A PRELIMINARY INVESTIGATION ON HOW METEOROLOGICAL CHANGES MAY AFFECT BEACH-SEINE CATCHES OF *LOLIGO VULGARIS* IN THE THRACIAN SEA (EASTERN MEDITERRANEAN)

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Daily catches of *Loligo vulgaris* and the fishing effort of commercial beach-seiners operating along the coasts of the Thracian Sea were recorded between October 1994 and May 1995. Taking into account the spatial distribution of the ports, the squid fishing grounds and the daily activity of the beach-seiners, five coastal zones were determined for the monitoring of fishery data. Multivariate analysis failed to show significant differences between the monthly catch rate (*cpue*) in the zones. However, *Loligo vulgaris cpue* was clearly seasonal, with a distinct peak in November and an evident decline from winter to spring. Temperature, rainfall and local wind records were used in making a preliminary investigation into meteorological factors that may affect beach-seine catches of squid. Multiple linear regression analysis revealed that temperature is a highly significant explanatory variable for *cpue* variation, whereas the intensity of the wind plays an important role, but mostly during winter. Rainfall was significantly related to variation in *cpue* in one zone. *Cpue* was generally negatively correlated with air temperature and rainfall. Most significant correlations of *cpue* with wind were also negative.

Loligo vulgaris is a nektobenthic species found over the continental shelf, generally up to a depth of 200 m (Boyle and Boletzky 1996). It is one of the most common squid species along the coasts of the North-East Atlantic and the Mediterranean Sea, where it is known as the European squid. In the Mediterranean, and especially in Spain, Italy and Greece, *Loligo vulgaris* is part of the traditional diet and plays an important role in local fish markets. Nevertheless, there is no specialized commercial fishery for it, and it is taken mainly as a bycatch of the multispecies trawl fishery. However, some directed handline jig-fishing, particularly artisanal fishing in coastal waters, is undertaken by a small number of fishermen and/or as a sport (Simon *et al*. 1996, Lefkaditou *et al*. in press).

In Greek waters, the average annual catch of European squid over the past decade was some 1 080 tons, 38% of which was taken by bottom trawl, 30% by beach-seine, 9% by purse-seine and 23% by other gear in small-scale fisheries. In the Thracian Sea, European squid may be considered as a target beach-seine species, because it constitutes 10% of the total beach-seine catch and 27.5% of the total income of the fishers (Lefkaditou *et al*. in press). Inspection of fisheries statistics reveals considerable seasonal and interannual variation in European squid catches in the Thracian Sea. Annual catches of other coastal loliginids, such as *Loligo forbesi* in Scottish waters, *L. opalescens* off California and *L. pealei* in the NW

Atlantic, also vary extensively and unpredictably (Boyle 1990). These fluctuations arise mainly from features of the life cycle and as a response to environmental stimuli (Caddy 1983, Boyle and Boletzky 1996); indeed, they may be a function of distribution rather than an index of overall abundance of the stocks (Pierce 1995). Links have been established between annual fluctuations in environmental parameters and landings of loliginid squids by Roberts and Sauer (1993) and Pierce (1995). Further, short-term changes in sea surface temperature and wind direction have been demonstrated to influence the behaviour and distribution of the adults of a closely related loliginid, *Loligo vulgaris reynaudii*, in their inshore spawning grounds (Sauer *et al*. 1991). Their availability to the inshore jig catches varies as a consequence.

In the Mediterranean Sea, the annual migration pattern of *Loligo vulgaris* was studied by Worms (1983), who showed spawning-cycle-related seasonal short-range movements, influenced evidently by oceanographic conditions. The available information about sea surface temperature and salinity inhabited by *L. vulgaris* is unfortunately limited. It seems that *Loligo vulgaris* is found in shallow water of surface temperature $11.3–22.7°C$ and salinity $>30\times10^{-3}$ (Tinbergen and Verwey 1945, Baddyr 1988). Temperature and salinity ranges under experimental conditions have been demonstrated as $13.3–26.0°C$ and $34–37\times10^{-3}$ respectively (Boletzky 1979, Turk *et al*. 1986).

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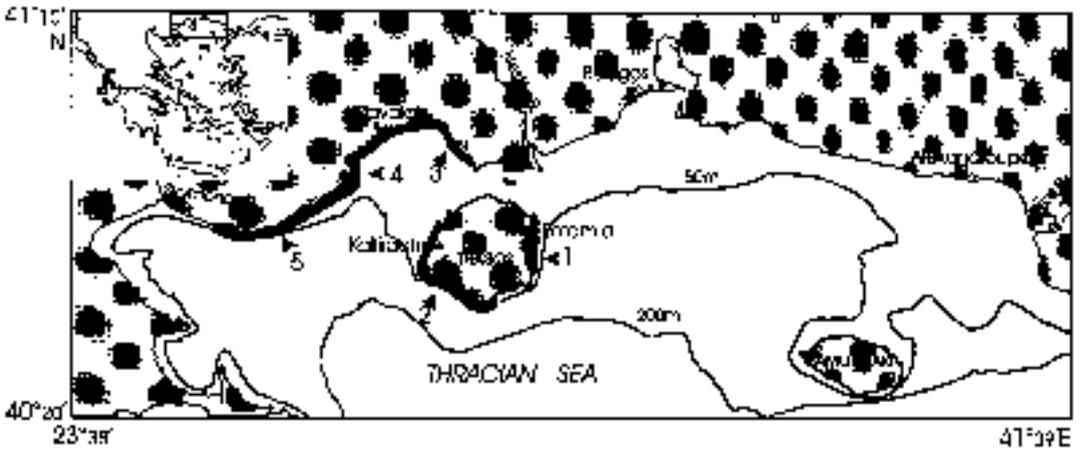
Fig. 1:   Map of the Thracian Sea showing the zones (shaded) in which beach-seiners operate and the main fishing
ports of the area. 1 – 5 are the fishing zones

In certain cases, oceanographic conditions seem to be closely related to meteorological conditions, although linkage of a realistic oceanographic component to a general circulation model of the atmosphere has yet to be accomplished (Glantz and Feingold 1992). Southward *et al.* (1988) noted that surface water temperature in coastal waters is reasonably correlated with air temperature. Astraldi *et al.* (1995) consider that air temperature could serve as a guide for investigating trends in sea surface temperature in the Ligurian Sea. It is worth noting that, in the northern Aegean Sea, sea surface temperature is significantly correlated with air temperature and sea level pressure (Stergiou and Christou 1996). Therefore, meteorological changes may indirectly influence the distribution and availability of species inhabiting shallow coastal water.

This study represents a preliminary investigation of the effect of meteorological factors on the availability of *Loligo vulgaris* on the inshore fishing grounds of the Thracian Sea, during eight months of fishing. In particular, the likely relationship between air temperature, wind, rainfall and catch rate of *Loligo vulgaris* caught by beach-seine is examined through multiple regression analysis.

MATERIAL AND METHODS

Environmental and fisheries background

The Thracian Sea has an area of approximately 9 480 km^2 and typically variable geomorphology and hydrology; it is the largest trawling area in Greek waters (Fig. 1). The continental shelf (<200 m) extends to a distance of between 5 and 27 miles from the coast. Most of the sea bed is coarse or muddy sand, the latter particularly near the run-offs of the rivers and the coasts of the city of Kavala. There are seagrass meadows almost all around the coast, but they are particularly extensive around the islands of Thasos and Samothraki. Extended detritic communities are found three miles from the east coast of Thasos, at depths of 55–70 m, and north-west of Thasos.

The most distinct hydrological feature in the Thracian Sea is the intrusion of water of Black Sea origin, low in salinity, which occupies the whole surface layer and contributes to the maintenance of low salinity (33–36×10^{-3}) from the surface down to depths of 50–60 m. Deeper than that, the salinity generally reaches normal values for the Aegean Sea (about 38.8×10^{-3}). The inflow of Black Sea water is stronger during late spring and summer, corresponding to an increase in river run-off and precipitation over the Black Sea. West of Thasos, salty Aegean water enters from the south-west to form a haloclinic front and a cyclonic circulation pattern south of the island. There, the salinity is relatively high (35–37×10^{-3}). Outflow from the three main rivers (Strymonas, Nestos and Evros) does not disturb the overall picture, although some tongues of low salinity are observed over the delta run-offs (Papaconstantinou *et al.* 1994). In the northern Aegean Sea, the NE part of which is called the Thracian Sea, sea surface temperature is significantly correlated with air temperature and reaches a maximum (22–25°C) in August and a minimum (14–16°C) in

Table I: Multiple regression and correlation coefficients between the log-transformed *cpue* of *Loligo vulgaris* and three meteorological variables: air temperature T (in °C), wind speed W (NE-SW component, in knots) and rainfall R (in mm). *Cpue* refers to the beach-seine fishery in the Thracian Sea during the fishing period October 1994 – May 1995. The analyses were performed on the combined data from seven boats and for five of the boats separately, for the whole fishing period as well as for shorter periods, as shown below

Period over which the data were analysed	Boats	Intercept and regression coefficients of the model $\log(cpue+1) = a + bT + cW + dR$				Multiple R^2 (%) (linear model)	n	F-ratio and Spearman's rank correlation coefficients of					
		a	b	c	d			Temperature		Wind		Rainfall	
								F	r_s	F	r_s	F	r_s
October 1994 – May 1995	All	3.3403	−0.0952	0.0426	−0.0488	18.85	201	34.79	−0.3710	6.71	0.0815	4.25	−0.1432
October – November 1994	All	5.6767	−0.1976	−0.1522		44.10	53	31.03	−0.5689	8.41	−0.0880		−0.1945
December 1994 – January 1995	All	2.9056		−0.1185		26.17	45		0.3668	15.24	−0.3856	15.94	−0.3105
February – March 1995	All	2.2074		−0.0797	−0.2818	39.77	47		−0.1141	13.12	−0.3051		−0.5173
April – May 1995	All	3.0642	−0.9643			25.04	56	18.04	−0.5078		0.1372		0.1838
October 1994 – May 1995	Boat 1	1.6692	−0.0603	−0.0076		29.31	106	42.48	−0.4513	0.23	0.2291		−0.0014
October – November 1994	Boat 1	2.8321	−0.1045	−0.0806		63.49	36	48.23	−0.7196	9.14	−0.0152		−0.1287
April – May 1995	Boat 1	1.4895	−0.0644			38.89	28	16.55	−0.6616		0.3071		0.4024
October 1994 – May 1995	Boat 2	1.2601	−0.0392			14.72	110	18.65	−0.3622		0.1023		0.0750
October – November 1994	Boat 2	2.2561	−0.0800			40.07	35	17.82	−0.5246		−0.0726		0.2844
December 1994 – March 1995	Boat 2	1.4524	−0.0891	−0.0597		25.24	38	12.16	−0.5618	3.57	0.1627		0.0139
April – May 1995	Boat 2	1.1751	−0.0406	−0.0331		17.92	37	3.69	−0.2144		−0.0467		−0.2839
October 1994 – May 1995	Boat 3	2.5688	−0.0693			8.26	158	14.05	−0.3093	3.73	0.1154		−0.0165
October – November 1994	Boat 3	1.7401	−0.0638			21.87	44	11.76	−0.4197		−0.0673		−0.1230
October 1994 – May 1995	Boat 4	1.7372	−0.0660			27.19	62	22.41	−0.5204		0.2691		0.0247
October – November 1994	Boat 4	2.5882	−0.1155			58.40	24	30.89	−0.7493		0.2467		0.0221
April – May 1995	Boat 4	2.0644	−0.0856			25.94	16	4.90	−0.5378		−0.0948		0.5951
October 1994 – May 1995	Boat 5	1.4050	−0.0231		−0.2389	21.30	90	3.02	−0.2384		0.1960	20.53	−0.3149
October – November 1994	Boat 5	1.4603			−0.2728	45.02	23		−0.1951		0.0830	17.19	−0.5298
February – March 1995	Boat 5	1.0078			−0.2103	27.90	28		−0.1386		−0.0889	10.06	−0.4542
April – May 1995	Boat 5	1.3210	−0.0382			21.07	20	4.81	−0.4591		−0.0129		−0.0607
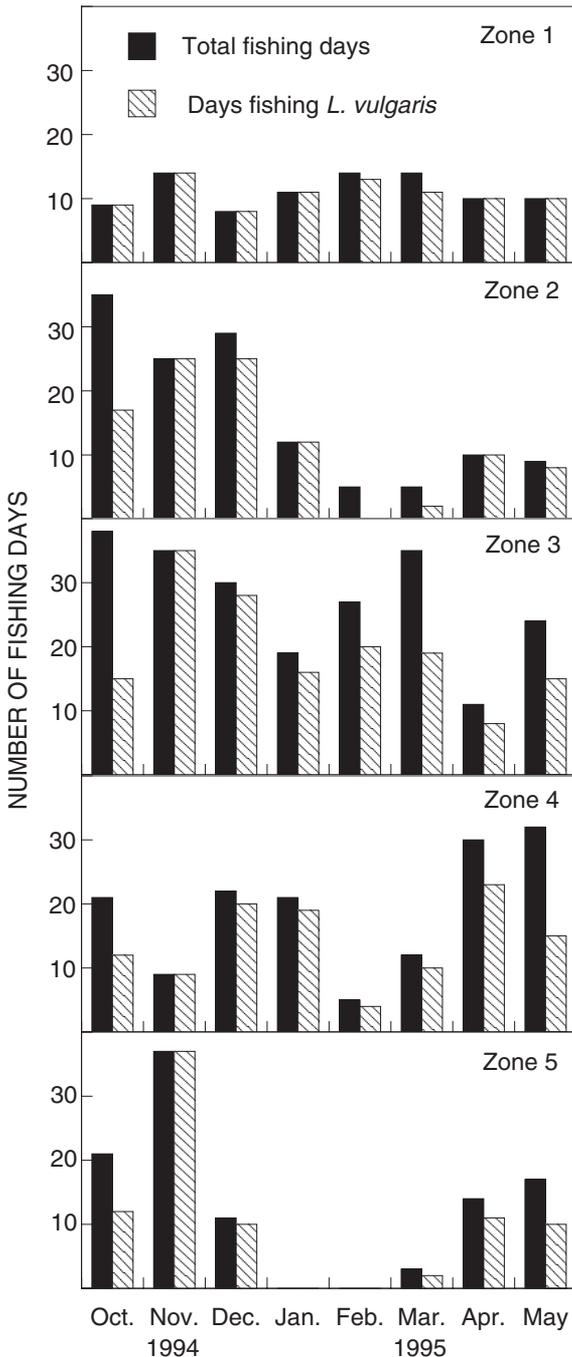
Fig. 2: Beach-seine fishing activity during the study period October 1994 – May 1995, by zone

February (Stergiou *et al.* 1997).

The fishing activity of beach-seiners nowadays is concentrated in the western part of the Thracian Sea and particularly along the coasts indicated in Figure 1. The shores from Keramoti to Alexandroupoli, although sandy, are inappropriate for beach-seine operations because of their low inclination and shallow water, whereas on the north coast of Thasos, the extensive use of fyke-nets for octopuses has made fishing with beach-seine impossible for the past 10 years.

Beach-seines are rarely used in the Mediterranean, but are quite important in the Greek coastal fishery. The Greek beach-seine fishing fleet currently numbers some 640 vessels and employs about 2 000 persons. Despite its name, the gear is really a boat-seine and the net is hauled by a special winch. The boats are 7–14 m long. However, according to Greek legislation, the gear is operated very close to shore, the boats anchoring within 70 m of the coast. Beach-seine nets used in the study area are 200–250 m long and 35–50 m deep, so covering an area of 20 000 – 180 000 m^2 in a single haul. Stretched mesh sizes range from the legal minimum of 16 mm at the codend to 1 000 mm in the wings.

Although there is a closed season for beach-seining extending from 1 June to 30 September, the gear is considered harmful to mullet and sparids owing to the catch of juveniles inshore. That situation has prompted fisheries managers to propose outlawing use of the gear after 2002 (European Community Regulation No 1626/27-6-94/L.171/1).

Data collection and analysis

Total daily landings of beach-seiners, including squid, were recorded between October 1994 and May 1995. During this fishing period, only seven of the nine registered boats operated along the coast of the western Thracian Sea. Four of them landed their catches at Kavala and three at fishing shelters on Thasos (two at Kallirahi and one at Potamia; Fig. 1). Five coastal zones were demarcated for monitoring catch-and-effort data, taking into account the spatial distribution of the ports, the fishing grounds for squid and the daily activity of the beach-seiners.

At Kavala, data were collected at the auctions. This was carried out through personal observation for 138 days out of the total of 208 days devoted to fishing. The activity of the beach-seiners landing at Thasos was not monitored daily because of time and distance constraints, but in terms of weekly reports. Days of activity, number of hauls, fishing zone and catch data were listed through receipts of sale and interviews
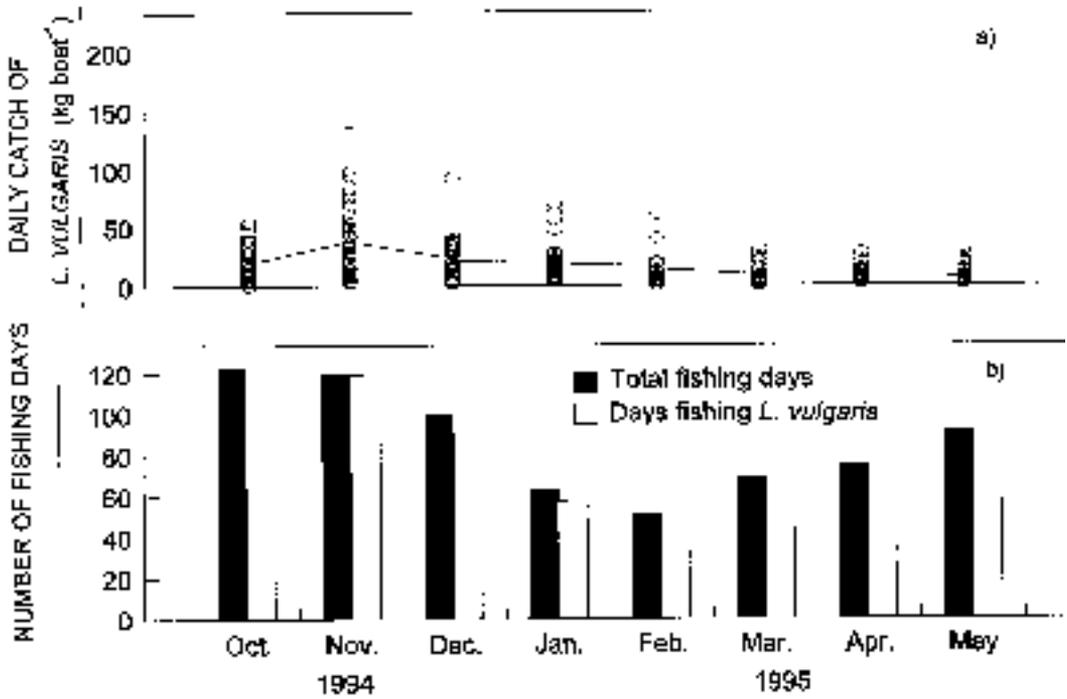
Fig. 3:   Monthly variation in (a) daily catch of *Loligo vulgaris* and (b) beach-seine fishing activity during the fishing
period October 1994 – May 1995 in the Thracian Sea

with the fishermen. As it was not possible to know the
catch per haul, catch per boat-day was used as a unit
of fishing effort.

The catch per unit effort (*cpue*) for each of the five
fishing zones was analysed on a monthly basis. A
daily average *cpue* was calculated from all seven ves-
sels, and a Bray-Curtis (Bray and Curtis 1957) mea-
sure of similarity applied to detect differences in *cpue*
and the catches of *Loligo vulgaris* between the differ-
ent zones.

Local records of average daily air temperature
(°C), daily rainfall (mm), hourly wind speed (knots)
and wind direction were provided by the National
Meteorological Service.

The relationship between the *cpue* of European
squid and meteorological factors was explored using
non-parametric correlation analysis and multiple
regression analysis (STATGRAPHICS Plus 2.0
Software). The analyses were performed for the
whole fishing period monitored and also for shorter
periods (see Table I), following the trends in the
Loligo vulgaris catch. Catch rates were examined for
all vessels combined and separately for the five boats

that had no missing data for the eight months of the
study period.

For the statistical analyses, the hourly wind data were
smoothed to 24-h values and orientated to a NE-SW
axis direction. *Cpue* values were log-transformed and
zero values included in the analyses. In all regression
analyses, the dependent variable was *cpue*, and the
meteorological factors (air temperature, wind, rain-
fall) were entered as independent variables.

The model used in the multiple regression analysis
was as follows:

$$\text{Log}\,(cpue_i + 1) = a + bT_i + cW_i + dR_i \qquad ,$$

where Log is the natural logarithm, T_i the air temper-
ature (in °C), W_i the wind speed in knots (NE-SW
component), and R_i the rainfall (in mm). At first, all
three independent variables were entered in the multiple
regression analysis, but when the *p*-value associated with
the significance of a variable was >0.1, that variable
was excluded from the model and regressions were
re-calculated using the remaining variables. Correlations

are reported for all three independent variables.

RESULTS

The fishing activity of beach-seiners by zone during the fishing period October 1994 – May 1995 is shown on Figure 2. The activity level of the vessels in each zone seems to be related primarily to the distance from the fishing harbours and only secondly to the relative abundance of the target species.

The lowest level of fishing activity was in Zone 1; there, only one vessel from Potamia was fishing despite there almost always being *L. vulgaris* in the daily catches. There was also a low level of fishing activity in Zone 2, because one of the two Kallirahi vessels was involved in a different type of fishing activity after January.

The fishing grounds of Zones 3, 4 and 5 were mainly exploited by the four vessels of Kavala. The highest level of fishing activity was in Zone 3, and the same zone realized the greatest number of fishing days with *L. vulgaris* in the catch. Zone 3 is close to lagoons and is inhabited by other commercially important species (e.g. *Lithognathus mormyrus*) targeted directly by the beach-seine fishery. In Zone 5 there was no fishing activity during January or February, probably because that area is quite far from shelter and is quite vulnerable to bad weather. However, in Zone 5, the frequency of *L. vulgaris* in the catches was the highest of all zones. Therefore, despite the relatively greater distance of Zone 5 from Kavala, the highest level of exploitation was there in November, the month of greatest abundance of *L. vulgaris*.

Peak beach-seine activity throughout the study area was in October-November and the lowest level of activity in February (Fig. 3b). In November *L. vulgaris* was found in all daily landings monitored. Lowest frequency of occurrence of the species was in October. Average monthly catch rates of *Loligo vulgaris* were clearly seasonal, peaking in November and declining from winter to spring. Daily catches also peaked in November (Fig. 3a).

Multivariate analysis failed to reveal significant differences between the monthly *cpue* in the five fishing zones. However, among monthly *cpue* values, those of January and February were separated at a 75% (Bray-Curtis) similarity level (Fig. 4).

Average daily values of temperature, wind speed and daily rainfall during the study period are plotted on Figure 5 together with squid *cpue* and fishing effort. It appears that *cpue* increases with decreasing temperature (down to 7°C) during the first two months of the study, that a further decline of temperature inverts this trend during December and January, but that temperature effects on *cpue* fluctuations are not obvious during the following months. Winds blowing
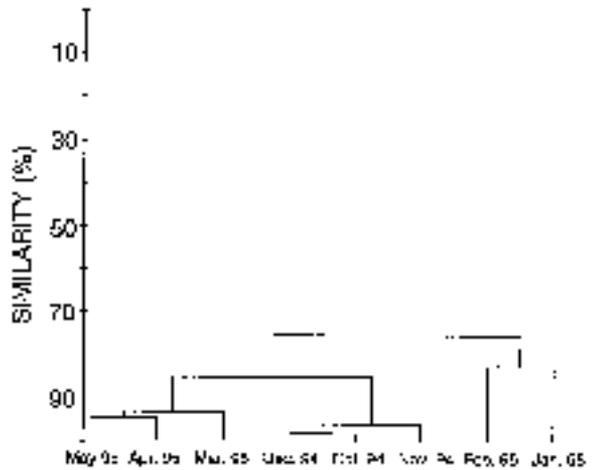
Fig. 4: Dendrogram showing group-average clustering, based on Bray-Curtis similarities between monthly *cpue* of *Loligo vulgaris* (kg·boat-day⁻¹) from the beach-seiners operating in five different fishing areas of the Thracian Sea

from the north-east seem generally to result in decrease of air temperature. Strong south-west winds (>5 knots), supposedly correlated with coastal water turbidity, were recorded during spring only, when the low abundance of *L. vulgaris* did not permit detection of their effect on catches and catch rates.

The multiple linear regression analyses confirmed the highly significant relationship between *cpue* and temperature in almost all cases (Table I). Wind also played a significant role in the overall *cpue*, explaining a higher percentage of *cpue* variation in the two-month periods December/January (15.24%) and February/March (13.12%). Rainfall was significantly related to overall *cpue* only in late winter ($F = 15.94$). However, it appeared to play the most important role in the variation of the *cpue* of Boat 5 operating in Zone 1, where surface salinity is relatively lower (Papaconstantinou *et al*. 1994). The catch rate was generally negatively correlated with air temperature and rainfall, whereas most significant correlations of *cpue* with wind were also negative.

The linear models developed could not explain the variability in the overall *cpue* values. Although the R^2 value increased when the analysis was performed for October-November, it exceeded 50% only for the *cpue* of Boats 1 and 4.

DISCUSSION

Subtle changes in fundamental environmental vari-
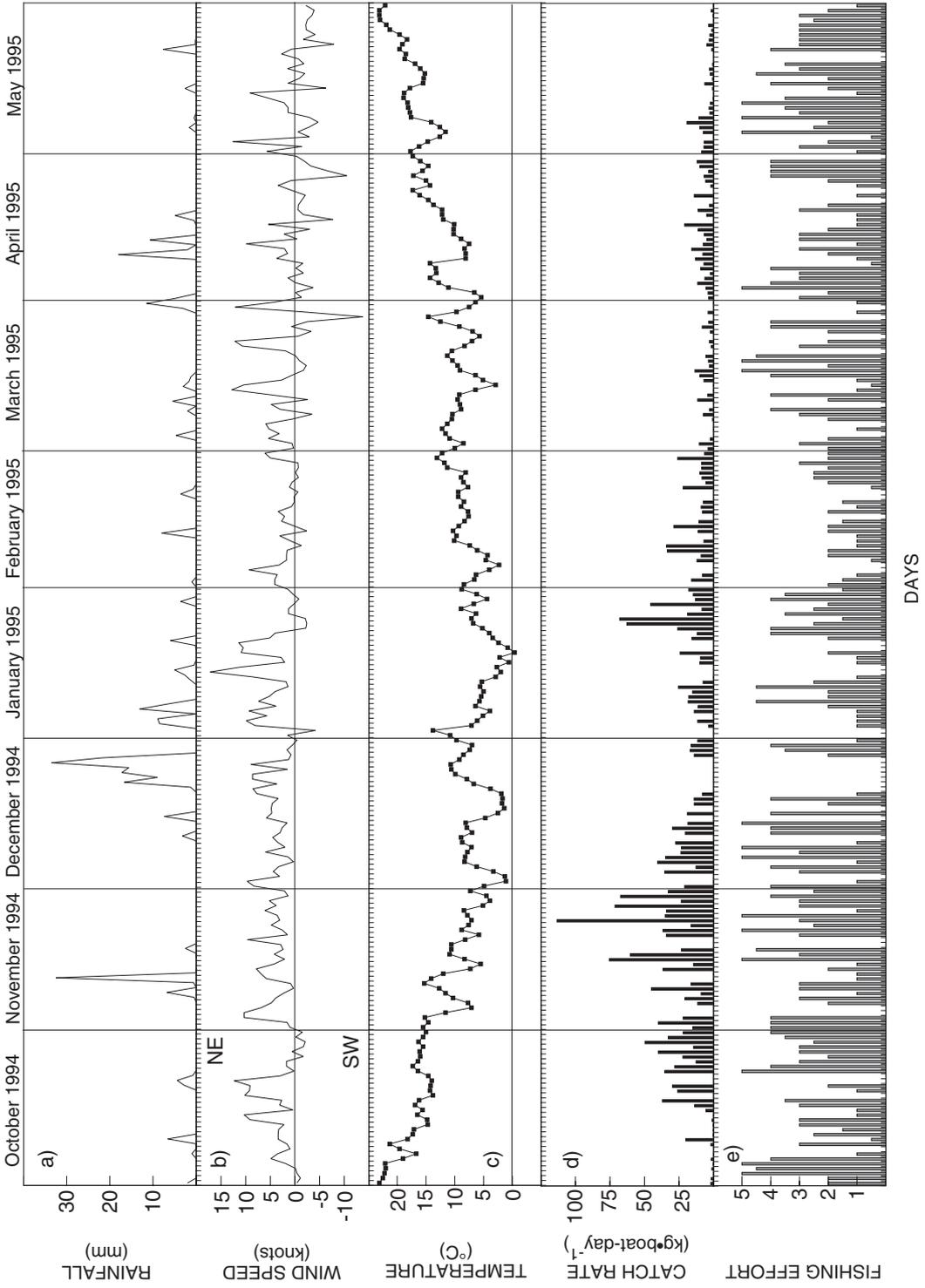
Fig. 5:   Average daily values of (a) rainfall, (b) wind speed (winds with a north-easterly component are given a positive wind speed, south-westerlies a negative one, (c) temperature, (d) European squid *cpue* (kg·boat-day⁻¹), (e) number of active boats (fishing effort)

ables (temperature, salinity, winds, currents) can alter the abundance, distribution and availability of fish populations sharply (Glantz 1992). For squid, sea surface temperature may be considered as the key environmental variable affecting their availability either directly or indirectly (Pierce 1995, Boyle and Boletzky 1996).

Direct environmental effects on migration patterns, spawning intensity and on planktonic juvenile stages of squid have been documented. Migration of the maturing animals towards the coast, proposed by Worms (1983), is influenced by sea surface temperature and results in two peaks of spawning, following the two mating periods of January and April. Spawning intensity of *Loligo vulgaris reynaudii* has been related to sea surface temperature variability by Sauer *et al*. (1991). Further, a highly significant relationship between annual fluctuations in sea surface temperature in the North Sea and landings of *Loligo forbesi* in Scotland has been established by Pierce (1995). Temperature is considered crucial in egg survival of *L. v. reynaudii* (Augustyn 1989), and it is also thought to influence growth rates in the early life history of squid (Forsythe 1993). Finally, the indirect effects of temperature can be related to the abundance of food available to adult squid. For instance, zooplankton abundance in the North Sea follows a similar trend to North Atlantic sea surface temperature (Pierce 1995).

In the Thracian Sea, the availability of *Loligo vulgaris* on the inshore fishing grounds peaked in the second half of November 1994 and to a lesser extent in the second half of January 1995 (Fig. 5). In other years, catch statistics reveal a later period of good beach-seine and hand-jigging catches of squid between late March and May. The relatively cooler weather of spring 1995 may have postponed the migration inshore of late-spawning *Loligo vulgaris*. Most (>80%) of the *Loligo vulgaris* caught by beach-seines from February to May in the Thracian Sea are fully mature or partially spent (EL, unpublished data), suggesting that the poor catches during spring may be due also to a high level of post-spawning mortality. The scarcity of *L. vulgaris* in October 1994, however, may well be due to the fact that the animals had not fully recruited to the beach-seine fishing grounds inshore, because in the same month, trawl catches of *Loligo vulgaris* peaked (Tsangridis *et al*. 1998). The documented seasonal bathymetric distribution by size in the western Mediterranean suggests that large (maturing or mature) squid move inshore in autumn and winter, probably to spawn (Sánchez and Guerra 1994).

The present results suggest a relationship between temperature and the availability of European squid on the inshore fishing grounds, although air temperature has been used rather than sea surface temperature. It is known, however, that there is a reasonable correla-
tion between the two parameters in coastal waters (Southward *et al*. 1988, Astraldi *et al*. 1995).

Wind and rainfall were generally less significantly related to the availability of *Loligo vulgaris*, indicating that, at least in the Greek beach-seine fishery, the most appropriate meteorological variable is air temperature. The high significance of rainfall in the variation of *cpue* in Zone 1 is exceptional and probably related to the relatively lower surface salinity east of Thasos (Papaconstantinou *et al*. 1994).

For now, however, it is still too early to take matters further and to suggest empirical relationships between indices of squid abundance and meteorological variables; the present data, although detailed, are after all restricted to a single year (and generation of *Loligo vulgaris*). Further data from long-term monitoring are needed to establish tighter relationships.

ACKNOWLEDGEMENTS

LITERATURE CITED

ASTRALDI, M., BIANCHI, C. N., GASPASRINI, G. P. and C. MORRI 1995 — Climatic fluctuations, current variability and marine species distribution: a case study in the Ligurian Sea (north-west Mediterranean). *Oceanologica Acta* **18**(2): 139–149.

AUGUSTYN, C. J. 1989 — Systematics, life cycle and resource potential of the chokker squid *Loligo vulgaris reynaudii*. Ph.D. thesis, University of Port Elizabeth: xi + 378 pp.

BADDYR, M. 1988 — The biology of the squid *Loligo vulgaris* in relation to the artisanal fishing site of Tifnit, Morocco. Ph.D. thesis, Institut Agronomique et Vétèrinaire Hassan II, Rabat: 93 pp.

BOLETZKY, S. von 1979 — Observations on the early post-embryonic development of *Loligo vulgaris* (Mollusca, Cephalo-

poda). *Rapp. Commn int. Mer Médit.* **25/26**(10): 155–158.

BOYLE, P. R. 1990 — Cephalopod biology in the fisheries context. *Fish. Res.* **8**(4): 303–321.

BOYLE, P. R. and S. von BOLETZKY 1996 — Cephalopod populations: definition and dynamics. *Phil. Trans. R. Soc. Lond.* **351B**: 985–1002.

BRAY, J. R. and J. T. CURTIS 1957 — An ordination of the upland forest communities of southern Wisconsin. *Ecol. Monogr.* **27**: 325–349.

CADDY, J. F. 1983 — The cephalopods: factors relevant to their population dynamics and to the assessment and management of stocks. In *Advances in Assessment of World Cephalopod Resources*. Caddy, J. F. (Ed.). *F.A.O. Fish. tech. Pap.* **231**: 416–452.

FORSYTHE, J. W. 1993 — A working hypothesis on how seasonal temperature change may impact the field growth of young cephalopods. In *Recent Advances in Cephalopod Fisheries Biology*. Okutani, T., O'Dor, R. K. and T. Kubodera (Eds). Tokyo; Tokai University Press: 133–143.

GLANTZ, M. H. (Ed.) 1992 — *Climate Variability, Climate Change, and Fisheries*. Cambridge; University Press: 450 pp.

GLANTZ, M. H. and L. E. FEINGOLD 1992 — Climate variability, climate change, and fisheries: a summary. In *Climate Variability, Climate Change, and Fisheries*. Glantz, M. H. (Ed.). Cambridge; University Press: 417–438.

LEFKADITOU, E., ADAMIDOU, A., TSANGRIDIS, A. and P. SÁNCHEZ (in press) — Examination of the effectiveness of an experimental jigging gear and the fishing gears in use, for the exploitation of the squid *Loligo vulgaris*. In *Proceedings of the 8^(th) Panhellenic Ichthyological Congress "Advances in Greek Fisheries", Thessaloniki, September 1997* (in Greek).

PAPACONSTANTINOU, C., STERGIOU, K. I., KAVADAS, S., KLEANTHOUS M., FOURTOUNI, A., CHATZINIKO-LAOU, P. and S. CHRISTIANIDIS 1994 — Hydro-acoustic assessment of the distribution and relative abundance of small pelagic fishes in the North Aegean Sea. National Centre for Marine Research, Athens, Greece, Final Report April 1994: 93 pp. (in Greek).

PIERCE, G. J. 1995 — Stock assessment with a thermometer: correlations between sea surface temperature and landings of squid (*Loligo forbesi*) in Scotland. *ICES Doc.* **C.M.1995/K:21**: 8 pp. (mimeo).

ROBERTS, M. J. and W. H. H. SAUER 1994 — Environment: the key to understanding the South African chokka squid (*Loligo vulgaris reynaudii*) life cycle and fishery? *Antarctic Sci.* **6**(2): 249–258.

SÁNCHEZ, P. and A. GUERRA 1994 — Bathymetric distribution and aspects of the life history of the loliginid squid *Loligo vulgaris* (Mollusca: Cephalopoda) in the Catalan Sea (NW Mediterranean). *Iberus* **12**(2): 1–12.

SAUER, W. H. H., GOSCHEN, W. S. and A. S. KOORTS 1991 — A preliminary investigation of the effect of sea temperature fluctuations and wind direction on catches of chokka squid *Loligo vulgaris reynaudii* off the Eastern Cape, South Africa. *S. Afr. J. mar. Sci.* **11**: 467–473.

SIMON, F., ROCHA, F. and A. GUERRA 1996 — The small-scale squid hand-jig fishery off the northwestern Iberian Peninsula: application of a model based on a short survey of fishery statistics. *Fish. Res.* **25**(3–4): 253–263.

STERGIOU, K. I. and E. D. CHRISTOU 1996 — Modelling and forecasting annual fisheries catches: comparison of regression, univariate and multivariate time series methods. *Fish. Res.* **25**(2): 105–138.

STERGIOU, K. I., CHRISTOU, E. D., GEORGOPOULOS, D., ZENETOS, A. and C. SOUVERMEZOGLOU 1997 — The Hellenic seas: physics, chemistry, biology and fisheries. In *Oceanography and Marine Biology. An Annual Review* **35**. Ansell, A. D., Gibson, R. N. and M. Barnes (Eds). London; UCL Press: 415–538.

SOUTHWARD, A. J., BOALCH, G. T. and L. MADDOCK 1988 — Fluctuations in the herring and pilchard fisheries of Devon and Cornwall linked to change in climate since the 16th century. *J. mar. biol. Ass. U.K.* **68**(3): 423–445.

TINBERGEN, L. and J. VERWEY 1945 — Zur Biologie von *Loligo vulgaris* Lam. *Archs neérl. Zool.* **7**(1–2): 213–286.

TSANGRIDIS, A., LEFKADITOU, E. and A. ADAMIDOU 1998 — Analysis of catch and effort data of *Loligo vulgaris* in the W. Thracian Sea (NE Mediterranean) using a depletion model. *Rapp. Commn int. Mer Médit.* **35**: 494–495.

TURK, P. E., HANLON, R. T., BRADFORD, L. A. and W. T. YANG 1986 — Aspects of feeding, growth and survival of the European squid *Loligo vulgaris* Lamarck, 1799, reared through the early growth stages. *Vie Milieu* **36**(1): 9–13.

WORMS, J. 1983 — Schéma migratoire d'une population de *Loligo vulgaris* Lam. (Cephalopoda, Teuthoidea) du Golfe de Lion (France). *Rapp. Commn int. Mer Médit.* **28**(5): 277–279.