Effects of Desertification Caused by *Lithophaga lithophaga* (Mollusca) Fishery on Littoral Fish Assemblages along Rocky Coasts of Southeastern Italy

PAOLO GUIDETTI,* SIMONETTA FRASCHETTI, ANTONIO TERLIZZI, AND FERDINANDO BOERO

Laboratory of Zoology and Marine Biology, Department of Biological and Environmental Sciences and Technologies, University of Lecce, 73100 Lecce, Italy

Abstract: *We surveyed shallow, rocky reefs in southwestern Apulia (Mediterranean Sea) to assess the effects on coastal fish assemblages of the date mussel (* Lithophaga lithophaga*) fishery, an illegal practice that strips the rocky reef bare. We visually sampled fish four times over 15 months at three locations, one affected by date-mussel fishery and two controls. The fish assemblage at the affected location differed significantly from those at the control locations over all sampling times. Herbivorous fishes, sparids, and labrids (genus* Symphodus*) contributed most to the differences between the affected location and controls. Lower densities of* Symphodus *spp. were observed at the affected location, whereas detritivorous fishes were recorded exclusively at control sites. Small serranids and sparids showed temporal trends that differed between the affected location and the control locations. Our results suggest that the date-mussel fishery affects fish assemblages chiefly through reduction of arborescent macroalgae (contributing to habitat complexity and primary production) and emphasize the need for more effective policing against this destructive practice.*

Key Words: date mussel, destructive fishery, fish assemblages, Mediterranean Sea, shallow rocky reefs

Efectos de la Desertificación Ocasionada por la Pesquería de *Lithophaga lithophaga* (Mollusca) sobre Ensambles de Peces de Litoral a lo largo de Costas Rocosas del Sureste de Italia

Resumen: *Muestreamos arrecifes rocosos someros en Apulia sudoccidental (Mar Mediterráneo) para evaluar los efectos de la pesquería de* Lithophaga lithophaga*, una práctica ilegal que desnuda al arrecife rocoso, sobre ensambles de peces costeros. Visualmente muestreamos peces cuatro veces a lo largo de 15 meses en tres localidades diferentes, una afectada por la pesquería y dos controles. El ensamble de peces en la localidad afectada difirió significativamente de los sitios control en todos lo tiempos de muestreo. Los peces que más contribuyeron a las diferencias entre la localidad afectada y los controles fueron herbívoros, espáridos y lábridos (género* Symphodus*). En la localidad afectada se observaron densidades menores de* Symphodus spp.*, mientras que en los sitios control se registraron peces detritívoros exclusivamente. Serránidos pequeños y espáridos mostraron tendencias temporales que difirieron entre la localidad afectada y los controles. Nuestros resultados sugieren que la pesquería de mejillón afecta principalmente a los ensambles de peces por la reducción de microalgas arborescentes (que contribuyen a la complejidad del hábitat y a la producción primaria) y enfatizan la necesidad de políticas más efectivas contra esta práctica destructiva.*

Palabras Clave: arrecifes rocosos someros, ensambles de peces, mejillón (*Lithophaga lithophaga*), Mar Mediterráneo, pesquería destructiva

Introduction

It is well known that habitat complexity may influence the diversity, abundance, distribution, and composition of fish assemblages in temperate and tropical reefs (Sale 1991; Garcìa-Charton & Pérez-Ruzafa 2001 and references therein). Structural complexity in rocky reefs reflects both physical features and biological architectural

*email paolo.guidetti@unile.it
Paper submitted August 5, 2002; revised manuscript accepted December 18, 2003.

complexity (Turner et al. 1999). In temperate seas, sessile organisms—chiefly erect macroalgae—may constitute a sizable fraction of the structures available to fishes (including commercially or recreationally valuable species), providing refuge from predation, food resources, and critical nursery and spawning zones (Anderson 1994; Carr 1994; Turner et al. 1999; Levin & Hay 2002). Unlike topographic features such as substrate rugosity, boulders, and crevices, sessile organisms change in abundance and size over a range of time and spatial scales (Dayton 1984). These changes, whether due to natural or anthropogenic disturbances (Terlizzi et al. 2002 and references therein), have the potential to influence associated fish assemblages (Shepherd et al. 1992; Carr 1994; Guidetti et al. 2002).

In southwestern Apulia (southeastern Italy), the marine protected area of Porto Cesareo was established in 1997 but is protected in name only. Inside the reserve and in other zones of Apulia and elsewhere in the Mediterranean (Fanelli et al. 1994; Dayton et al. 1995), the illegal fishery of the rock-boring mollusk date mussel (*Lithophaga lithophaga*) (hereafter DMF for date-mussel fishery) is widely practiced, although it has been formally prohibited since 1988. Date-mussel fishers, equipped with scuba, systematically scrape off the upper centimeters of rocky substrates with hammer and chisel to make extraction of mollusks easier. The major consequence of the DMF is the removal of the biological cover (macroalgae and zoobenthos), which ranges from bare patches to complete desertification (Fraschetti et al. 2001).

Guidetti et al. (2003*a*) reported that in affected substrates sea urchins show significantly greater biomass than in control areas. In addition, in these damaged areas sea urchins usually forage in open areas far away from their shelters. Sea urchins thus seem to prevent the recovery of benthic assemblages in rocky substrates affected by DMF through their unselective grazing on macroalgae and newly settled organisms (McClanahan et al. 1995; Fanelli et al. 1994). Rocky substrates affected by DMF may thus remain devoid of macroalgae for a long time, with potential consequences for those fish using vegetated habitats for shelter, food, nesting, and settlement. We therefore investigated the effects of the substrate desertification caused by the DMF on fishes in shallow, subtidal rocky reefs.

Methods

Study Area

We surveyed three locations along the southwestern Apulian coast of southeastern Italy (Mediterranean Sea) characterized by calcarenitic rocky plateaus with gentle to medium slope, dropping from the water surface to about 8–12 m on sand. The density of macroalgal vegetation (and sessile animals) is low on rocky substrates at the DMF-affected location, where the substrate is almost completely desertified. Two control locations with similar environmental features (e.g., depth, slope) but with a fairly continuous macroalgal cover were selected north and south of the affected location.

Data Collection and Sampling Design

We performed underwater visual censuses along transects of 25 × 5 m (Harmelin-Vivien et al. 1985). We estimated the abundance of fishes (number of individuals/125 m^2) by counting single specimens up to 10 individuals and by counting abundance classes for larger schools (11–30, 31–50, 51–100, 101–200, 201–500 individuals). At each of the three locations, we performed nine censuses in each of the four sampling times (T1, May 2000; T2, July 2000; T3, February 2001; T4, July 2001), for a total of 108 underwater surveys.

Ecological Categories of Fishes

We grouped fishes with similar ecological requirements into eight ecological groups (in some cases corresponding to families or single species) defined on the basis of the prevailing feeding habits and/or spatial organization in the water column: (1) labrids of the genus *Symphodus* and *Thalassoma pavo*, thriving in vegetated rocky habitats; (2) *Coris julis*, a labrid fish living in seagrass and rocky substrates; (3) herbivorous fishes, such as the sparid *Sarpa salpa* and the scarid *Sparisoma cretense*; (4) small serranids (*Serranus* spp.), which represent site-attached carnivorous fishes feeding on juvenile fishes; (5) sparids of the genus *Diplodus* and *Spondyliosoma cantharus*; (6) small benthic fishes such as Blennidae, Gobidae, and Tripterygidae; (7) planktivorous fishes inhabiting the water column, often aggregated in schools, such as Atherinidae, Centracanthidae, Pomacentridae, and the sparid *Oblada melanura*; and (8) particulate organic matter feeders (i.e., Mugilidae). Occasional species (the moronid *Dicentrarchus labrax* and the carangid *Seriola dumerilii*) and others with peculiar requirements (e.g., *Apogon imberbis*) were excluded from some analyses.

Statistical Analyses of Data

We used multivariate techniques to analyze fish assemblages with the Primer software package (Plymouth Marine Laboratory, Plymouth, United Kingdom; Clarke 1993; Clarke & Warwick 1994). Abundance data were log-transformed to arrange all taxa in the same range of abundance. We used analysis of similarity (ANOSIM) to examine differences among locations in each of the four sampling times and the Bray-Curtis similarity matrix to generate two-dimensional plots with nonmetric multidimensional scaling ordinations. We used the similarity percentage procedure to identify the fish categories contributing most to the observed differences.

We used asymmetrical analyses of variance (ANOVA; GMAV5 software package, University of Sydney, Sydney, Australia) to test for differences between affected and unaffected locations. Asymmetrical (ACI) designs, and their mechanics and potential for detecting spatiotemporal disturbances, are discussed by Glasby (1997). We used four random times, considered the *impact versus controls* term to be fixed and orthogonal to time, and considered the term *between controls* to be random. Prior to analysis, we tested the homogeneity of variances with Cochran's test and, whenever necessary, transformed abundance data to $\ln(x+1)$ (Underwood 1997).

Results

We identified 38 fish taxa (Table 1). Atherinids and mugilids were not identified to species level due to the difficulty of the specific determination with underwater visual surveys. At the affected location we recorded about two-thirds of the fish taxa found at the controls (affected location, 20 species; control 1, 32 species; control 2, 33 species).

One-way analysis of similarity (ANOSIM) revealed significant differences in assemblage structure among locations in all four sampling times. Pairwise tests showed that dissimilarities between the two controls were always lower than the values obtained by comparing each control with the affected location (Table 2). The nonmetric multidimensional scaling ordinations (with stress values always lower than 0.20, which means we obtained reliable two-dimensional representations) showed that the fish assemblage structure over the four sampling times from the affected location tended to separate from that of the two control locations (Fig. 1). Three categories of fishes, namely *Symphodus* spp., herbivorous fishes, and sparids of the genus *Diplodus* (i.e., the ecological categories 1, 3, and 5; see Methods), were identified as mostly contributing to dissimilarities between the affected and control locations in all four sampling times (with percentage dissimilarities ranging from 10% to 30%). Planktivorous fishes also contributed to the dissimilarity (12–40%) except in T1, when they were replaced by small serranids (15%).

Number of species (Fig. 2a) and total abundance (Fig. 2b) did not show any statistical difference between the affected location and the controls (Table 3), although slightly lower values were observed at the location affected by DMF for both variables (Fig. 2a & 2b). The average abundance of labrid fishes of the genus *Symphodus* was significantly lower at the DMF-affected location than at the controls in all four sampling times (Table 3; Fig. 2c). Moreover, DMF appeared to significantly affect temporal patterns in the average abundance of sparid fishes and

Table 1. Presence or absence of fish taxa recorded at the location affected by date-mussel fishery (F) and the two control locations (C1, C2).*

Family and species	*Ecological category*	*Location* F	*Location* C1	*Location* C2
Apogonidae				
Apogon imberbis	6	—	•	•
Atherinidae (unidentified)	7	—	•	•
Blenniidae				
Parablennius gattorugine	6	—	•	•
Parablennius rouxi	6	•	•	•
Carangidae				
Seriola dumerili		—	•	—
Centracanthidae				
Spicara maena	7	—	•	—
Gobiidae				
Gobius bucchichii	6	•	•	•
Gobius geniporus	6	—	—	•
Labridae				
Coris julis	2	•	•	•
Labrus merula	1	•	—	•
Labrus viridis	1	—	•	—
Symphodus cinereus	1	•	•	•
Symphodus doderleini	1	—	•	•
Symphodus mediterraneus	1	•	•	•
Symphodus ocellatus	1	—	•	•
Symphodus roissali	1	—	•	•
Symphodus rostratus	1	—	•	—
Symphodus tinca	1	•	•	•
Thalassoma pavo	1	•	•	•
Moronidae				
Dicentrarchus labrax		—	—	•
Mugilidae (unidentified)	8	—	•	•
Mullidae				
Mullus surmuletus	6	—	•	•
Pomacentridae				
Chromis chromis	7	•	•	•
Scaridae				
Sparisoma cretensis	3	•	•	•
Scorpaenidae				
Scorpaena porcus	6	—	•	•
Serranidae				
Epinephelus costae (juvenile)	4	•	—	—
Serranus cabrilla	4	•	•	•
Serranus scriba	4	•	•	•
Sparidae				
Diplodus annularis	5	•	•	•
Diplodus puntazzo	5	—	•	•
Diplodus sargus	5	•	•	•
Diplodus vulgaris	5	•	•	•
Oblada melanura	7	•	•	•
Sarpa salpa	3	•	•	•
Spondyliosoma cantharus	5	•	•	•
Sphyraenidae				
Sphyraena viridensis				
Tripterygiidae				
Tripterygion delaisi	6	•	•	•
Tripterygion minor	6	—	—	•

**Key: •, present; —, absent.*

Table 2. One-way analysis of similarity testing for differences among the three locations (one location affected by date-mussel fishery and two control locations) in each of the four sampling times.*

	Time 1		*Time 2*		*Time 3*		*Time 4*	
	R	p	R	p	R	p	R	p
Among locations	0.418	0.01	0.603	<0.01	0.454	<0.01	0.275	<0.01
Pairwise tests								
C1 vs. C2	0.124	ns	0.419	<0.01	0.076	ns	0.192	<0.05
C1 vs. F	0.486	<0.01	0.845	<0.01	0.576	<0.01	0.375	<0.01
C2 vs. F	0.618	<0.01	0.589	<0.01	0.672	<0.01	0.378	<0.01

**Abbreviation: ns, not significant.*

small serranids (ecological groups 4 and 5; see Methods; Table 3), both tending to show lower densities at the affected location (Fig. 2f & 2g). No impact was statistically detected for the remaining categories of fishes (Fig. 2d, 2h, & 2i), although Fig. 2e seems to reveal larger values of density of herbivorous fishes (mainly *Sarpa salpa*) at the controls than at the affected location. Nevertheless, the large variability in the abundance estimates of herbivorous fishes (reflecting their patchy distribution) likely decreased the power of statistical tests. Fishes that feed on particulate organic matter (Fig. 2j) occurred only in control locations.

Discussion

Our results provide suggestive evidence that desertification caused by date-mussel fishery may alter fish assemblages in Mediterranean rocky reefs. Significant effects were detected in the structure of assemblages, total number of species, and distribution patterns of some ecological categories of fishes.

The total number of species was lower at the affected location (where approximately 35% fewer species were recorded) than at the controls, and a lower number of *Symphodus* species and individuals were detected at the

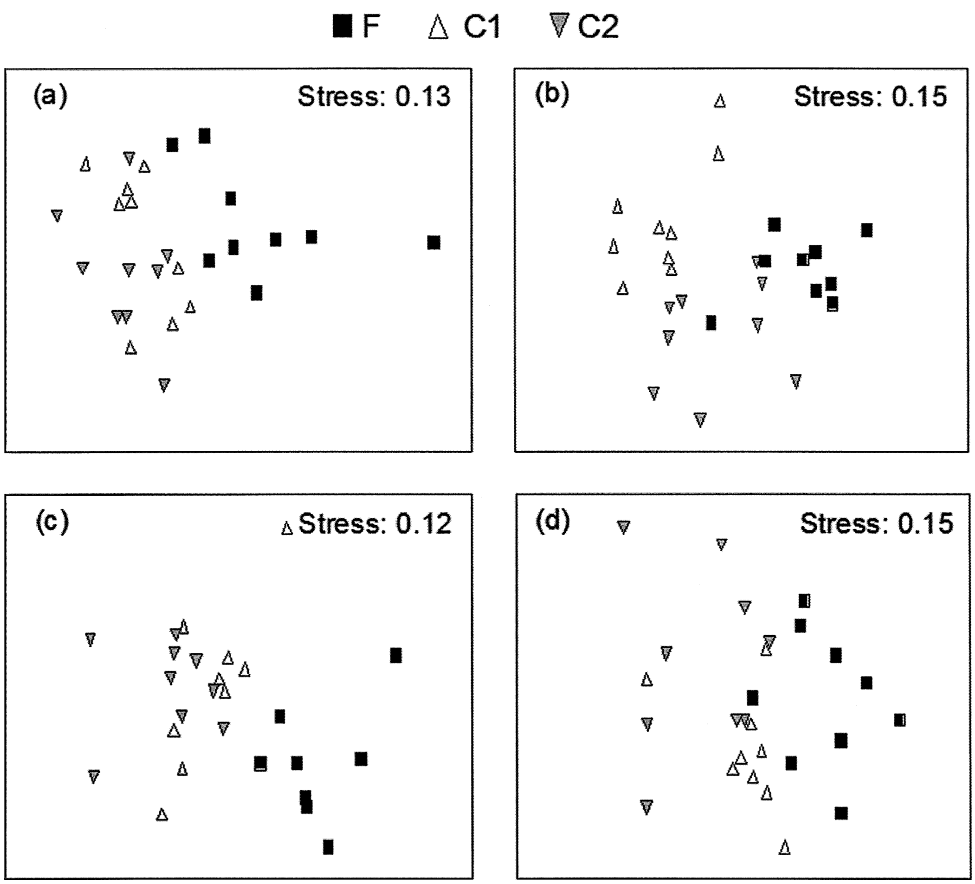

Figure 1. Two-dimensional, nonmetric multidimensional scaling ordinations of individual replicates comparing fish assemblages from the location affected by the date-mussel fishery (F) and the two controls (C1 and C2) in each of the four sampling times: (a) T1,(b) T2, (c) T3, and (d) T4.

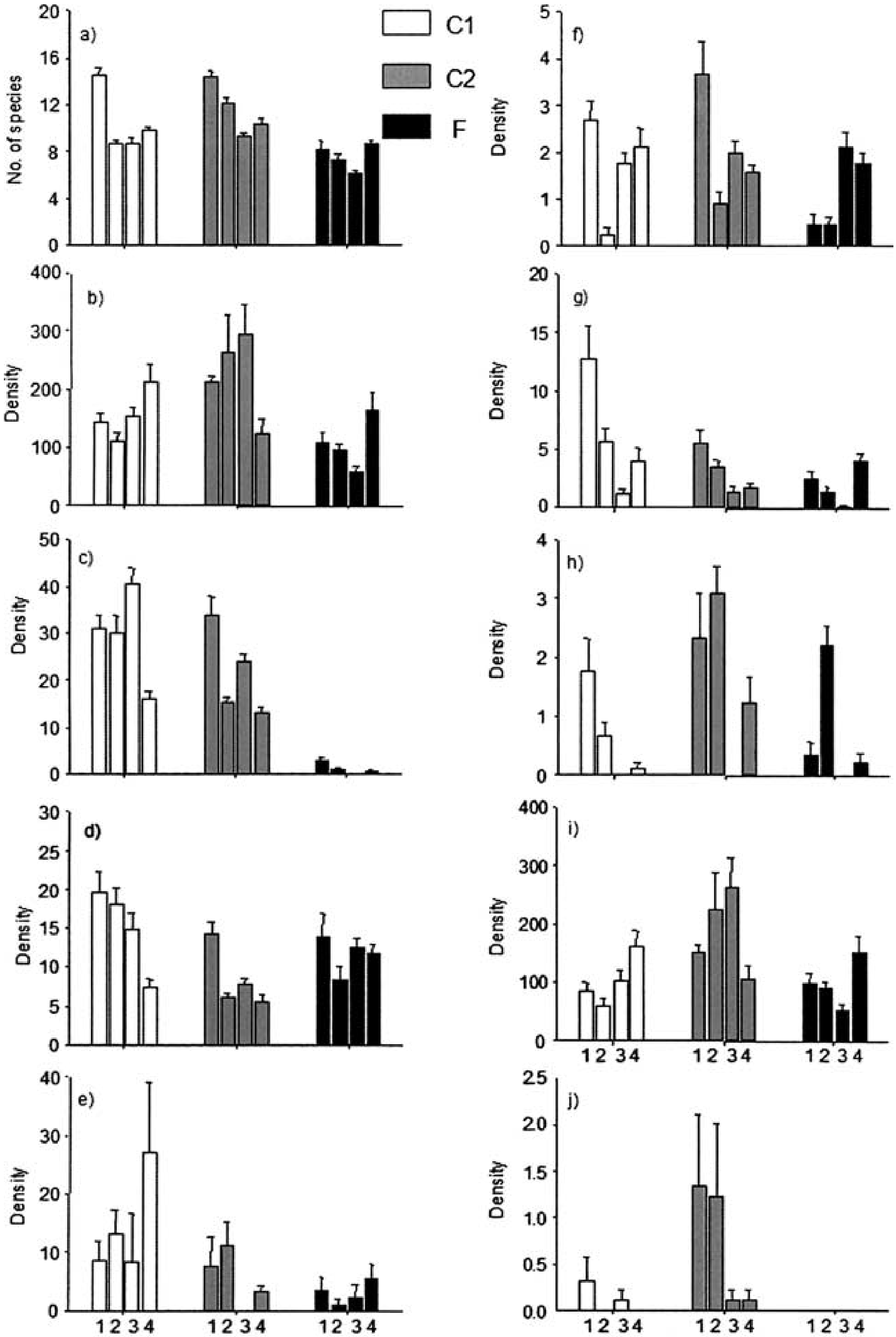

Figure 2. (a) Mean (±SE) number of species, (b) total fish density (number of individuals/125 m^2), and (c–j) density of fishes belonging to the eight ecological categories at the location affected by date-mussel fishery (F) and the two control locations (C1 and C2) in each of the four sampling times. Ecological categories of fishes: (c) category 1, labrids of the genus Symphodus *and* Thalassoma pavo*; (d) category 2,* Coris julis*; (d) category 3, herbivorous fishes; (e) category 4, small-sized serranids; (f) category 5, sparids of the genus* Diplodus *and* Spondyliosoma cantharus*; (g) category 6, small benthic fishes; (h) category 7, planktivorous fishes; (i) category 8, particulate organic matter feeders.*

Table 3. Asymmetrical analyses of variance comparing species richness, total number of individuals, and abundance of each ecological category of fish[a] (see Fig. 2 for definitions) at four times, at one location affected by date-mussel fisheries (F), and two control locations (Cs).[b]

Source of		*Species richness*		*No. of individuals*		*Category 1*		*Category 2*		*Category 3*		*Category 4*		*Category 5*		*Category 6*		*Category 7*	
variation	*df*	*MS*	F	*MS*	F	*MS*	F	*MS*	F	*MS*	F	*MS*	F	*MS*	F	*MS*	F	*MS*	F
Time (T)	3	90.33		0.22		7.73		1.59		9.56		15.99		7.81		5.07		0.25	
Location (L)	2	147.25		4.08		13.51		2.39		10.71		6.33		5.00		1.94		4.30	
F vs. Cs	1	237.37		5.13		26.05	40.15**	0.01		10.98	1.05 ns	10.67		6.26		0.77	0.84 ns	2.60	
Cs	1	21.12		3.02		0.98	1.15 ns	4.74		10.45	5.27*	2.00		3.74		3.12	4.00 ns	6.01	
T × L	6	18.01		1.94		0.66	3.30*	0.82		2.38		6.72		1.48		0.92	6.57**	2.33	
T × F vs. Cs	3	24.50	2.12 ns	1.72	0.80 ns	0.19	1.10 ns	1.14	2.33 ns	3.25	1.63 ns	11.40	5.56**	2.33	4.24*	1.05	1.35 ns	2.03	0.77 ns
T × Cs	3	11.53	5.39*	2.15	9.77**	0.85	3.40 ns	0.49	4.45**	1.50	1.01 ns	2.04	0.78 ns	0.63	1.31 ns	0.78	3.54*	2.63	4.17*
Residual	72	1.51		0.24		0.16		0.10		1.31		0.67		0.24		0.14		0.28	
Cochran's test			ns		ns		ns		ns		ns	ns		ns		ns		ns	
Transformation			nil		ln(x+1)		ln(x+1)		ln(x+1)		ln(x+1)	nil		ln(x+1)		ln(x+1)		ln(x+1)	

[a]*Ecological categories of fishes: 1, labrids of the genus* Symphodus *and* Thalassoma pavo*; 2,* Coris julis*; 3, herbivorous fishes; 4, small serranids; 5, sparids of the genus* Diplodus *and* Spondyliosoma cantharus*; 6, small benthic fishes; 7, planktivorous fishes; 8, particulate-organic-matter feeders.*

[b]*Significance levels: ns,* $p > 0.05$; $^{*}p < 0.05$; $^{**}p < 0.01$.

affected location in all four sampling times. Sparids and small serranids showed different spatiotemporal trends at the affected location than at the control locations, with densities at the affected location generally tending to be lower than at the controls. These results may be explained by the close association of many fishes (mainly labrids) with macroalgal beds, which occurs in the Mediterranean Sea (Ruitton et al. 2000) and elsewhere (Choat & Ayling 1987; Levin & Hay 2002), and they support the hypothesis that habitat complexity provided by erect macroalgae is positively related to fish diversity (Choat & Ayling 1987). Many Mediterranean fishes require arborescent macroalgae for refuge and/or food (e.g., small invertebrates inhabiting macroalgae) (Ruitton et al. 2000), especially during the early stages of their life history (Garcia-Rubies & Macpherson 1995). Thus, the loss of habitat structure and the decrease in primary production (and detritus) caused by DMF could affect carnivorous fishes feeding on small invertebrates (e.g., labrids), particulate-organic-matter feeders (exclusively found at the control sites) and other fishes requiring refuge from predators. More robust data are needed to test for putative changes in herbivorous fishes in DMF-affected areas and to determine whether sea urchins may out-compete herbivorous fishes when food resources are scarce (McClanahan et al. 1995).

Total fish density was not significantly influenced by the DMF (although slightly but not significantly lower values of density were observed at the affected location). This outcome, nevertheless, should be interpreted in light of the fact that planktivorous fishes swimming in the water column mostly determine total abundances. These fishes are usually relatively unaffected by the characteristics of the benthic habitat (Guidetti & Bussotti 2002), being mostly influenced by the trophic state of the waters they inhabit (e.g., organic and nutrient enrichment; Guidetti et al. 2003*b*).

Distribution patterns of the entire fish assemblage suggest chronic disturbance by the DMF. The desertification caused by date-mussel fishers (Guidetti et al. 2003*a*) thus seems to affect the entire community on rocky reefs, where recolonization of erected macroalgae does not occur (Turner et al. 1999). This continuously desertified status of rocky reefs affected by DMF (Fanelli et al. 1994) could be reflected in fish assemblage structures that are persistently different from those found in control locations, an outcome that distinguishes the DMF impact from other sorts of disturbance. Sewage, for instance, affects distribution patterns of fish, but when the causes of the disturbance are (even temporarily) removed or reduced, fish assemblages quickly recover (Guidetti et al. 2003*b*).

There are no studies of the effects of DMF on fishes in other areas. Shepherd et al. (1992) investigated the response of fishes to coral mining in the Maldives and detected differences in fish community structure between affected and control locations that they attributed to destruction of biotic cover. Similarly, many fishing practices—such as trawling and dredging—affect coral, temperate rocky reefs, and soft bottoms (Dayton et al. 1995; Watling & Norse 1998; Turner et al. 1999), with consequent alterations of ecosystem structure and function (Thrush et al. 1998; Turner et al. 1999).

Ten to 12 km of rocky coasts per year are progressively dismantled by DMF in southeastern Italy (Fanelli et al. 1994). Thus, pressing topics for future research are assessment of the effects of desertification on fish settlement and recruitment thresholds in the level of habitat fragmentation, with related effects on adult and juvenile fishes.

Our results show that illegal date-mussel fishery may alter fish assemblages in Mediterranean subtidal rocky reefs, producing changes in functional groups of fishes and decreasing the abundance of fishes requiring arborescent macroalgal habitats for food and refuge. Our results also stress the need for more effective policing against this fishery, a goal that should be achieved in the framework of long-term policies aimed at protecting the natural heritage, structure, and functioning of coastal ecosystems and promoting tourism and underwater activities in marine protected areas.

Acknowledgments

This research was funded by Regione Puglia (Interreg II Greece-Italy) and Ministero dell' Università e delle Ricerca Scientifica e Tecnologica (Progetto confinanziato). We thank S. Thrush of the National Institute of Water and Atmospheric Research, New Zealand, for critical review of the manuscript and C. Vaglio for assistance during the field work.

Literature Cited

Anderson, T. W. 1994. Role of macroalgal structure in the distribution and abundance of a temperate reef fish. Marine Ecology Progress Series **113:**279–290.

Carr, M. H. 1994. Effects of macroalgal dynamics on recruitment of a temperate reef fish. Ecology **75:**1320–1333.

Choat, J. H., and A. M. Ayling. 1987. The relationship between habitat structure and fish faunas on New Zealand reefs. Journal of Experimental Marine Biology and Ecology **110:**257–284.

Clarke, K. R. 1993. Non-parametric multivariate analyses of changes in community structure. Australian Journal of Ecology **18:**117–143.

Clarke, K. R., and R. M. Warwick. 1994. Change in marine communities: an approach to statistical analysis and interpretation. Natural Environment Research Council, Plymouth, United Kingdom.

Dayton, P. K. 1984. Processes structuring some marine communities: are they general? Pages 181–197 in D. Strong, D. S. Simberloff, and A. B. Thistle, editors. Ecological communities: conceptual issues and the evidence. Princeton University Press, Princeton, New Jersey.

Dayton, P. K., S. F. Thrush, T. M. Agardy, and R. J. Hofman. 1995. Environmental effects of marine fishing. Aquatic Conservation: Marine and Freshwater Ecosystems **5:**205–232.

Fanelli, G., S. Piraino, G. Belmonte, S. Geraci, and F. Boero. 1994. Human predation along Apulian rocky coasts (SE Italy): desertification caused by *Lithophaga lithophaga* (Mollusca) fisheries. Marine Ecology Progress Series **110:**1–8.

Fraschetti, S., C. N. Bianchi, A. Terlizzi, G. Fanelli, C. Morri, and F. Boero. 2001. Spatial variability and human disturbance in shallow subtidal hard substrate assemblages: a regional approach. Marine Ecology Progress Series **212:**1–12.

Garcìa-Charton, J. A., and A. Pérez-Ruzafa. 2001. Spatial patterns and the habitat structure of a Mediterranean rocky reef fish local assemblage. Marine Biology **138:**917–934.

Garcia-Rubies, A., and E. Macpherson. 1995. Substrate use and temporal patterns of recruitment in juvenile fishes of the Mediterranean littoral. Marine Biology **124:**35–42.

Glasby, T. M. 1997. Analysing data from post-impact studies using asymmetrical analyses of variance: a case study of epibiota on marinas. Australian Journal of Ecology **22:**448–459.

Guidetti, P., and S. Bussotti. 2002. Effects of seagrass canopy removal on fish in shallow Mediterranean seagrass (*Cymodocea nodosa* and *Zostera noltii*) meadows: a local scale approach. Marine Biology **140:**445–453.

Guidetti, P., G. Fanelli, S. Fraschetti, A. Terlizzi, and F. Boero. 2002. Coastal fish indicate human-induced changes in the Mediterranean littoral. Marine Environmental Research **53:**77–94.

Guidetti, P., S. Fraschetti, A. Terlizzi, and F. Boero. 2003*a*. Distribution patterns of sea urchins and barrens in shallow Mediterranean rocky reefs impacted by the illegal fishery of the rock-boring mollusc *Lithophaga lithophaga*. Marine Biology **143:**1135–1142.

Guidetti, P., A. Terlizzi, S. Fraschetti, and F. Boero. 2003*b*. Changes in Mediterranean rocky-reef fish assemblages exposed to sewage pollution. Marine Ecology Progress Series **253:**269–278.

Harmelin-Vivien, M. L., J. G. Harmelin, C. Chauvet, C. Duval, R. Galzin, P. Lejeune, G. Barnabe, F. Blanc, R. Chevalier, J. Duclerc, and G. Lasserre. 1985. Evaluation des peuplements et populations de poissons: méthodes et problèmes. Revue Ecologie (Terre Vie) **40:**467–539.

Levin, P. S., and M. E. Hay. 2002. Fish-seaweed association on temperate reefs: do small-scale experiments predict large-scale patterns? Marine Ecology Progress Series **232:**239–246.

McClanahan, T. R., A. T. Kamukuru, N. A. Muthiga, M. Gilagabher Yebio, and D. Obura. 1995. Effect of sea urchin reductions on algae, coral, and fish populations. Conservation Biology **10:**136–154.

Ruitton, S., P. Francour, and C. F. Boudouresque. 2000. Relationships between algae, benthic herbivorous invertebrates and fishes in rocky sublittoral communities of a temperate sea (Mediterranean). Estuarine, Coastal and Shelf Science **50:**217–230.

Sale, P. F. 1991. The ecology of fishes on coral reefs. Academic Press, New York.

Shepherd, A. R., R. M. Warwick, K. R. Clarke, and B. E. Brown. 1992. An analysis of fish community response to coral mining in the Maldives. Environmental Biology of Fishes **33:**367–380.

Terlizzi, A., S. Fraschetti, P. Guidetti, and F. Boero. 2002. The effects of sewage discharge on shallow hard substrate sessile assemblages. Marine Pollution Bulletin **44:**542–548.

Thrush, S. F., J. E. Hewitt, V. J. Cummings, P. K. Dayton, M. Cryer, S. J. Turner, G. A. Funnel, R. G. Budd, C. J. Milburn, and M. L. Wilkinson. 1998. Disturbance of the marine benthic habitat by commercial fishing: impacts at the scale of the fishery. Ecological Applications **8:**866–879.

Turner, S. J., S. F. Thrush, J. E. Hewitt, V. J. Cummings, and G. Funnell. 1999. Fishing impacts and the degradation or loss of habitat structure. Fishery Management and Ecology **6:**401–420.

Underwood, A. J. 1997. Experiments in ecology: their logic design and interpretation using analysis of variance. Cambridge University Press, Cambridge, United Kingdom.

Watling, L., and E. A. Norse. 1998. Disturbance of the sea bed by mobile fishing gear: a comparison to forest clearcutting. Conservation Biology **12:**1180–1197.