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COMPARING PREDATOR ABUNDANCE AND FISH DIVERSITY IN MPA SITES (KORNATI NP, CROATIA) AND ADJACENT SITES EXPLOITED BY FISHERIES

C. Kruschel[1]*, S. T. Schultz[1], T. Bakran-Petricioli[2], D. Petricioli[3]

Summary

Fishing activities and other anthropogenic influences have direct and indirect effects on fish community structure. One expectation may be that with increasing fishing pressure and decreasing size selectivity of fisheries all predator populations decline and consequently fish assemblages change. Comparisons of MPAs with unprotected areas are considered valid natural experiments to test hypotheses on how predation structures communities. Here we report on the use of a lure-assisted visual census in the Central Croatian Adriatic to assess and compare fish assemblages in MPA sites (Kornati NP) with adjacent unprotected sites. We detected a significant protection effect on mesopredator abundance and overall fish diversity/richness and that protection status explained a significant portion of the fish assemblage variability, all independent of additional predictor variables, like habitat and depth. As we continue to expand the spatiotemporal scale and magnitude of the approach, we hope that it will eventually provide us with a long-term data series needed for testing many hypotheses in coastal ecology, including the effects of MPAs, coastal development, fishing and global climate change on the species interactions, abundance, diversity and assembly of animal species across multiple spatial scales.

Key words: Croatian Adriatic, Marine Protected Area (MPA), lure assisted visual census, fish community

INTRODUCTION

Fishing activities and other anthropogenic influences have direct and indirect effects on fish community structure. One expectation may be that, with increasing fishing pressure

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[1] Claudia Kruschel* (corresponding author, e-mail: ckrusche@unizd.hr), Stewart T. Schultz, Department of Maritime Science, University of Zadar, Pavlinovića bb, 23000 Zadar, Croatia;

[2] Tatjana Bakran-Petricioli, Division of Biology, Faculty of Science, University of Zagreb, Rooseveltov trg 6, 10000 Zagreb, Croatia;

[3] Donat Petricioli, D.I.I.V. Ltd., for marine, freshwater and subterranean ecology, Obala Petra Lorinija bb, 23281 Sali, Croatia

and decreasing size selectivity of fisheries (due to multiple fishing techniques targeting various fish sizes), all predator populations decline and consequently, due to losses of interactions and the indirect effects thereof (e.g. mesopredator release, changes in competitive interactions, release of predation on some and increase on other fish prey), entire fish communities change in structure, e.g. become less diverse (taxonomically and functionally) and less similar to protected locations (Guidetti and Sala, 2007). Generally there seems to be an agreement that one valid approach to test hypotheses on the influence of fishing on fish community structure is to compare MPAs (marine protected areas), where fishing is restricted or closed, to unprotected areas (UA) open to fishing with various degrees of intensity and selectivity. Despite evidence for great variability in the outcome of such natural experiments, they are still considered a valid method and most consistent changes of the highest magnitude have been detected when older and larger no-take MPAs are chosen as the protection treatment (Guidetti and Sala, 2007, Goetze et al., 2011). Two main challenges of this approach are to adequately describe and quantify the fish communities and to account for factors other than level of protection/fisheries restriction.

Various fish survey methods are in use and they all have their limits and biases (Murphy and Jenkins, 2010). Netting methods are biased against cryptic fish, large mobile and alert predators and fish small enough to pass through the mesh (Harmelin-Vivien and Francour, 1992), and they cannot provide accurate habitat and depth data for the caught fish. Visual census has the advantage of matching observed fish with their occupied habitat and depth but is biased against large predatory fish capable of early detection and active avoidance of the diver/snorkeler carrying out the survey (Bozec et al., 2011). Other potential biases, e.g. due to cryptic behavior or fast movement of fish (Brock, 1982; Lincoln Smith, 1988), can be avoided by the use of ichthyocides/anesthetics and baits (Golani et al., 2007; Stobart et al., 2007). A novel method is the presentation of a lure during visual census which has been shown to improve visibility of fish that are difficult to detect or identify (Kruschel and Schultz, 2012). These include species hidden within three dimensional structure, buried in or camouflaged with the substrate, and fast swimmers.

Several natural and anthropogenic factors could in theory confound the effect of protection/fisheries restriction on fish communities and they can not all be assessed. Some important factors such as habitat availability can be controlled by statistical methods or experimental design. Demersal fish in the Mediterranean and worldwide have been shown to prefer and avoid specific benthic habitats, with such preferences often varying across life stages (Garcia-Rubies and Mcpherson, 1995; Schultz et al. 2009). Benthic habitats within a marine protected area may differ substantially from those immediately outside for several reasons, including natural geological or oceanographic variability, direct destruction of habitat by fishing gear (Caddy, 2008), reduction of water clarity resulting in reduced seagrass coverage (Anton et al., 2011) and exploitation-induced differences in predator abundance that trigger transitions from algal reefs to urchin barrens (Guidetti and Dulčić, 2007). Another important factor structuring fish communities that can be methodologically controlled is depth, which may vary between locations due to natural differences in subsea topography or due to logistical restrictions to sampling access (Dufour et al., 1995). In shallow water adjacent to the shoreline depth usually is correlated with the distribution/zoning of habitats. In addition, effects of protection/fishing restrictions may depend on depth with deeper waters providing refuge from fishing in UAs (Goetze et al., 2011). In addition, MPAs and UAs both are subject to gradients and non-directional spatial variability that may be difficult or impossible to detect and therefore control. Clemente et al. (2011) have shown that not accounting for such context variability can obscure important effects of protection status on communities. One way to address this problem is to sample at various scales and with an effort proportional to the level of spatiotemporal heterogeneity. Within MPAs sampling should consider spatial gradients relative to the center of the MPA, and sampling locations in UAs should be environmentally paired as closely as possible to those in MPAs. Incorporating spatial scale variability requires that distance between sampling locations (within both MPAs and UAs) varies across the range of spatial scales considered.

Here we report on the use of a lure-assisted visual census in the Central Croatian Adriatic to compare fish communities in shallow water inside and in neighboring areas outside an MPA, Kornati National Park. We predicted that predator abundance and overall fish diversity and richness are higher in MPA sites than at unprotected sites, and that there is a protection effect independent of habitat and depth effects. Furthermore, we predicted that the protection/fisheries restriction factor can explain a significant portion of the fish assemblage variability, but that other factors, like habitat and depth, have an independent effect whose magnitude is comparable to the MPA effect itself.

MATERIALS AND METHODS

Study sites

Of the 17 study sites, ten were located within the Kornati National Park, established in 1980 and occupying about **220 km^2 in area**. Here only traditional fishing for subsistence by local land owners is allowed, except in some strictly protected areas as well as some fishing for educational and scientific purposes. The remaining seven sites were located off the Islands of Ugljan, Pašman and Murter, primarily at outer coast locations (Figure 1). UA sites are under multiple fishing pressures including net fishing, subsistence and small commercial hook and line fishing, trap fishing and recreational fishing, including angling and spear fishing. Because commercial trawling is restricted to locations at least one nautical mile from the shore, sites located in areas that do not offer such a distance may be less affected than others that are more exposed to open waters. However, those sites that are not in close proximity to commercial trawling may still experience some smaller vessel trawling nearshore (less than 1 nautical mile). Although an illegal activity, it is relatively common and has been observed (after sunset and by the author) in some locations. Three UA sites are in proximity to fish farms, which may have an effect on the local fish community and on the level of fisheries exploitation (see discussion).

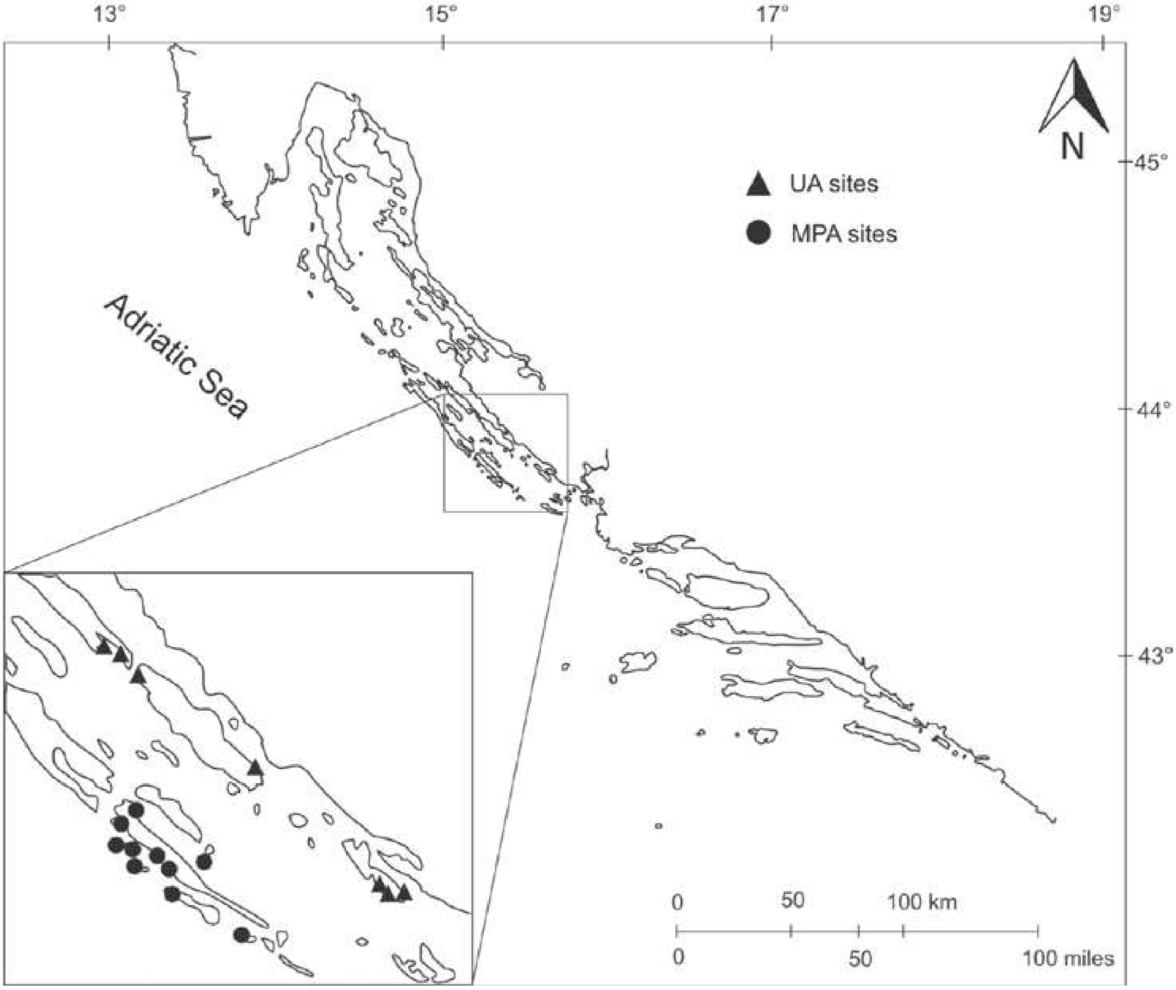

Figure 1: Map of the fishing sites visited in late summer/early fall 2009. Black triangles represent the sites in unprotected areas open to fisheries (UA sites). Black circles represent the sites within the boundaries of the Kornati National Park, Croatia (MPA sites).

Slika 1: Karta lokacija s mjestima na kojima je vršen ribolov u razdoblju kasnog ljeta/jeseni 2009. Crni trokuti predstavljaju lokacije izvan zaštićenog područja gdje je dozvoljen ribolov (UA). Crni krugovi predstavljaju lokacije unutar granica Nacionalnog parka Kornati, Hrvatska (MPA).

Lure assisted visual census

At each of the 17 locations, the same individual observer (C. Kruschel) conducted 25-125 independent short visual census belt transects in 45-180 minutes of snorkeling/swimming at the surface, in the late summer and early fall of 2009. The artificial lure used in these lure-assisted visual census transects was a lead weight attached to the end of a monofilament line, equipped with depth markers and presented in a vertical position above the sea bottom/substrate to a maximum depth of 12 m (for details see Kruschel and Schultz, 2012).

After completion of each transect, the following data were recorded: transect depth, fish taxon, number of individuals and groups of individuals, and the estimated proportional cover of all present basic habitat types, including rock (which can be bare, covered with algal turf or supporting an algal canopy), bare sediments, algae on sediment, *Posidonia oceanica* and *Cymodocea nodosa*. Furthermore, predatory fish to categorize them as either carnivorous fish feeding top predators (>30 cm) or carnivorous mesopredators (15-30 cm). Small benthic carnivores and juvenile fish (<5 cm) of all other functional categories (herbivores, planktivores, omnivores) were identified as potential prey for fish feeding predators. The size estimates basically required of the observer (CK) to be able to make three categorical judgements: is a fish larger than 30 cm, smaller than 15 cm but larger than 5 cm, or smaller than 5 cm. The observer (CK) is well trained for such estimates, as she has been visually censusing fish along an average of 20 km of census transect per year for the last 6 years and had in various incidences the opportunity to combine observations with subsequent handling and ruler measurements of the fish.

Data analysis

The effect of the MPA on single response variables was tested with a linear mixed model in which habitat, depth and the MPA (in/out) were fixed effects, and location was a random effect nested within the MPA (in/out). Individual transects were considered independent replicates within the local sampled site, depth and habitat. First the full model was fitted, then the model eliminating the MPA (in/out) factor. The difference between the two models and its associated probability provided the test of the MPA effect independently of the effects of habitat and depth, using the chi-square test statistic. The Gaussian family was used in all cases because residuals were not significantly different from normal (Shapiro-Wilk test, Royston, 1982) and the data were homoscedastistic (Bartlett test, Bartlett, 1937). Response variables were total abundance of all species, abundance of mesopredators only, abundance of prey only, species richness or species diversity. Species richness was defined as the total number of species observed in a transect. Species diversity was defined as the Simpson measure equal to the estimated probability that two random individuals within a transect belonged to different species (Lande, 1996).

The effect of the MPA on the fish community was tested with a non-parametric, permutational, multivariate analysis of variance (Anderson, 2001). In this test the response variable was the matrix of mean species abundance (columns) within each sampled site (rows). Predictor variables were the mean depth of sampled transects within sites, the overall proportion of rock habitat within each sampled site and the protection status of the sampled site (inside or outside the MPA). First the proportion rock model was fitted, then the depth model was fitted to the residuals of the rock model, then the MPA was finally fitted to the residuals of the depth model. Hence the effect of the MPA on the community was measured independently of the effects of proportion rock and mean depth of the sampled site. Proportion rock was chosen as the habitat dimension of this model because, among other tested habitat variables, it predicted the most fish community variation. The probability of this test was computed by comparing the observed F statistic to the null distribution obtained through 10000 unconstrained random permutations of the rows of the species abundance matrix.

RESULTS

Fish community

A total of 458 lure assisted transects at ten MPA sites allowed the detection of 6207 fish belonging to 40 species. A total of 396 transects at seven UA sites allowed the detection of 10060 fish belonging to 31 species. Richness ($X^2 = 18.19$, df = 1, $p < 0.001$) and diversity ($X^2 = 16.47$, df = 1, $p < 0.001$) were significantly higher inside MPA than in UA sites in an analysis controlling for depth and habitat (Figure 2a and b). A complete list of species observed at MPA and UA sites is given in Table 1 and for those recorded along transects the overall relative abundance within the two locations is given. When comparing fish community structure of the 17 sites, significant effects were found due to protection status (MPA vs. UA) and the relative abundance of rocky groundcover in a site (Table 2). Approximately equal portions of fish community variability were explained by three factors: proportion of rock habitat, mean site depth and protection status, for a total of 44% explained (Table 2).

Fish abundance

The unweighted mean total fish abundance per transect within MPA and UA sites were respectively 13.47 and 25.11, but this difference was not significant in an analysis controlling for depth and habitat ($X^2 = 0.55$, df = 1, $p = 0.459$).

Table 1: Species list for MPA sites and unprotected area (UA) sites and their relative abundances (p_{abund}). Mode of species detection "D" is indicated by "t" if detected along transects and with "o" if observed only outside transects.

Tablica 1: Popis vrsta u zaštićenim morskim područjima (MPA) i nezaštićenim područjima (UA) i njihova relativna brojnost (p_{abund}). Način opažanja vrsta "D" označen je s "t" za vrste opažene duž transekata i sa "o" za vrste opažene izvan područja transekata.

Families / Porodica	**Species / Vrsta**	**MPA sites / Zaštićena morska područja**		**UA sites/ Nezaštičena morska područja**	
		D	p_{abund}	D	p_{abund}
ATHERINIDAE	*Atherina spec.*	t	0.004	*t*	0.009
BLENNIDAE	*Parablennius gattorugine*	o		o	
	Parablennius incognitus	o			
	Parablennius rouxi	*t*	0.011	*t*	0.003
	Parablennius tentacularis	t	0.001	*t*	0.001
	Parablennius sanguinolentus	*t*	0.005	*o*	
BOTHIDAE	*Bothus podas podas*	*t*	0.002		
CARANGIDAE	*Seriola dumerili*	o			
CENTRACANTHIDAE	*Spicara maena*	*t*	0.003	o	
	Spicara smaris	o			
CONGRIDAE	*Conger conger*	o			

GOBIDAE	*Gobius* no ID	***t***	<0.000	***t***	0.007
	Gobius bucchichi	t	0.030	*t*	0.072
	Gobius cobitis	o		o	
	Gobius cruentatus	*t*	0.002	*t*	0.003
	Gobius geniporus	*t*	0.004	*t*	0.040
	Gobius niger	o		o	
	Gobius paganellus	*t*	0.002		
	Gobidae <5cm	*t*	0.013	*t*	0.023
	Pomatoschistus marmoratus			*t*	0.002
LABRIDAE	*Coris julis*	*t*	0.203	*t*	0.105
	Labrus merula	o			
	Labrus viridis	*t*	<0.000		
	Symphodus cinereus	*t*	0.010	*t*	0.056
	Symphodus doderleini	*t*	0.001	*t*	0.001
	Symphodus mediterraneus	*t*	0.004	*t*	0.003
	Symphodus melanocercus	o			
	Symphodus ocellatus	*t*	0.017	*t*	0.047
	Symphodus roissali	o		*t*	0.003
	Symphodus rostratus	*t*	0.002	*t*	0.002
	Symphodus tinca	*t*	0.007	*t*	0.018
	Thallassoma pavo	o			
MUGLIDAE	*Muglidae* spec.	*t*	0.014	*t*	<0.000
MULLIDAE	*Mullus* spec.	*t*	0.020	*t*	0.004
MURAENIDAE	*Muraena helena*	o			
POMACENTRIDAE	*Chromis chromis*	*t*	0.168	*t*	0.176
	Chromis chromis juvenile	*t*	<0.000	*t*	<0.000
RAJIDAE	*Raja* spec.	o			
SCIAENIDAE	*Sciaena umbra*	o			
SCORPAENIDAE	*Scorpaena porcus*	o			
	Scorpaena scrofa	o			
SERRANIDAE	*Epinephelus marginatus*	o			
	Serranus cabrilla	*t*	0.004	*t*	0.008
	Serranus hepatus	*t*	0.004	*t*	0.052
	Serranus scriba	*t*	0.060	*t*	0.058
SPARIDAE	*Boops boops*	*t*	0.009	*t*	<0.000
	Dentex dentex	o		o	
	Diplodus annularis	t	0.126	*t*	0.023
	Diplodus annularis juvenile	*t*	<0.000	*t*	<0.000
	Diplodus puntazzo	*t*	0.002	*t*	<0.000
	Diplodus vulgaris	t	0.060	t	0.174
	Diplodus sargus	*t*	<0.000	*t*	0.005
	Lithognathus mormyrus	*t*	0.001		
	Oblada melanura	*t*	0.092	*o*	
	Oblada melanura juvenile	*t*	<0.000	o	
	Pagrus pagrus	*t*	0.028	*t*	0.002

	Pagrus pagrus juvenile	*t*	<0.000	*t*	<0.000
	Sarpa salpa	*t*	0.041	*t*	0.037
	Sarpa salpa juvenile	*t*	<0.000	*t*	<0.000
	Sparus aurata	*t*	0.001	*t*	0.001
	Spondyliosoma cantharus	*t*	0.001	*t*	<0.000
SYNGNATHIDAE	*Hippocampus ramulosus*	o			
	Syngnathus acus	o			
TRIGLIDAE	*Trigloporus* spec.	o		o	
TRACHINIDAE	*Trachinus draco*	*t*	0.004	o	
	Trachinus radiatus	*t*	0.001		
TRYPTERIGLIDAE	*Tripterygion* spec.	*t*	<0.000	*t*	0.003
Unidentified/n. det.	juvenile fish <2cm	*t*	0.040	*t*	0.033

Predator and prey abundance

The rarity of observed top predators prevented the comparison of their abundance inside and outside the MPA. Mesopredator abundance was significantly higher at MPA than UA sites in an analysis controlling for depth and habitat (respectively 3.69 and 2.24 individuals per transect; $X^2 = 9.21$, df = 1, p = 0.00240; Figure 2b). While mean prey abundance was strikingly lower in MPA than UA sites (respectively 2.36 and 18.64 individuals per transect), this relationship was not quite significant in an analysis controlling for habitat and depth ($X^2 = 2.90$, df = 1, p = 0.089).

Table 2. Permutational, multivariate analysis of variance table for the effect of the indicated predictor variables on the fish species abundance matrix.

Tablica 2. Tablica permutacijske, multivarijatne analize varijance za utjecaj odabranih varijabli utjecaja na matricu brojnosti vrsta riba.

Predictor variables/ Prediktori	**df**	**SS**	**MS**	***F***	**r^2**	***p***
Proportion rock habitat/ Udio stjenovitog staništa	1	0.407	0.407	1.968	0.100	0.055
Mean site depth/ Prosječna dubina lokacije	1	0.521	0.521	2.518	0.128	0.155
Protection status/ Status zaštite	1	0.440	0.440	2.128	0.108	0.038
Residuals/Ostatak	13	2.688	0.207		0.663	
Total/Ukupno	16	4.056			1.000	

DISCUSSION

The lure-assisted, visual census method proved effective for most fish, but was unable to detect large, mobile top predators. This indicates the need for other methods for quantifying these species in studies requiring this information, such as experimental fishing or baited video devices which are less likely to be behaviorally avoided than a diver or

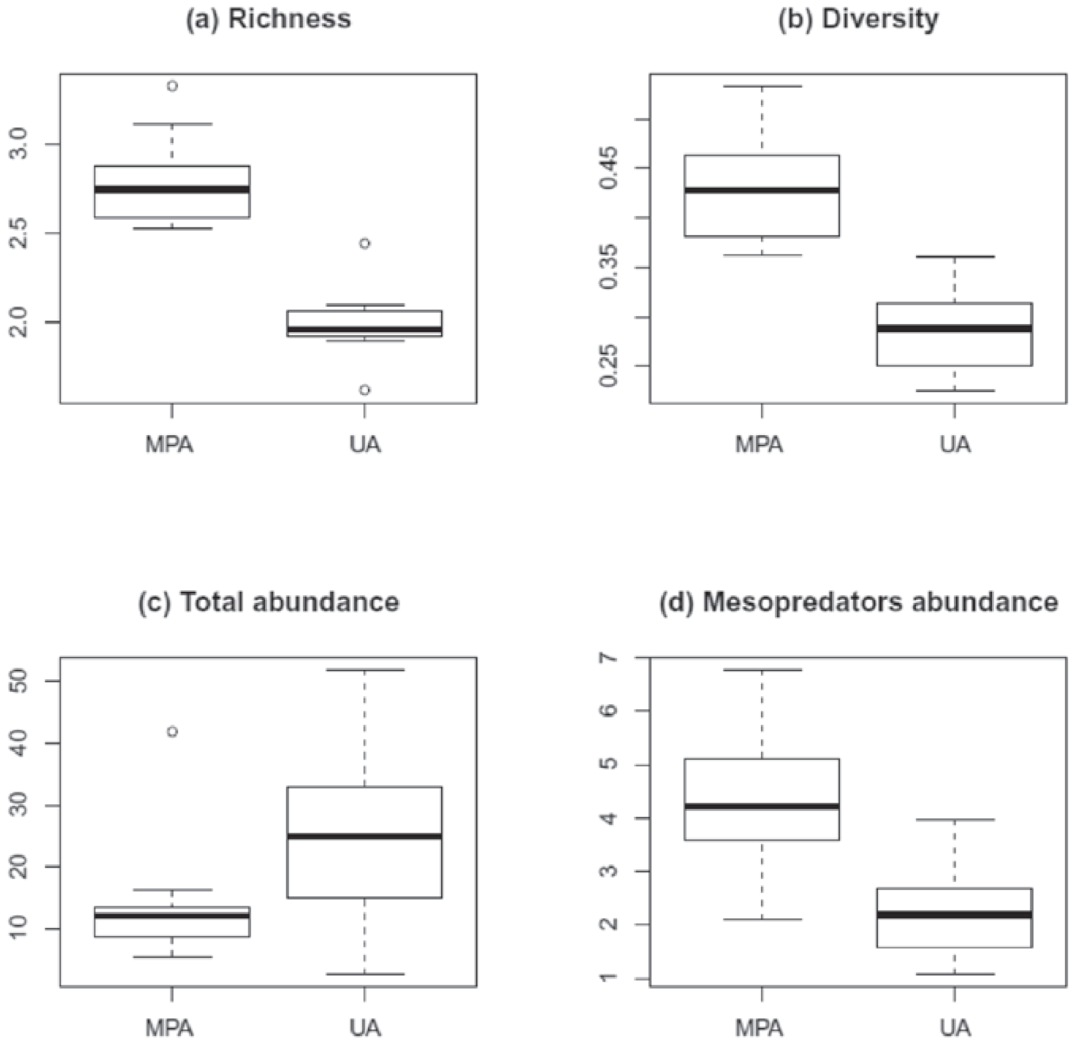

Figure 2: Boxplots of (a) species richness, (b) species diversity, (c) total abundance, and (d) mesopredator abundance in MPA and unprotected areas. Richness is the mean number of species per transect, and diversity the Simpson's diversity per transect. Abundances are the mean number of individuals observed per transect, averaged for each location. For all plots, results are pooled over habitats and depths.

Slika 2: Boxplot dijagrami za (a) brojnost vrsta, (b) raznolikost vrsta, (c) ukupnu brojnost i (d) brojnost mezopredatora unutar zaštićenih područja i izvan zaštićenih područja. Brojnost vrsta je srednji broj vrsta po transektu, a raznolikost vrsta je Simpsonova raznolikost po transektu. Ukupna brojnost je srednji broj jedinki opaženih na transektu, s prosjekom za svaku lokaciju. Za sve dijagrame, prikazani su združeni rezultati za različita staništa i dubine.

snorkeler but provide an equally precise match of individuals with their occupied habitat and depth as the visual census (Cardona et al., 2007; Watson et al., 2009).

Total fish abundance was not significantly different between MPA and UA sites when analysis was controlled for differences in habitat (proportion rock habitat) and mean site depth. Similar published studies have revealed that often abundances are similar between MPAs and UAs while average fish size and therefore biomass are more likely to be elevated in MPAs (e.g. Harmelin-Vivien et al., 2008, Sala, et al. 2012). Mesopredator density was significantly higher at protected sites. This was somewhat unexpected, as assumed lower top predator density in fishing sites was predicted to release mesopredators from top-down control in fishing (UA) sites. However, when fisheries in UA sites is not selective for top predators but also targets or incidentally diminishes mesopredator densities, such release may not manifest. While basically the same predator species were observed in MPAs and UAs, differences in relative abundance of certain mesopredator species were observed. Relative *Coris julis* abundance was twice as high and the proportion of *Mullus surmuletus* five times as high at MPA than at UA sites. This is interesting as *Coris julis* is known to monitor the success of other species (e.g. *Mullus*), followed by joining them and scrounging their food discovery (De Pirro et al., 1999). In contrast to *Coris julis* and *Mullus surmuletus*, mesopredator sized *Gobius* abundance in UA sites was 10 times higher than in MPA sites. *Coris julis* is, according to our observations, a very aggressive predator and is the fish species with the highest occurrence of lure following, often resulting in attempts to bite into the lure (Kruschel and Schultz, 2012). It is also known to be a species highly susceptible to hook and line fishing (Cardona et al., 2007). The abundance differences MPA vs. UA could therefore be caused by a predicted difference in the intensity of angling activity. However, these differences may also be triggered by habitat availability differences, as *Coris julis* and *Mullus surmuletus* may prefer habitats that are less abundant UA sites. They may, however, also be affected by altered competitive interactions related to top predator loss. *Gobius*, an important prey group for piscivorous predators (Froese and Pauly, 2000), may increase in fishing sites due to lowered top predator abundance and may then have a negative competitive effect on other demersal carnivorous mesopredators. A more detailed taxon specific analysis (habitat preferences, abundance correlations) of 2009, and preferably all additional data from the 100 sites visited until 2012, may shed more light on the mechanisms behind the observed fish community differences. However, we felt that such an analysis would go beyond the scope of this manuscript. Within the genus *Diplodus*, *D. vulgaris* was the most common species at UA sites, while *D. annularis* was most common in MPA sites. This may reflect differences in habitat preference: *D. annularis* is known to be associated with *Posidonia oceanica* patches which were rare at UA sites. Guidetti (2000) found that *D. annularis* was 24x as abundant in *Posidonia* as in rocky reefs, while *D. vulgaris* was 7 times as abundant in rocky reefs as in *Posidonia*. Total *Diplodus* proportion, however, was similar in MPA and UA fish communities at 0.19 and 0.2, respectively. Overall, fish species composition differed significantly between MPA and UA sites; however, only a small portion of the total variability (12%) was explained by MPA, and depth and rock habitat availability each explained a similar proportion of the total variation in the species abundance matrix. These results demonstrate the importance of sampling designs, data collection strategies and analytical tools capable of distinguishing among several predictor variables in mixed models containing both fixed and random effects. One predictor variable not taken in consideration here is the presence vs. absence of fish farms near UA sites. The three sites neighboring fish farms are too far away (450 - 1500 m) to be within the fishing restricted zone immediately (100 m) around the farms. Yet, the fish community in the wider surrounding may still be affected, e.g. by the increase in certain fish taxa attracted to the artificially increased availability of food produced by the excess farm feed (Fernandez-Jover, et al., 2009; Šegvić-Bubić et al., 2011). Also sites near the fish farm no-take boundaries may be affected by the potentially increased fishing pressure by small subsistence and recreational fisheries taking advantage of the fish attraction effect (Šegvić-Bubić et al., 2011).

The data presented in this study marked the beginning (August 2009) of a larger project which, since the end of 2011, encompasses over 100 sites (many revisited) that are distributed along the entire Croatian Adriatic from the main coast to the outermost islands, including protected areas and areas of varying degree of anthropogenic and natural stresses. We hope that this approach will eventually provide us with a long-term data series that will be necessary for testing many hypotheses in coastal ecology, including the effects of MPAs, coastal development, fishing and global climate change on the species interactions, abundance, diversity and assembly of animal species across multiple spatial scales.

Sažetak

USPOREDBA BROJNOSTI PREDATORA I RAZNOLIKOSTI RIBA U ZAŠTIĆENIM PODRUČJIMA (NP KORNATI, HRVATSKA) I SUSJEDNIM PODRUČJIMA U KOJIMA JE DOZVOLJEN RIBOLOV

C. Kruschel[1]*, S. T. Schultz[1], T. Bakran-Petricioli[2], D. Petricioli[3]

Ribolovne i druge antropogene aktivnosti izravno i neizravno utječu na sastav zajednica riba. Jedna od pretpostavki je da povećani ribolovni napor dovodi do smanjenja populacije predatorskih vrsta riba što dovodi do promjena u sastavu zajednica riba. Usporedba zaštićenih i nezaštićenih područja smatra se vjerodostojnom eksperimentalnom metodom za testiranje hipoteze na koji način struktura predatora utječe na zajednicu riba. Ovdje predstavljamo rezultate korištenja metode vizualnog cenzusa uz pomoć mamca na području srednjeg Jadrana kako bi procijenili i usporedili sastav zajednica riba u zaštićenom području (NP Kornati) i susjednim nezaštićenim područjima. Zabilježili smo značajan utjecaj zaštite na brojnost meso-predatora i na ukupnu raznolikost/brojnost riba kao i to da je zaštitom moguće objasniti značajan dio varijabilnosti u sastavu zajednica riba, neovisno o drugim faktorima poput tipa staništa ili dubine. Daljnjim proširivanjem naših istraživanja na prostornoj i vremenskoj skali, očekujemo da ćemo prikupiti vrijedne i dugotrajne podatke koji su potrebni kako bismo testirali mnoge pretpostavke u ekologiji

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[1] Claudia Kruschel* (corresponding author, e-mail: ckrusche@unizd.hr), Stewart T. Schultz, Department of Maritime Science, University of Zadar, Pavlinovića bb, 23000 Zadar, Croatia;

[2] Tatjana Bakran-Petricioli, Division of Biology, Faculty of Science, University of Zagreb, Rooseveltov trg 6, 10000 Zagreb, Croatia;

[3] Donat Petricioli, D.I.I.V. Ltd., for marine, freshwater and subterranean ecology, Obala Petra Lorinija bb, 23281 Sali, Croatia

priobalne zone, uključujući one o u utjecaju zaštićenih područja, razvoju obale, ribolovu, dostupnosti staništa te globalnim klimatskim promjenama na odnose među različitim vrstama, brojnost, raznolikost i sastav životinjskih vrsta na raznim prostornim skalama.

Ključne riječi: Jadransko more, zaštićena morska područja (MPA), metoda vizualnog cenzusa, riblje zajednice

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