The Distribution of Phytoplankton Pigments and the Fishery of Anchovy *(Engraulis encrasicolus)* in the Hellenic Seas

K.I. STERGIOU and D. GEORGOPOULOS

Abstract

A brief description of the Greek fisheries for the anchovy (*Engraulis encrasicolus*, Engraulidae) is given, with emphasis on the spatial distribution of the catch. Satellite images of phytoplankton pigment distribution obtained with NIMBUS-7 are used to explain local abundance of the dynamics of anchovy populations.

Introduction

In 1987, the Greek purse-seine fishery landed 51,282 t of fish which comprised 49% of the total catch. Anchovy (*Engraulis encrasicolus*), comprised 46.6% of the purse-seine catch; the remainder included sardine (*Sardina pilchardus*), horse mackerel (*Trachurus* spp.), bogue (*Boops boops*), chub mackerel (*Scomber japonicus*) and bonito (*Sarda sarda*) (Stergiou 1990a).

In this study we examine, by comparing the distribution of phytoplankton pigments as derived from satellite images taken by the Coastal Zone Color Scanner (CZCS) on board NIMBUS-7, with that of the commercial catches of anchovy in 16 fishing subareas, whether this gradient is reflected in the commercial catches of anchovy (Hovis et al. 1980). The CZCS images are presented for the first time for Greek waters.

Materials and Methods

Forty-six images of the Ionian, Aegean and northwestern Levantine Seas were obtained, covering the period 1981-82. The spatial resolution in the nadir of the satellite is 825 x 825 m^2. The images were analyzed in the Joint Research Center, Ispra, Italy. The final product of the CZCS data evaluation is a quantitative map of the distribution of phytoplankton pigments and suspended material in the surface layer of the sea. The method used to obtain the maps is based on Sturm (1981).

Annual catches of anchovy (1964 to 1987) in the 16 fishing subareas (Fig. 1) were gathered from the Bulletins of the National Statistical Service of Hellas (1968-89).

Results and Discussion

The annual commercial catches of anchovy in the 16 fishing subareas are shown in Table 1. During 1964-87 the variability in annual catches per subarea ranged from a minimum of 42% for subarea 8 to a maximum of 422% for subarea 16. Subareas 3 to 7 (Ionian Sea) and 9 made up 6.1% of the mean catch in 1964-87, whereas the remaining 93.9% was caught in the Aegean Sea. The western/northern edge of the Aegean Sea (subareas 8 and 12 to 14) comprised 67.9% and the enclosed subareas 10 and 11 comprised 20% of the mean anchovy catch in 1964-87 (Table 1). Overall, subareas 8 and 12 to 14 comprised 64% of the mean total catch for 1982-1985 (Stergiou 1989).

Anchovy catches show a marked seasonal pattern (Fig. 2) which is most likely related to the seasonal offshore and inshore migrations of anchovy and the nature of the purse-seine fishery (Stergiou 1990b, 1992). Purse-seiners in Greek waters do not operate in the open sea but mainly in coastal areas where schools of anchovy (and sardine) migrate

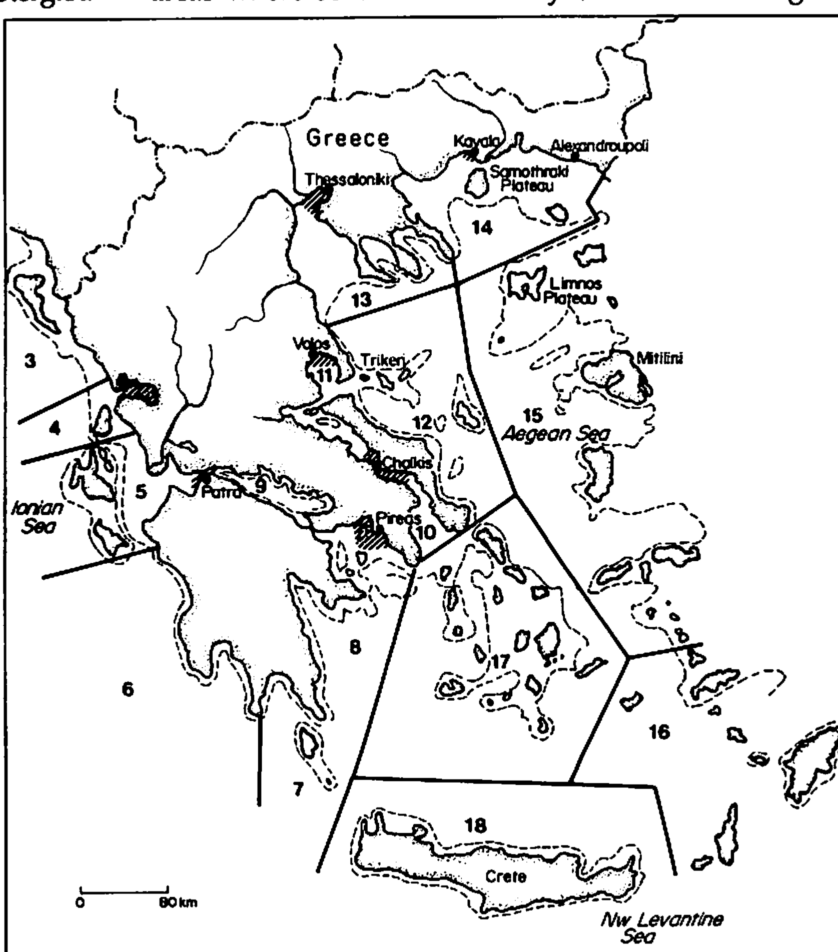

Fig. 1. *Map showing the 16 Greek fishing subareas (subareas 1 and 2, not shown, refer to the North Atlantic and northwestern Coast of Africa, respectively). The dotted line represents the 200-m isobath. Hatched areas show areas where anthropogenic eutrophication is locally important.*

Table 1. Annual commercial catches (in t) of anchovy (*Engraulis encrasicolus*) in 16 Greek fishing subareas (see Fig. 1), 1964-1987. CV = coefficient of variation.

Year	Fishing subareas																Total
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
1964	1	9	96	2	0	2,263	3	574	1,158	54	488	646	78	0	4	10	5,387
1965	6	32	56	0	0	767	1	1,081	881	17	584	676	84	0	3	2	4,190
1966	4	32	164	0	0	1,140	43	745	799	56	1,744	301	127	0	0	0	5,155
1967	5	10	317	0	0	2,157	77	1,130	1,194	82	627	1,421	224	1	18	1	7,264
1968	2	20	233	17	0	1,236	83	867	1,172	116	682	1,675	215	0	1	0	6,319
1969	1	3	69	3	0	2,122	21	343	1,737	133	1,326	1,055	217	0	4	1	7,035
1970	0	11	209	0	1	2,299	57	453	782	31	2,011	431	88	0	0	0	6,373
1971	12	18	321	0	0	2,907	38	557	1,580	66	2,250	217	61	0	17	0	8,044
1972	20	37	262	0	0	3,214	62	493	964	56	3,090	204	61	0	34	0	8,497
1973	3	11	404	0	0	2,821	75	581	1,829	15	1,379	788	76	0	76	0	8,058
1974	0	53	835	0	3	1,350	189	275	1,355	1	825	1,171	109	0	13	0	6,178
1975	0	9	987	0	0	1,042	149	266	539	12	1,182	1,261	160	0	49	1	5,657
1976	2	125	619	8	14	1,476	164	693	2,079	3	1,588	2,091	316	0	88	0	9,266
1977	2	63	493	0	5	762	51	255	1,498	55	1,957	1,996	183	0	68	0	7,388
1978	34	110	668	0	21	1,873	106	286	874	152	2,230	1,702	164	0	132	2	8,354
1979	27	291	582	10	0	1,815	254	389	1,469	171	2,798	1,685	204	0	138	4	9,837
1980	1	92	296	0	0	3,055	195	293	1,379	821	3,746	963	328	0	0	18	11,187
1981	1	20	448	29	0	2,091	83	313	1,531	230	4,203	961	134	1	9	0	10,054
1982	0	45	918	34	0	864	161	592	821	2,016	6,420	2,209	65	42	18	1	14,206
1983	3	122	734	2	0	913	120	889	67	2,359	5,026	1,756	125	23	13	0	12,151
1984	0	191	631	0	0	1,468	114	641	27	3,619	7,215	2,508	49	2	65	0	16,530
1985	1	268	161	0	0	1,635	109	1,073	76	3,619	6,197	4,156	245	2	0	0	17,542
1986	1	611	12	0	0	2,582	29	1,506	936	742	8,554	2,709	113	527	19	0	18,339
1987	1	80	3	0	0	864	115	1,335	79	2,094	13,493	6,484	178	0	1	3	24,729
Mean	5	94	397	4	2	1,780	96	651	1,034	688	3,317	1,628	150	25	32	2	9,906
%	0.1	1.0	4.0	0.0	0.0	18.0	1.0	6.6	10.4	6.9	33.5	16.4	1.5	0.3	0.3	0.0	100
CV	167	141	72	209	274	42	66	54	55	163	93	83	52	422	126	217	50

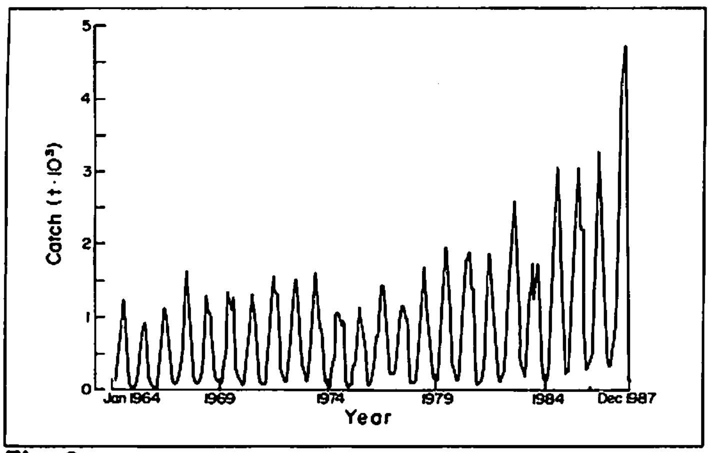

Fig. 2. *Monthly commercial catches (in 1,000 t) of anchovy (Engraulis encrasicolus) in Greek waters, 1964 to 1987.*

seasonally. The mass occurrence of anchovy in the coastal areas takes place from March to August, with a peak in the catches in August, and the schools disperse in late summer and fall (Tsimenidis and Caragitsou 1984; Stergiou 1992). The anchovy spawning season in the eastern Mediterranean extends from April to September with a peak in the summer months (Demir 1965; Regner 1985).

From Fig. 3 it is evident that subareas 8 and 10 to 14, which account for 87.9% of the mean annual anchovy catch, are all characterized by one order of magnitude higher pigment concentrations than the Ionian Sea and other areas. A similar distributional pattern of phytoplankton pigments is also indicated in winter, although because of mixing, concentrations are generally higher (northern/western rim of the Aegean Sea >0.5 mg·m^{-3}; Ionian, southeastern Aegean and northwestern Levantine Seas: about 0.2 mg·m^{-3}; D. Georgopoulos, unpubl. data). This general pattern of phytoplankton pigment distribution is also true of all the 46 images examined for the period 1981-82 (D. Georgopoulos, unpubl. data), and coincides also with that of nutrient distribution in Greek waters, the latter being derived from historical data (Miller et al. 1970) and from recent cruises in open sea (1986-90): Physical Oceanography of the Eastern Mediterranean (POEM); Pollution Research and Monitoring Program in the Aegean and Ionian Seas (MEDPOL); Hellenic National Program for Open Sea Oceanography (HNPOSO); (E. Souvermezoglou, pers. comm.) and coastal waters (early 1980s; Friligos 1980, 1987; Friligos and Karydis 1988). Hence, the images shown in Fig. 3 are representative of the general pattern of phytoplankton pigment distribution in Greek waters.

Subareas 12 to 14 are influenced by Black Sea waters (BSW) which are colder, less saline and richer in nutrients than the waters of Levantine origin (LW) influencing subareas 15 to 18 (Georgopoulos et al. 1989; Theocharis and Georgopoulos, in press). The general sea surface circulation of BSW and LW in the Aegean Sea, as derived from historical data (e.g., Lacombe et al. 1958; Miller et al. 1970; Ovchinnikov 1976) and recent cruises (1986-90: POEM, MEDPOL and HNPOSO), also confirm the above inferences. BSW enter subarea 10 (through the Trikeri channel in the north: Balopoulos and Papageorgiou 1991) and subarea 8 (Georgopoulos and Theocharis 1984). In the Aegean Sea, BSW and LW form thermohaline fronts (Theocharis and Georgopoulos 1992) which coincide with zones of strong productivity gradients (Fig. 3).

Apart from the presence of BSW, other factors which may also contribute to the relatively high concentration of pigments in subareas 8 and 10 to 14 include: (a) 15,028 x 10^6 $m^3 \cdot year^{-1}$ of freshwater (Therianos 1974) entering subareas 13 and 14 (Friligos and Karydis 1988); (b) the extended continental shelf of subareas 8, 13 and 14 (Fig. 1); (c) localized anthropogenic eutrophication (see Fig. 1; Friligos 1980, 1987); and (d) upwelling in the northern part of subarea 10 (Balopoulos and Papageorgiou 1991). The high values of pigment concentration (about 1 $mg \cdot m^{-3}$) along the northern coast of the Aegean Sea (Fig. 3) may be partly attributed to suspended material derived from river runoff.

In the Ionian Sea (subareas 3 to 7) anchovy catches (Table 1) and pigment concentrations (Fig. 3) are higher in subareas 5 and 9. The relatively high pigment concentration in these subareas must be attributed to the upwelling along the northern coast of these subareas (Laskaratos et al. 1989), although river runoff (6,861 x 10^6 $m^3 \cdot year^{-1}$; Therianos 1974) is also important in subarea 5.

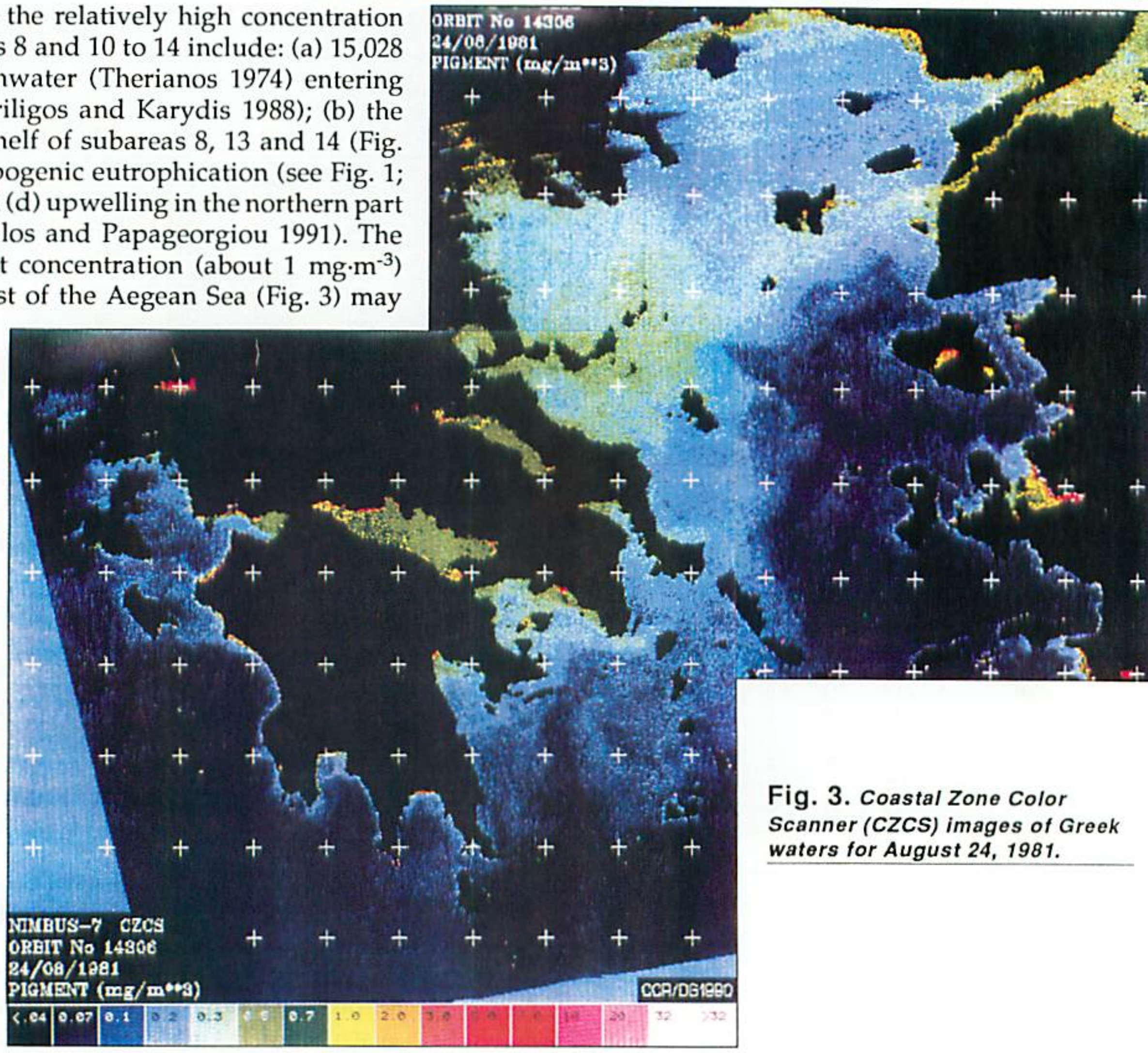

Fig. 3. *Coastal Zone Color Scanner (CZCS) images of Greek waters for August 24, 1981.*

Anchovy catches exhibit an increasing trend for the years following the late 1970s (Fig. 2), due to the sharp increase in the catches of subareas 12, 13 and 14 (Table 1). The annual catches of anchovy in the areas directly affected by BSW (subareas 8, 12, 13 and 14) were positively correlated with each other, with the exception of catches in subarea 8 which were only correlated (negatively) with the catches in subarea 14 (Table 2). The examination of the cross-correlations with lags from -7 to 7 (not shown) revealed that correlation coefficients were highest for zero lag with the exception of subarea 12 which showed maximum correlation coefficients at lag 2 year. Although catches have not been calibrated for fishing effort because annual fishing effort is not available per fishing subarea, the positive correlations most likely indicate that the factors affecting the interannual changes in the anchovy catches of subareas 12, 13 and 14 are common. The increasing trend of the catches in subareas 12, 13 and 14 may be attributed to: (a) socioeconomic factors, inasmuch as purse-seine fishing in Greek waters since the late 1970s is anchovy-oriented rather than sardine-oriented because of the higher price of anchovy (Stergiou 1990a, 1990b); and/or (b) the long-term eutrophication of BSW (e.g., Petran and Rusu 1990; Skolka and Bologa 1990) and/or locally of Greek waters. Apart from the increasing trend, year-to-year fluctuations in the catches (Table 1) may be related to climatic changes (e.g., Pucher-Petkovic et al. 1971; Stergiou 1992a).

Table 2. Correlation coefficients between the annual commercial catches of anchovy in Greek fishing subareas 8, 12, 13 and 14 for the years 1964-87 (N=24). ns = not significant.

Fishing subarea	Fishing subarea 8	12	13
12	ns	-	-
13	ns	0.71 P<0.001	-
14	-0.41 P<0.05	0.65 P<0.001	0.81 P<0.001

The contrasting spatial differences in the pigment concentrations in the generally oligotrophic Greek waters (Fig. 3; see also Becacos-Kontos 1968, 1977; Friligos 1980, 1987; Friligos et al. 1985; Christou 1991) may be more critical as compared with those in eutrophic marine regions (e.g., North Sea), and may have important implications for the fisheries ecology and management of that area (Bakun 1985; Stergiou, in press (a)). In general, there is evidence suggesting the existence of nutrient-dependent intraspecific geographical differences in life-history parameters (e.g., maximum observed length and age, von Bertalanffy growth parameters, natural mortality, length and age at 50% maturation) of fish species inhabiting Greek waters differing in "trophic" potential (Stergiou, in press (a,b); Stergiou et al. 1992). The available information on the geographic variability in the life history of anchovy in the Greek Seas is scant; yet, it seems to be consistent with such a pattern. The analysis of data collected from seven fishing ports (Patra, Pireas, Chalkis, Volos, Thessaloniki, Kavala and Mitilini; Fig. 1) showed that maximum catch/effort (2,200 $kg \cdot night^{-1} \cdot boat^{-1}$) and maximum age (4+ years) of anchovy were recorded in the Thessaloniki samples (subarea 13; Tsimenidis and Caragitsou 1984). Modal age at recruitment was found to be two years in the Pireas, Thessaloniki and Kavala samples (subareas 8, 13 and 14) and one year in the remaining ones (Tsimenidis and Caragitsou 1984). In addition, a recent study of genetic distances, based on electrophoretic variation, and of 12 morphometric and meristic characters using multivariate analysis, from anchovy samples collected from the Ionian (Patra) and Aegean Sea (Kavala and Volos), indicates that the Aegean and Ionian populations of anchovy do not form one panmictic population (Spanakis et al. 1989). Since many fishery management models are based on biological parameters which may vary with the degree of eutrophication (anthropogenic and/or natural), management strategies should vary accordingly. This must be taken into consideration if a common fisheries policy is to be enforced in the Mediterranean Sea.

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K.I. Stergiou *and* D. Georgopoulos *are from the National Center for Marine Research Agios Kosmas, Hellinikon, Athens 16604, Greece.*

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