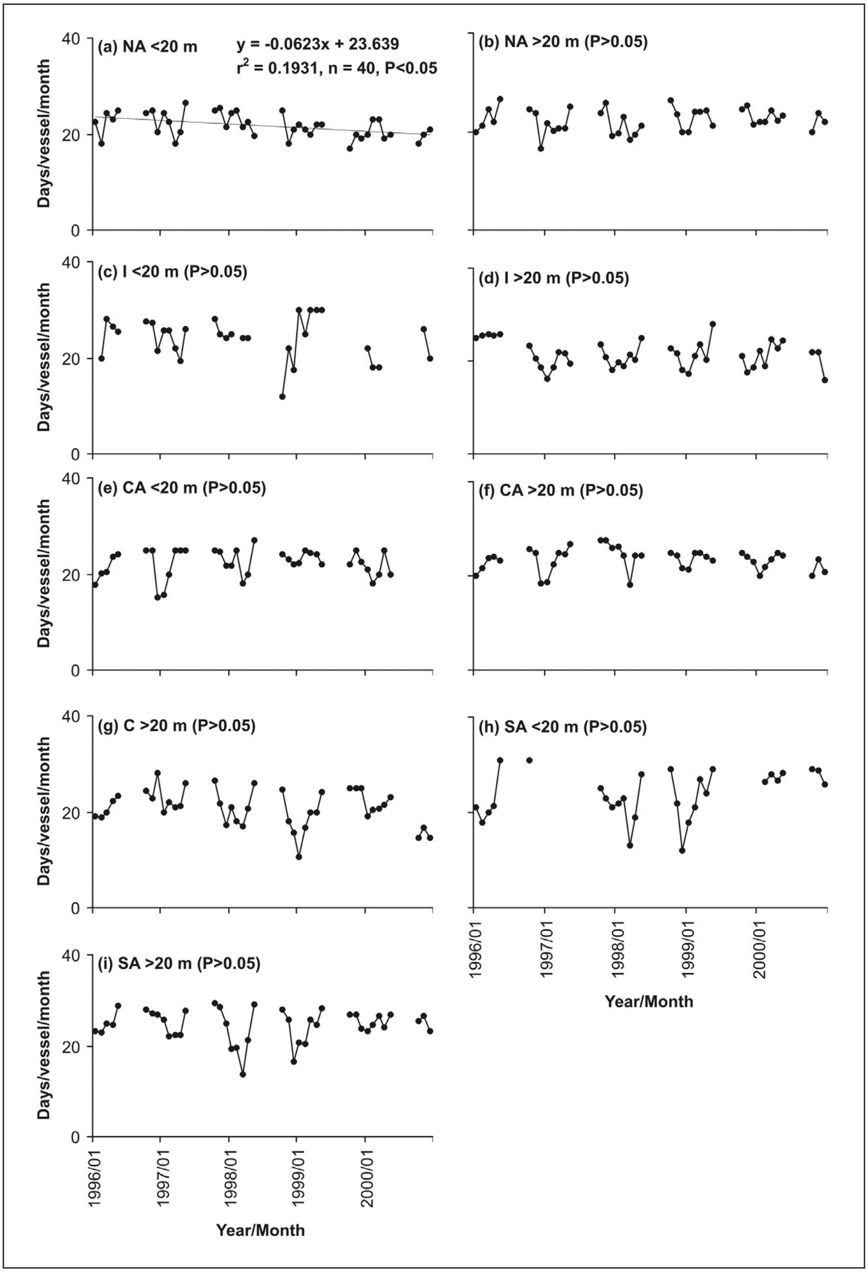

Fig. 2: Mean monthly number of fishing days for trawlers. Greek waters, 1996-2000. (a) North Aegean Sea, NA, vessels <20 m; (b) North Aegean Sea, vessels >20 m; (c) Ionian Sea, I, vessels <20 m; (d) Ionian Sea, vessels >20 m; (e) Central Aegean Sea, CA, vessels <20 m; (f) Central Aegean Sea, vessels >20 m; (g) Cretan waters, C, vessels >20 m; (h) South Aegean Sea, SA, vessels <20 m; and (i) South Aegean Sea, vessels >20 m. Trend lines with slope significantly (P<0.05) different from zero are also shown.

Table 2
Results of Least Significant Difference test for differences in the mean number of days per vessel for trawlers. N = number of data points.

Area	N	Mean	Homogeneous Groups
Cretan waters, vessels >20 m	40	20.78	X
Ionian Sea, vessels >20 m	40	21.46	XX
North Aegean Sea, vessels <20 m	40	21.77	XX
North Aegean Sea, vessels >20 m	40	22.26	XX
Central Aegean Sea, vessels <20 m	37	22.29	XXX
Central Aegean Sea, vessels >20 m	40	23.43	XXX
South Aegean Sea, vessels <20 m	29	23.85	XX
Ionian Sea, vessels <20 m	31	24.04	X
South Aegean Sea, vessels >20 m	40	24.50	X

The monthly days/vessel for small- and large-sized purse-seiners in the five sub-areas from 1996 to 2000 is shown in Figure 4. For all sub-areas and size categories, the mean number of days/vessel did not change significantly ($P>0.05$) with time (Fig. 4). It ranged from 14.3, for purse seiners larger than 15m operating in Cretan waters, to 19.9 days/vessel for vessels larger than 15m operating in the N. Aegean Sea (Table 3). Fishing effort differed significantly (ANOVA, for all $F>5.04$, $P<0.05$) among gear-size/sub area categories.

The mean monthly effort was not estimated for purse seiners smaller than 15m in

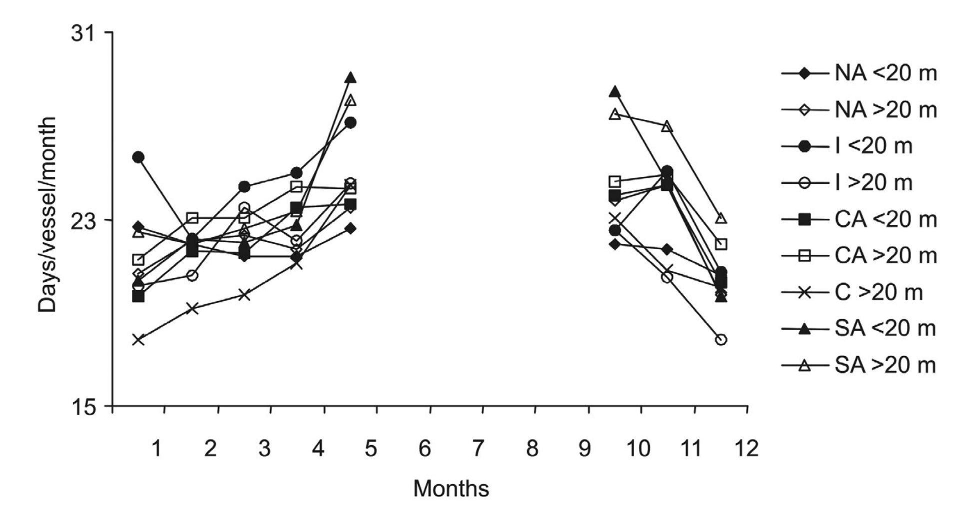

Fig. 3: Monthly averages of fishing effort of trawlers in number of days per vessel. Greek waters, 1996-2000. NA: North Aegean Sea; I: Ionian Sea; CA: Central Aegean Sea; C: Cretan waters; SA: South Aegean Sea; < and > imply vessels smaller or larger than the indicated size.

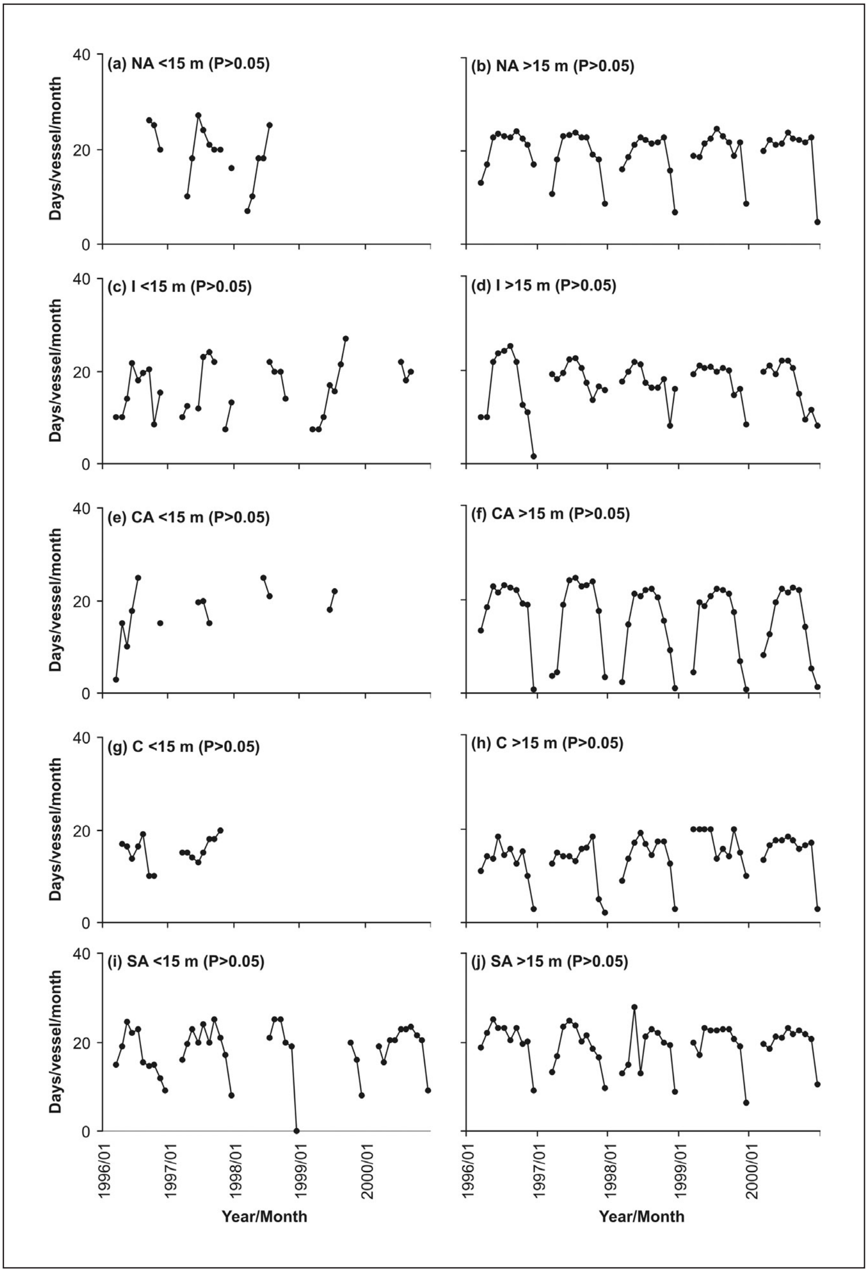

Fig. 4: Mean monthly number of fishing days for purse seiners. Greek waters, 1996-2000. (a) North Aegean Sea, NA, vessels <15m; (b) North Aegean Sea, vessels >15m; (c) Ionian Sea, I, vessels <15m; (d) Ionian Sea, vessels >15 m; (e) Central Aegean Sea, CA, vessels <15m; (f) Central Aegean Sea, vessels >15m; (g) Cretan waters, C, vessels 15 m; (h) Cretan waters, vessels >15m; (i) South Aegean Sea, SA, vessels <15m; and (j) South Aegean Sea, vessels >15m. Trend lines with slope significantly (P<0.05) different from zero are also shown.

Table 3
Results of Least Significant Difference test for differences in the mean number of days per vessel for purse seiners. N = number of data points.

Area	N	Mean	Homogeneous Groups
Cretan waters, vessels >15 m	50	14.29	X
Cretan waters, vessels <15 m	15	15.38	XXX
Central Aegean Sea, vessels >15 m	50	15.97	XX
Ionian Sea, vessels <15 m	31	16.25	XXXX
Ionian Sea, vessels >15 m	50	17.31	XXX
Central Aegean Sea, vessels <15 m	13	17.40	XXXXX
South Aegean Sea, vessels <15 m	38	18.76	XX
North Aegean Sea, vessels <15 m	16	19.06	XXX
South Aegean Sea, vessels >15 m	50	19.49	X
North Aegean Sea, vessels >15 m	50	19.88	X

the N. and Central Aegean Sea and in Cretan waters because of the small number of available observations. The mean number of days/vessel exhibited a clear seasonal cycle, being higher from May to October (Fig. 5), ranging between 2 and 24 days/vessel, depending on the area and vessel size.

Monthly catch per fishing day

The estimated general linear models for landing/day indicated the significant effect of year, sub area and vessel size for trawlers and of year, sub area and month for purse seiners ($p<0.05$). Applying the

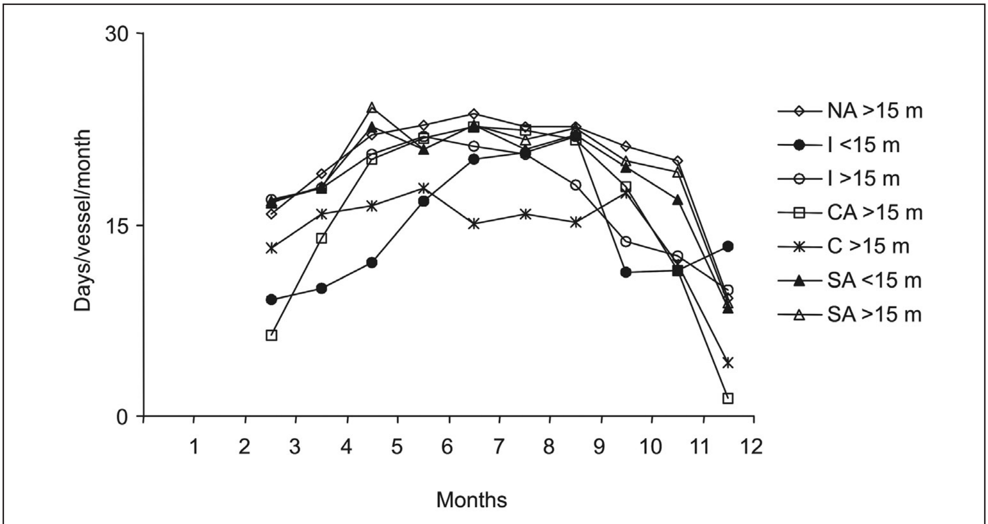

Fig. 5: Monthly averages of fishing effort of purse seiners in number of days per vessel. Greek waters, 1996-2000. NA: North Aegean Sea; I: Ionian Sea; CA: Central Aegean Sea; C: Cretan waters; SA: South Aegean Sea; < and > imply vessels smaller or larger than the indicated size.

estimated models the mean value for set of parameters could be calculated:

Trawlers:

$Ln(C) = 5.592 + 0.220T_1 + 0.007T_2 - 0.038T_3 - 0.167T_4 + 0.342A_1 - 0.289A_2 - 0.173A_3 + 0.213A_4 + 0.291S_1$ ($r^2 = 0.475$); and

Purse seiners:

$Ln(C) = 6.647 + 0.329T_1 + 0.204T_2 - 0.003T_3 - 0.357T_4 - 0.712A_1 + 0.064A_2 - 0.081A_3 + 0.733A_4 + 0.151M_3 + 0.094M_4 - 0.076M_5 + 0.248M_6 + 0.170M_7 + 0.059M_8 + 0.010M_9 + 0.017M_{10} - 0.143M_{11}$ (r^2=0. 562),

where C= landings kg/day; T_1, T_2, T_3 and T_4= 1 if Year=1996 to 1999 respectively, -1 if Year=2000 and 0 otherwise; A_1 = 1 if Area= Cretan waters, -1 if Area=S. Aegean (SA), 0 otherwise; A_2 = 1 if Area=Central Aegean (CA), -1 if Area=SA, 0 otherwise; A_3 = 1 if Area=Ionian Sea, -1 if Area=SA, 0 otherwise; A_4 = 1 if Area=N. Aegean, -1 if Area=SA, 0 otherwise; M_1, M_2, M_3, M_4, M_5, M_6, M_7, M_8, M_9, M_{10} and M_{11} = 1 if Month =1 to 11, respectively, -1 if Month=12, 0 otherwise; and S = 1 for large vessels, -1 for small vessels.

Overall, 19 monthly landing/day time series were constructed, 11 (58%) of which displayed a significant ($P<0.05$) declining trend with time and eight that did not display any significant ($P<0.05$) trend (Figs 6 and 7). The monthly trawl landing/day declined significantly ($P<0.05$) with time for trawlers smaller than 20m and larger than 20m operating in the N. Aegean and Ionian Seas and for trawlers larger than 20m in Cretan waters, whereas it did not change significantly ($P>0.05$) with time for the remaining cases (Fig. 6). The very small mesh sizes used in the study area (i.e., 14 mm for trawlers, 10 mm for purse seiners) clearly indicate that such a decline cannot be the result of a decrease in gear catchability because of a shift in the population size structures towards smaller individuals.

The mean trawl landing/day ranged from 235 kg/day, for vessels smaller than 20m operating in the Ionian Sea, to 540 kg/day for vessels larger than 20m operating in the Cretan waters (Table 4) and differed significantly among gear-size/sub area categories (ANOVA, F=24.8, $P<0.05$).

The monthly landing/day of purse seiners declined significantly ($P<0.05$) with time for all cases with the exception of purse seiners smaller than 15m operating in N. Aegean, Ionian, Central Aegean and Cretan waters, for which time series were generally incomplete (Fig. 7). The mean landing/day ranged from 397 kg/day, for purse seiners smaller than 15m operating in the N. Aegean Sea, to 1788 kg/day for vessels larger than 15m operating in the N. Aegean Sea (Table 4). The mean monthly landing/day differed significantly among gear-size/sub area categories (ANOVA, F=16.5, $P<0.05$).

Generally, the mean monthly trawl landing/day was slightly higher just after the opening of the fishing season in October (Fig. 8a) whereas that of purse seiners did not display any clear seasonal pattern of fluctuation (Fig. 8b), exhibiting maxima in different months depending on the area.

Discussion

In the present study we analyzed the monthly days/vessel and landing/day for trawlers and purse seiners from 1996 to 2000. These fishery time series are the first

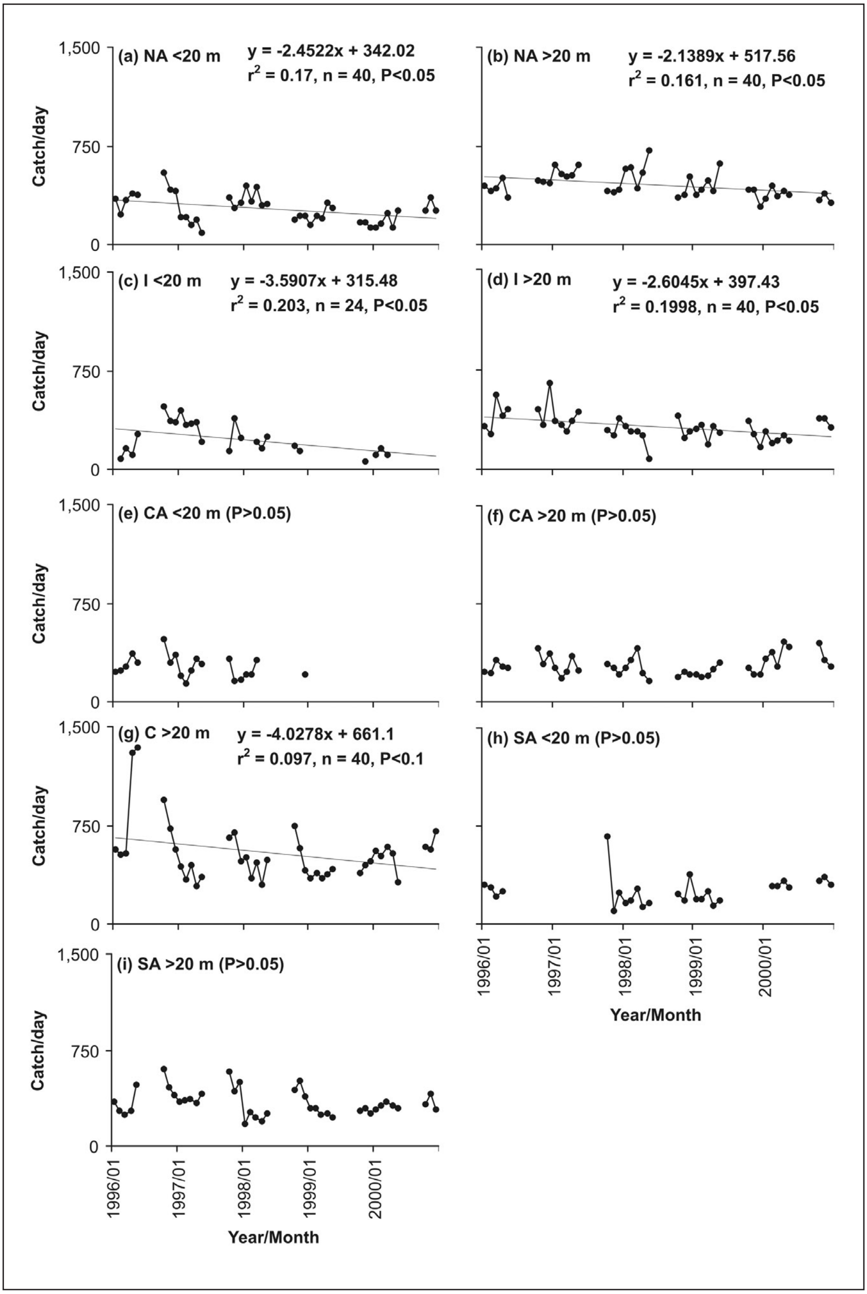

Fig. 6: Mean monthly landing/day of trawlers. Greek waters, 1996-2000. (a) North Aegean Sea, NA, vessels <20m; (b) North Aegean Sea, vessels >20m; (c) Ionian Sea, I, vessels <20m; (d) Ionian Sea, vessels >20m; (e) Central Aegean Sea, CA, vessels <20m; (f) Central Aegean Sea, vessels >20m; (g) Cretan waters, C, vessels >20m; (h) South Aegean Sea, SA, vessels <20m; and (i) South Aegean Sea, vessels >20m. Trend lines with slope significantly (P<0.05) different from zero are also shown.

Table 4
Results of Least Significant Difference test for differences in the mean catch per day for trawlers and purse seiners. N = number of data points.

Gear	Area	N	Mean	Homogeneous Groups
Trawlers	Ionian Sea, vessels <20 m	24	234.54	X
	South Aegean Sea, vessels <20 m	27	255.65	X
	Central Aegean Sea, vessels <20m	40	266.01	XX
	North Aegean Sea, vessels <20m	40	268.45	XX
	Central Aegean Sea, vessels >20 m	40	278.80	XX
	Ionian Sea, vessels >20 m	40	319.29	XX
	South Aegean Sea, vessels >20 m	40	340.60	X
	North Aegean Sea, vessels >20 m	40	453.39	X
	Cretan waters, vessels >20 m	40	540.27	X
Purse seiners	North Aegean Sea, vessels <15 m	16	396.78	XX
	Cretan waters, vessels >15 m	50	440.60	X
	South Aegean Sea, vessels <15 m	37	739.93	XX
	Ionian Sea, vessels >15 m	50	796.36	X
	Cretan waters, vessels <15 m	15	796.56	XX
	Central Aegean Sea, vessels <15 m	17	866.90	X
	Ionian Sea, vessels <15 m	33	925.68	X
	South Aegean Sea, vessels >15 m	50	943.73	X
	Central Aegean Sea, vessels >15 m	50	990.72	X
	North Aegean Sea, vessels >15 m	50	1788.42	X

ones to be reported for the eastern Mediterranean. General Linear Models indicated that both effort and landing/day were affected by sub-area, year and month.

Days at sea were generally higher for trawlers than for purse seiners. Our results indicated that the numbers of days at sea were lower in the winter. This is attributed to the bad weather conditions prevailing during this period. Spatially, for each gear category the number of days at sea was generally lower in Cretan waters. This is also attributed to the worst sea conditions prevailing in the southern areas when compared to northern ones due to the higher fetch (STERGIOU *et al.,* 1997). We point out that in addition to the effect of bad sea conditions, purse seiners also do not operate for two days before, during, and two days after the full moon (i.e. five days per month).

The mean landing/day was higher for purse seiners, which targeted small and medium pelagic species, whereas the landings of trawlers are dominated by demersal species (in Greece, trawlers are banned from landing small pelagic species in quantities >5% of the total landings). Temporally, the trawl landing/day was generally higher in October, i.e. just after the opening of the fishing season. In contrast, the landing/day of purse seiners did not display any common seasonal pattern. This might indicate that purse seine catch rates are not a good indicator of fish abundance in the sea, as well as that effort for purse

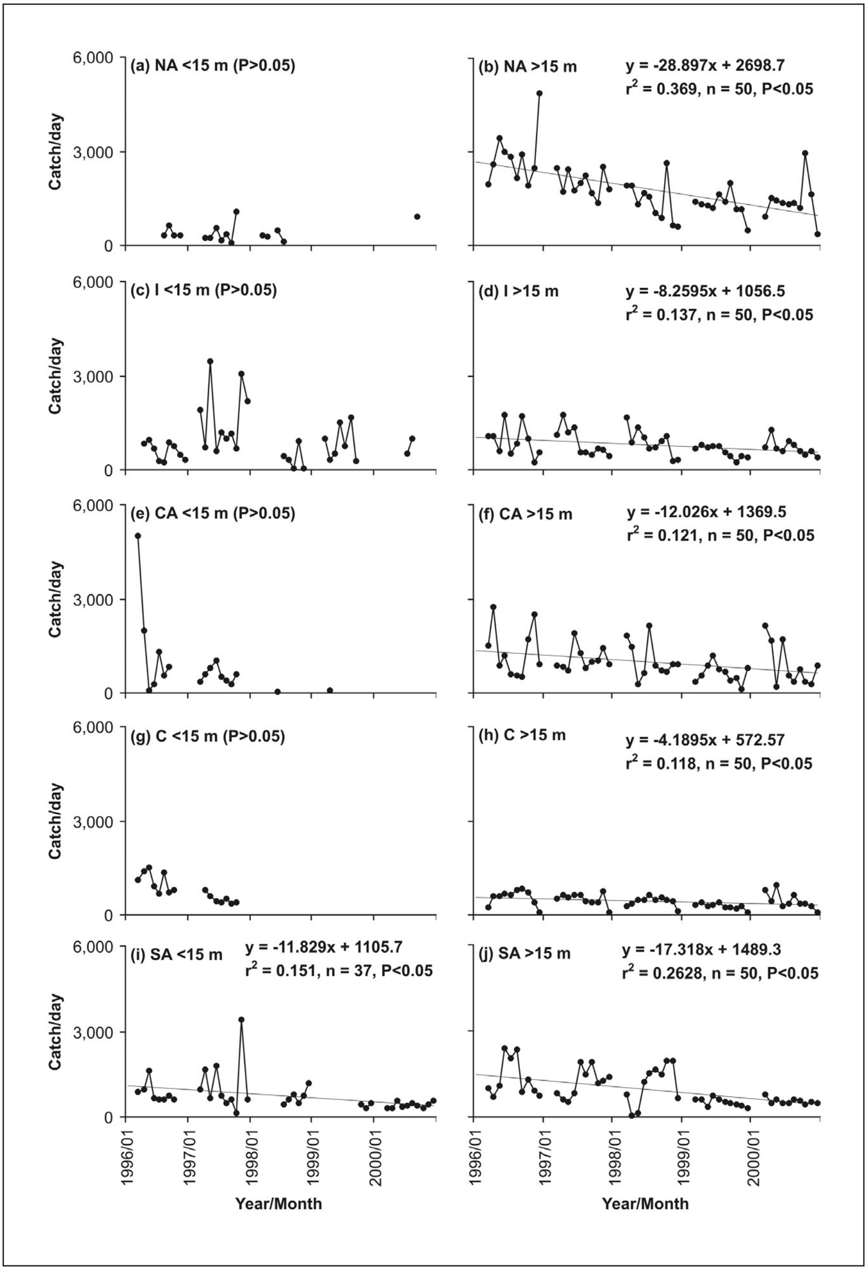

Fig. 7: Mean monthly landing/day of purse seiners. Greek waters, 1996-2000. (a) North Aegean Sea, NA, vessels <15m; (b) North Aegean Sea, vessels >15m; (c) Ionian Sea, I, vessels <15m; (d) Ionian Sea, vessels >15m; (e) Central Aegean Sea, CA, vessels <15m; (f) Central Aegean Sea, vessels >15m; (g) Cretan waters, C, vessels <15m; (h) Cretan waters, vessels >15m; (i) South Aegean Sea, SA, vessels <15m; and (j) South Aegean Sea, vessels >15m. Trend lines with slope significantly (P<0.05) different from zero are also shown.

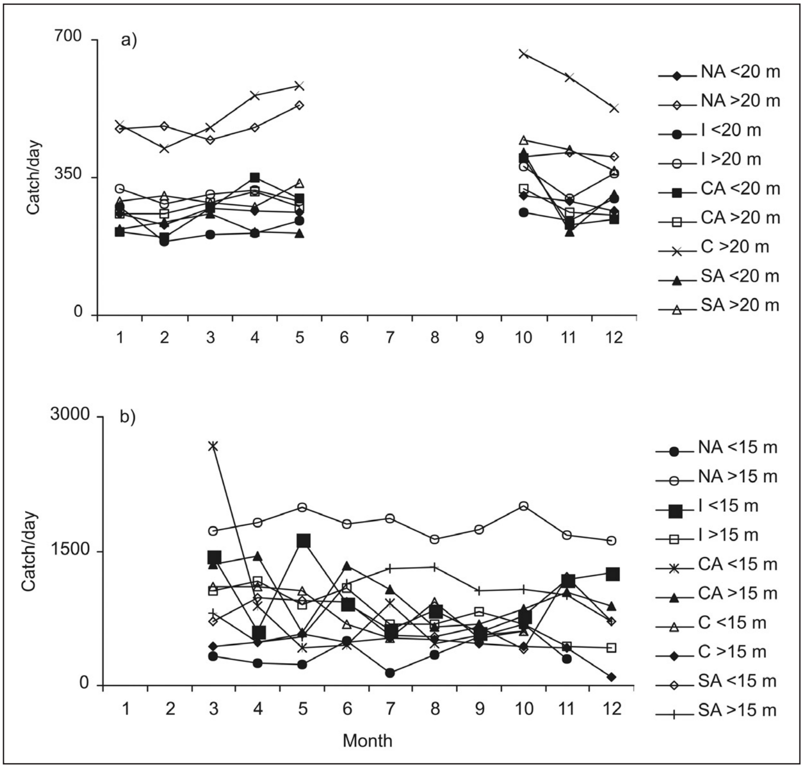

Fig. 8: (a). Monthly averages of landing/day of trawlers. ***(b).*** Monthly averages of catch/day of purse seiners. Greek waters, 1996-2000. NA: North Aegean Sea; I: Ionian Sea; CA: Central Aegean Sea; C: Cretan waters; SA: South Aegean Sea; < and > imply vessels smaller or larger than the indicated size.

seiners should also incorporate other variables such a search time (FREON & MISUND 1999).

For both large boat categories, the mean landing/day was generally higher in the N. Aegean Sea. For large purse seiners, the landing/day generally declined from north to south. The same was also true for both small and large trawlers, with the exception of large trawlers operating in Cretan waters for which the mean landing/day was the highest recorded. The above-mentioned spatial patterns in landing/day agree to a large extent with the results of the analysis of the NSSH catch data by fishing subarea (STERGIOU *et al.,* 1997), which also indicate that catches are much higher in the N. Aegean Sea when compared to other fishing sub-areas and decline from north to south. The main factors contributing to such a geographical differentiation in mean landing/day as well as total catches could be: (a) the gradient in trophic status and river runoff of the Aegean Sea waters along a NNW to SSE axis, and (b) the differences in the width of the continental shelf within the Aegean Sea (STERGIOU *et al.,* 1997).

The majority of days/vessel time series (with one exception) did not exhibit any significant time trend. This might be attributed to the fact that trawlers and purse seiners are subject to extended closed periods and thus an effort is made to operate on as many fishing days as possible irrespective of weather conditions. The latter is mediated by recent vessel modernization.

The landing/day time series presented here are useful for drawing conclusions concerning the state of the fishery resources, although they must be considered with caution because of the shortness of the available time series. The mean trawl landing/day in the N. Aegean and Ionian Seas, two of the most important Greek fishing grounds, as well as in Cretan waters declined significantly ($p<0.05$) with time for both vessel size categories. Such a decline in landing/day is a strong indication that demersal resources are declining in these areas (TSIKLIRAS & STERGIOU, 2007). This finding is in agreement with data derived from experimental fishing surveys (STERGIOU *et al.,* 1997). All complete purse seine landing/day time series and especially those referring to vessels larger than 15m, which account for the major part of the small pelagic landings, also exhibited a declining trend. Although additional information might be required together with landing/day trends in Greek waters, heavy exploitation cannot easily be ruled out. Thus, one may conclude that both pelagic and demersal fishery resources are either heavily exploited or overfished (STERGIOU *et al.,* 2007a). Declining landing/day trends are regarded as strong indicators of overfishing, especially in the light of the fact that high catch rates are maintained by fishing in 'hot spots'. (JENNINGS *et al.,* 2001).

The inadequacy of the Greek management regulations currently in force for demersal and inshore fisheries (i.e., closed seasons and costal areas, limited issue of licenses, minimum legal landing sizes and mesh size regulations: KAPANTAGAKIS, 2007) - mainly related to the multi-species and multi-gear nature of the Greek fisheries (and of the Mediterranean fisheries in general) - and for pelagic fisheries (i.e., closed seasons, limited issue of licenses, minimum legal landing sizes, mesh size regulations, banning of pelagic trawl, no permission to fish small pelagics with bottom trawl or electric lights) are justified by the declining trends in the trawl and purse seine landing/day time series. For demersal stocks, large marine protected areas (or no-take zones), which are considered to be the extreme case of the precautionary approach (LAUCK *et al.,* 1998) and satisfy most ecosystem objectives for management (STERGIOU, 2002), could mediate the rebuilding of overfished stocks (e.g. SLADEK NOWLIS & ROBERTS, 1999; POLUNIN, 2002) especially when combined with a decrease in fishing capacity. Furthermore, for pelagic stocks, which fluctuate greatly over time, a management plan based on the scientific monitoring of stock abundance is required. Based on this, additional measures (i.e. closed fishery over certain areas) should be taken any time the stock abundance declines below safe biological limits.

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