

## DO FISH ASSEMBLAGES AT SITES FEATURING MAN-MADE CONCRETE WALLS DIFFER FROM THOSE AT NATURAL ROCKY-REEF SITES?

*Claudia KRUSCHEL & Julia HARRAS*University of Zadar, Department of Ecology, Agronomy and Aquaculture &  
CIMMAR – Center for Interdisciplinary Marine and Maritime Research, 23000 Zadar, Croatia  
e-mail: ckrusche@unizd.hr*Irmgard BLINDOW*

Biological Station Hiddensee, Ernst-Moritz Arndt University Greifswald, Biologenweg 15, 18565 Kloster/Hiddensee, Germany

*Stewart T. SCHULTZ*University of Zadar, Department of Ecology, Agronomy and Aquaculture &  
CIMMAR – Center for Interdisciplinary Marine and Maritime Research, 23000 Zadar, Croatia

## ABSTRACT

*The urban development of seashores is predicted to lower biodiversity. After we validated a stationary lure-assisted visual-census method, we proceeded to test the overall hypothesis that fish community structure changes when complex and heterogeneous natural rocky habitats are displaced by less complex vertical hard surfaces. Taxonomic fish community descriptors derived from pristine rocky shorelines were compared with those featuring concrete walls and to natural rocky reefs directly neighboring such developments. Fish communities differed very little between sites across the three levels of development and existing differences were not consistent across all sites within a level. We conclude that in the Croatian Adriatic, the typically small-scale concrete-wall developments do not cause major disruptions of natural near-shore fish assemblages.*

**Key words:** fish community, lure visual census, rocky reefs, seawalls, urbanization, predation intensity

## LE COMUNITÀ ITTICHE IN SITI CON PARETI ANTROPICHE DI CEMENTO SONO DIVERSE DA QUELLE IN SITI ROCCIOSI NATURALI?

## SINTESI

*Lo sviluppo urbano delle zone costiere contribuisce alla diminuzione della biodiversità. Dopo aver convalidato un metodo di censimento visivo assistito da un'esca, gli autori hanno verificato l'ipotesi generale che la struttura della comunità ittica subisca variazioni quando complessi habitat rocciosi naturali ed eterogenei vengono sostituiti da superfici solide verticali meno complesse. I descrittori tassonomici della comunità ittica di coste rocciose incontaminate sono stati confrontati con quelli ottenuti dal censimento su pareti di cemento e con quelli rilevati su scogliere rocciose naturali direttamente vicine a tali costruzioni. Le comunità ittiche differivano di poco tra i siti classificati secondo tre livelli di sviluppo, e le differenze esistenti non erano coerenti tra i siti all'interno dello stesso livello. Gli autori pertanto concludono che nell'Adriatico croato le costruzioni verticali in cemento su piccola scala non causano gravi disturbi nelle comunità ittiche in prossimità della costa.*

**Parole chiave:** comunità ittiche, esca censimento visivo, scogliere rocciose, costruzioni verticali, urbanizzazione, intensità di predazione

## INTRODUCTION

Urbanization of coastal areas adds artificial structures to the marine landscape (Clynick *et al.*, 2007; Bulleri & Chapman, 2010; Airolidi & Bulleri, 2011). Concrete walls within marinas and swimming enclosures are now common features of coastal environments (Chapman & Bulleri, 2003; Bulleri, 2005, 2006; Clynick *et al.*, 2008; Bulleri & Chapman, 2010; Di Franco *et al.*, 2011); however, there is insufficient knowledge of their ecological effects. A better understanding about their impact is necessary to support the integration of environmental protection into coastal management plans and to reduce the magnitude of human impact (Chapman & Bulleri, 2003; Bulleri & Chapman, 2004;

Bulleri, 2005; Bulleri *et al.*, 2005; Clynick *et al.*, 2007; Bulleri & Chapman, 2010; Airolidi & Bulleri, 2011; Di Franco *et al.*, 2011). Urban structures differ from natural environments in several ways. Man-made concrete walls are vertically aligned, hard surfaces that are less complex and heterogeneous than natural reefs (Clynick *et al.*, 2009). Although the existence of structure at all is enough for the recruitment of many fish species (Jenkins & Wheatley, 1998), seawall surfaces facilitate less microhabitat for colonization (Moschella *et al.*, 2005) and less refuges from predators, especially for larval fish (Kruger & Strydom, 2010). Concrete walls may not shelter viable fish population sizes (Clynick *et al.*, 2008) and steep walls in marinas may not function as fish nursery habitats due to the absence of shallow marginal water

**Tab. 1a: Locations with GPS coordinates and association with either (i) lure pre-experiment (effect of presence/absence of a lure on fish richness and abundance) or (ii) fish census to detect site difference in fish communities (natural sites vs. developed and adjacent sites).**

**Tab. 1a: Lokalitete z GPS koordinatami in oznaka, ali gre za (i) predposkus (vpliv prisotnosti/odsotnosti vabe na ribjo pestrost in abundanco) ali za (ii) opazovalni cenzus rib z namenom ugotavljanja razlik v ribji združbi med lokalitetami (naravna okolja proti razvitim oz. bližnjim okoljem).**

Coastal Location	Northing	Easting	Lure exper.	Site difference study			
				nat. site	adj. site	dev. site	cement wall usage
South of Prevlaka	42.40571	18.50647	no	yes	no	no	NA
<b>North of Prevlaka</b>	<b>42.40723</b>	<b>18.51299</b>	<b>no</b>	<b>no</b>	<b>yes</b>	<b>yes</b>	<b>as military structure</b>
<b>Cavtat</b>	<b>42.57954</b>	<b>18.21390</b>	<b>no</b>	<b>no</b>	<b>yes</b>	<b>yes</b>	<b>as hotel swimming area</b>
Slano	42.77285	17.88325	no	yes	no	no	NA
North of Slano	42.80302	17.84438	no	yes	no	no	NA
<b>Trogir</b>	<b>43.49894</b>	<b>16.21764</b>	<b>no</b>	<b>no</b>	<b>yes</b>	<b>yes</b>	<b>sheltering small boats</b>
<b>Murter</b>	<b>43.77535</b>	<b>15.63076</b>	<b>no</b>	<b>no</b>	<b>yes</b>	<b>yes</b>	<b>in small marina</b>
East of Tkon	43.90845	15.43872	yes	NA	NA	NA	NA
Tkon	43.90845	15.43872	no	yes	no	no	NA
U. Kablin	44.00628	15.26060	yes	yes	no	no	NA
Zdrelac	44.01490	15.25469	yes	NA	NA	NA	NA
Susina	44.02608	15.23367	yes	NA	NA	NA	NA
U. Lamjana Vela	44.03677	15.21466	yes	NA	NA	NA	NA
U. Koštanj	44.05000	15.23000	yes	NA	NA	NA	NA
Kolovare (Zadar)	44.10083	15.23977	yes	NA	NA	NA	NA
<b>Lukoran</b>	<b>44.10742</b>	<b>15.15363</b>	<b>no</b>	<b>no</b>	<b>yes</b>	<b>yes</b>	<b>in small marina</b>
U. Kobiljak	44.10895	15.10255	yes	yes	no	no	NA
Ceprljanda	44.12577	15.11704	yes	NA	NA	NA	NA
Borik	44.13160	15.20973	yes	NA	NA	NA	NA
<b>Muline</b>	<b>44.13468</b>	<b>15.06889</b>	<b>yes</b>	<b>NA</b>	<b>yes</b>	<b>yes</b>	<b>in small marina</b>
Sušica	44.14572	15.08266	yes	yes	NA	NA	NA
<b>Zaton</b>	<b>44.21875</b>	<b>15.16371</b>	<b>no</b>	<b>no</b>	<b>yes</b>	<b>yes</b>	<b>as breakwater</b>
Vinjerac	44.25873	15.46940	yes	NA	NA	NA	NA
North of Modrić	44.27020	15.52350	yes	NA	NA	NA	NA

(Kruger & Strydom, 2010). Fish populations at natural sites may be more productive than at artificial structures, as has been shown for limpets which are larger and produce more eggs on natural rocks compared to seawalls (Moreira *et al.*, 2006). Yet, adding artificial structures as new habitat may result in overall higher species richness within the area (Connell & Glasby, 1999) but may also provide habitats for invasive species as already discovered for rocky-bottom invertebrates (Vaselli *et al.*, 2008) and algae (Bulleri & Aioldi, 2005). Currently the general prediction seems to be that artificial structures do not constitute a surrogate for natural environments even though they may accommodate a similar suite of fish species as natural habitats (Rooker *et al.*, 1997). In some studies fish assemblages indeed differed across naturally rocky shores and seawalls (Clynick *et al.*, 2008 and therein, Sala *et al.*, 2012).

Our study compares fish communities in the shallow Croatian Adriatic Sea that are associated with three different levels of shoreline development. Pristine natural sites (at least 5 km distant from any developments) contain natural rocky-algal reefs (in the following the terms “natural” or “nat” are used) that feature a habitat sequence starting at the shore line with big boulders or bedrock-cliffs followed by smaller boulders, followed by sand and eventually seagrass beds (*Posidonia oceanica* or *Cymodocea nodosa*) and/or algal meadows on sediment. At sites with man-made concrete walls (in the following the terms “developed” or “dev” are used) rocky reefs were removed and replaced by more homogeneous and less complex vertical concrete walls e.g. within marinas or swimming enclosures (Tab. 1a and 1b) where *C. nodosa* is more likely to consolidate the neighboring sand than *P. oceanica*. Aside from these two extremes, natural sites and concrete-wall sites, we also investigated sites which lie adjacent (within 0.5 km) to concrete-development sites but feature the natural offshore sequence of habitats (in the following the terms “adjacent” or “adj” are used).

We tested the overall prediction that fish communities differ across sites with different levels of development: natural, developed, adjacent. Fish assemblages may vary with regard to the abundance of individual fish of each species, the total abundance of fish individuals and in taxonomic richness, diversity, and evenness. We also expected to see unique taxa at each type of site due to small-scale habitat preferences or behaviors. We structured our sampling scheme to test six null hypotheses:

1. There is no difference in the abundance of individual fish taxa or in total fish abundance;
2. There is no significant difference in taxonomic richness, diversity or evenness;
3. There are no species unique to each level of development;
4. Across levels of development relative habitat coverage and habitat richness do not differ;

5. Overall fish taxonomic richness is equal comparing seawalls with natural large rocky surfaces such as large boulders and bedrock cliffs;
6. Sites belonging to the same level of development will not cluster together based on the relative abundance of the observed taxa.

## MATERIALS AND METHODS

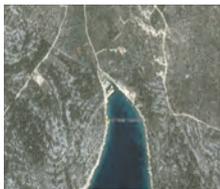
Before testing the null hypotheses, we tested the assumption that using a visual census assisted by a stationary lure results in observing more taxa and higher fish abundance than a lure-less census (Bohnsack & Bannerot, 1986; Kruschel & Schultz, 2010 a, 2010 b, 2012). The lure is a lead weight (2.5 cm long) with a double cone-shape and the largest diameter at its centre (0.75 cm). The lure was attached to a nylon fishing line.

Starting 1 m from the lure, 6 spherical lead weights with a diameter of 0.5 cm were placed in 1 m increments to allow for estimation of water depths to 7 m, the maximum depth investigated. For 50% of many replicate fish counts at each of 13 sites, one snorkeler placed the lure for 10 seconds and at 10 cm above the benthic substrate cover in the center of a 1 m<sup>2</sup> benthic area while a second snorkeler identified and counted all fish present at the benthic substrate and in the above water column for the time it took to place, present, and retrieve the lure.

The other 50% of fish counts were done without a lure but within independent 1 m<sup>2</sup> x water-depth volumes investigated for an equivalent amount of time as used for the lure assisted presentations. In both sets of observations experimental plots were selected systematically by swimming in a straight line from a random starting point while counting to 20 upon which the observer stopped. In case there was a barrier or the visibility was too low to see fish at the bottom the snorkeler randomly changed the direction and continued to count to 20 again until suitable conditions were found. We conducted the pre-experiment at a group of thirteen sites in the Zadar area (Tab. 1a). For each site we collected data on fish abundance and taxonomical richness from pooled presentations with and without a lure. Whether the application of a lure results in a difference in observed taxonomic richness and fish abundance, compared to the non-lure treatment, was tested with R (R Development Core Team 2012) with the non-parametric Wilcoxon rank sum test on untransformed response variables considering that at a large amount of experimental plots zero fish were detected for either method and that Wilcoxon does not assume normal distribution. We found a highly significant difference (Fig. 1) across the two methods in both fish abundance ( $p < 0.001$ ) and taxonomic richness ( $p < 0.001$ ). Based on these results, only the lure-assisted visual census was used to test all hypotheses in this study.

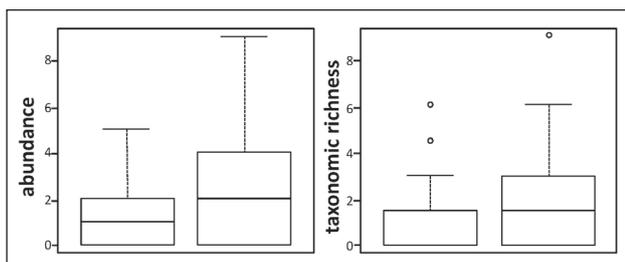
To study fish communities in response to shoreline-habitat differences, lure-assisted stationary visual-

**Tab. 1b: Locations names, GPS coordinates, description and illustration of the seven sites featuring cement walls (developed sites).****Tab. 1b: Lokalitete, GPS koordinate, opis in fotografije okolij z betonskimi stenami (razvita okolja).**

Location name	GPS position	Description	Google image
Zaton, near Zadar	44.218753 15.163708	Concrete wall not enclosing marina, breakwater	
Muline, Ugljan	44.134680 15.068890	Concrete wall enclosing small marina	
Lukoran, Ugljan	44.107420 15.153630	Concrete wall enclosing small marina	
Murter	43.775350 15.630760	Concrete wall enclosing small marine	
Trogir	43.498940 16.217640	Concrete wall enclosing a few small boats	
Cavtat	42.579540 18.213900	Concrete wall with swimming enclosure at Hotel	
North Prevlaka	42.407233 18.512992	Concrete structure for former military use	

census events were performed at 21 sites (Tab. 1a). We investigated seven developed (concrete wall) sites (116 census events, Tab. 1b), seven matching adjacent sites (less than 0.5 km away from concrete walls, 130 census events), and seven natural rocky shore sites (at

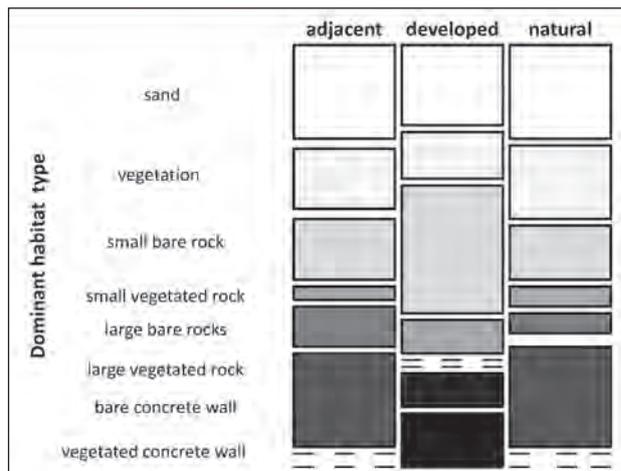
least 5 km away from any shoreline development, 117 census events). For each fish taxon, abundance was recorded to calculate total and relative abundances and taxonomic richness. Schools of fish were counted as one observation because individual fish within schools



**Fig. 1:** Boxplots showing the significant differences in fish abundance and taxonomic richness observed in the pre-experiment to test the hypothesis that lure-assisted stationary visual census is more powerful in detecting fish taxa and fish individuals within an observational area than lure-less stationary visual census. *Sl. 1:* Box-plot diagram prikazuje statistično značilne razlike v ribji abundanci in taksonomski pestrosti v predposkusu, s katerim so avtorji testirali hipotezo, da lahko z metodo opazovalnega cenusa z vabo popišemo večje število ribjih vrst in osebkov na opazovanem območju kot z metodo opazovalnega cenusa brez vabe.

do not constitute independent observations and should therefore not be used in a study of site preference. Disregarding the lack of independence of individuals in schools, e.g. of *Atherina* spp., *Chromis chromis*, *Oblada melanura*; can lead to the masking of differences in fish community structure across sites that are truly based on fish individual's choices of place.

A linear mixed-model expressed each response variable in reference to the three levels of shoreline development nested inside locations. A visual census event constituted the counting of all fish, except within schools, and the estimation of relative coverage for each habitat type within a square meter above the sea bottom and within the water column above with a lure placed 10 cm above the benthic cover in the center of the resulting water volume (1 m<sup>2</sup> x water depth, maximum depth 7 m) for 30 seconds. Selection of experimental plots was again random. The lure was identical to the one used in the pre-experiment. One snorkeler placed the lure for 30 seconds of bottom time while a second snorkeler (always JH) identified and counted all fish present on the benthic substrate and in the above water column exclusively during the bottom time of the lure but not during the placement and retrieval time. Depth and relative benthic habitat cover was recorded afterwards (by JH). Unidentified fish and juvenile fish were not taken into account as taxa, thus not contributing to derived richness, diversity and evenness, except if only juvenile fish and/or if only unidentified fish had been observed. Fish identified to the genus level only (*Gobius*, *Parablennius*, *Symphodus*) were recognized as taxa (contributing to derived richness, diversity, and evenness) only if no



**Fig. 2:** Proportions of habitat groups in different levels of development (adj = adjacent, dev = developed, nat = natural).

*Sl. 2:* Deleži skupin habitatov v različnih stopnjah razvoja (adj = bližnji, dev = razviti, nat = naravni).

species-level observations within the same genera were made. However, all fish contributed to the total fish abundance.

Rank abundance for each species-level taxon was calculated for natural, adjacent, developed samples using the R (R Development Core Team, 2012) packages BiodiversityR and vegan. These packages also were used to assemble a cluster dendrogram with Bray distances for taxa across all sites categorized by their level of development.

Total taxonomic richness, Shannon's diversity index, and evenness were calculated by hand in an Excel spreadsheet for each level of development according to Camargo (1995). Unique taxa were defined as taxa that were not observed at every level of development, but may have been observed at one or two level(s) of development. Observed abundance and taxonomic richness were calculated for each lure presentation. Using R (R Development Core Team, 2012), statistical analysis had been performed via ANOVA with residuals of a linear mixed-effect model for the Poisson distribution to adjust to the non-normal response variables (due to frequent zero values) abundance and taxonomic richness. The linear mixed-effect model expressed the response variable in reference to the level of development, nested inside the sites categorized by their level of development, assuming all individual lure-presentations were independent replicate experiments. The difference deviance ( $\chi^2$ ), degrees of freedom and probability are reported in the results.

For each experimental plot all present dominant habitat groups had been recorded (Fig. 2). Using R (R

Development Core Team, 2012), the statistical tests were carried out as described above for fish taxa richness and abundance. If tested as significant a post hoc test, a pairwise t-test with Bonferroni corrections, compared each dominant habitat group pair. In R (R Development Core Team, 2012) a cross-table was created because both predictor and response variables (level of development and dominant habitat group) are categorical variables. Fisher's exact test for count data was carried out to test if the presence and relative abundance of dominant habitat groups are influenced by the level of development.

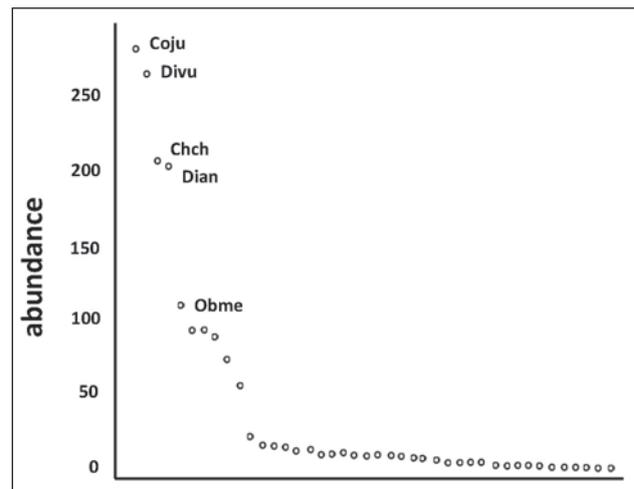
For each experimental plot habitat richness had been calculated. Two-sided Spearman's rank correlation had been used for testing the correlation across habitat richness and taxonomic richness in R (R Development Core Team, 2012), and the probabilities are reported in the results. Subsequently it was tested with the help of R (R Development Core Team, 2012), whether there is a significant difference in habitat richness due to the levels of development. Habitat richness had been transformed via boxcox transformation. The transformed data was tested on normal distribution by Shapiro-Wilk normality test and non-parametric Kruskal-Wallis rank sum test was applied. The difference deviance ( $\chi^2$ ), degrees of freedom and probability are reported in the results.

**RESULTS**

**Hypothesis 1:** There is no difference in the abundance of individual fish taxa or in total fish abundance across the three levels of shoreline development.

Total abundances were not significantly different across levels of development ( $\chi^2 = 3.0$ , Df = 2, p = 0.22). Across all sites four of the five most abundant species, *C. chromis*, *C. julis*, *D. annularis* and *D. vulgaris* were shared across all three levels of development (Tab. 2a). The four shared species were overall 100 to 250 times more abundant than most other species across all 21 investigated sites (Fig. 3).

The relative abundance of the four most abundant species are presented in Table 2b. While *C. julis* is clearly (3.9 x) most abundant in adjacent sites, *D. annularis* is



**Fig. 3:** Rank abundance for taxa pooled over all sites. For abbreviations and full species names see Tab. 4. **Sl. 3:** Rangi abundanc taksonov, združenih za vse lokalitete. Za okrajšave in polna imena rib glej Tab. 4.

most abundant (2.7 x) at developed sites. *C. chromis* and *D. vulgaris* are more evenly distributed across the developed and adjacent sites than the species above but are also least abundant in natural sites.

**Hypothesis 2:** There is no significant difference in taxonomic richness, diversity or evenness.

As predicted, no significant differences in taxonomic richness, diversity or evenness have been detected (Tab. 3).

**Hypothesis 3:** There are no species unique to each level of development.

Across the 21 sites 49 species and two higher taxa (unidentified species within two families) have been observed (see Tab. 4) and identified. Only five species were unique to one of the levels of development and another nine species were absent at one of the levels of development. The level of uniqueness across levels of

**Tab. 2a:** Rank abundances (relative abundance) for the 5 most common taxa at each of the three levels of development.

**Tab. 2a:** Rangi abundanca (relativna abundanca) za 5 najbolj pogostih taksonov rib glede na tri stopnje razvoja (naravno, bližnje in razvito okolje).

Rank	Natural		Adjacent		Developed	
1	<i>Diplodus vulgaris</i>	0.30	<i>C. julis</i>	0.42	<i>D. annularis</i>	0.29
2	<i>Chromis chromis</i>	0.20	<i>C. chromis</i>	0.19	<i>D. vulgaris</i>	0.26
3	<i>Coris julis</i>	0.19	<i>D. vulgaris</i>	0.19	<i>C. chromis</i>	0.18
4	<i>Diplodus annularis</i>	0.18	<i>Atherina</i> spp.	0.10	<i>Symphodus ocellatus</i>	0.15
5	<i>Gobius bucchichi</i>	0.13	<i>D. annularis</i>	0.10	<i>C. julis</i>	0.12

**Tab. 2b: Ranking of the relative abundances of the four most abundant species according to site developmental status.****Tab. 2b: Rangji abundance (relativna abundanca) za 4 najbolj pogoste vrste rib glede na tri stopnje razvoja (nat - naravno, adj - bližnje in dev - razvito okolje).**

Rank		<i>Coris julis</i>		<i>Diplodus vulgaris</i>		<i>Diplodus annularis</i>		<i>Chromis chromis</i>
1	adj	0.66	dev	0.32	dev	0.57	dev	0.35
2	dev	0.18	adj	0.41	adj	0.21	adj	0.41
3	nat	0.16	nat	0.28	nat	0.22	nat	0.24

development was low, 73% of the observed taxa have been found within all levels of development.

**Hypothesis 4:** Across levels of development relative habitat coverage and habitat richness do not differ.

All levels of development supported six major habitat types (Fig. 1). Adjacent and natural sites feature a natural sequence of spatial distribution of the basic habitats within the investigated depth range (max. 7 m) over a larger area than at developed sites. This is because the removal of the reefs to make room for concrete walls necessitates the shortening of the littoral and sublittoral zone and all habitats investigated, large rock surfaces, small rock surfaces, vegetated sands and bare sands are confined within a more or less shorter distance from the shore.

The main and default difference in terms of presence/absence of habitats is that large boulders, bare and vegetated, are completely replaced by concrete walls, bare and vegetated, in developed sites. The total proportion of large rock-surfaces (larger than diver's body size) is about 1/3 less in developed sites than at natural and adjacent sites. Another trend is that at developed sites 1/3 of the vegetated rock surfaces are contributed by small vegetated rocks, exclusively covered in turf algae, while this proportion of small vegetated rocks is 1/6 in adjacent sites and only 1/9 at natural sites. Most of the rock-based vegetation in natural and adjacent sites is located on larger boulders and much of it supports canopy vegetation, like *Cystoseira* sp., a trend stronger in natural than adjacent sites. Another trend is that developed sites

have the highest proportion of small bare rocks on the expense of vegetated and bare sediments. Overall we can conclude that: 1. tall dense vegetation on rocks is most abundant in natural, less in adjacent and substantially less in developed sites, 2. small turf-algae covered rocks and also small bare rocks are most common in developed sites and least common in natural sites, 3. vegetation on sediment is most abundant in natural sites, less in adjacent sites and least in developed sites, 4. in the benthic zone between shoreline and 7 m depth, bare sediments are most abundant in adjacent sites, less in natural sites and least in developed sites (Fig. 2).

**Hypothesis 5:** Considering all sites sampled fish taxonomic richness is equal at seawalls and natural large and small rocky surfaces.

The proportions of dominant habitats in every level of development are illustrated in Figure 2, while Figure 4 shows the significant differences in taxonomic fish richness ( $\chi^2 = 21.3$ , Df = 7,  $p = 0.003$ ) across levels of development and main habitats. In detail, large vegetated rocks are less species rich than bare concrete walls ( $p = 0.023$ ) and small vegetated rocks are less species rich than vegetated concrete walls ( $p = 0.025$ ), small bare rocks and large vegetated rocks are more species rich than small vegetated rocks ( $p = 0.032$  and  $p = 0.004$ ). Small bare rocks are less species rich than vegetation ( $p = 0.043$ ). Fisher's exact test for count data showed that the probability of observing dominant habitat groups is not influenced by the level of development equals  $p < 0.001$ .

**Tab. 3: Taxonomic richness, Shannon's diversity index, evenness and the effective number of species (richness) at each of the three levels of development.****Tab. 3: Taksonomska pestrost, Shannonov diverzitetni indeks, indeks enakomernosti porazdelitve in efektivno število vrst (pestrost) na vsaki razvojni stopnji.**

Level of development	Richness	Diversity	Evenness	Effective richness
natural	32	2.59	0.75	13
adjacent	34	2.43	0.69	11
developed	35	2.67	0.75	14

**Tab. 4:** Listed are all taxa that have been detected within this study and if they are unique for one or two levels of development.

**Tab. 4:** Popis ugotovljenih vrst v raziskavi in njihova opredelitev, ali se pojavljajo v enem ali na dveh nivojih razvoja (DEV - razvito, ADJ – bližnje in NAT - naravno).

<b>Apogonidae</b> Apim - <i>Apogon imberbis</i> (ADJ, DEV)	<b>Gobiidae</b> Gobu - <i>Gobius bucchichi</i>	<b>Muraenidae</b> Muhe - <i>Muraena helena</i> (NAT)
<b>Atherinidae</b> Atbo - <i>Atherina</i> spp.	Goco - <i>Gobius cobitis</i>	<b>Pomacentridae</b> Chch - <i>Chromis chromis</i>
<b>Belonidae</b> Bebe - <i>Belone belone</i>	Goge - <i>Gobius geniporus</i> (DEV, NAT) Goni - <i>Gobius niger</i> (DEV)	<b>Scorpaenidae</b> Scno - <i>Scorpaena notata</i> (ADJ, DEV)
<b>Blennidae</b> Sapa - <i>Salaria pavo</i> (ADJ) Pain - <i>Parablennius incognitus</i> Paga - <i>Parablennius gattorugine</i> (ADJ, DEV) Paro - <i>Parablennius rouxi</i> Pasa - <i>Parablennius sanguinolentus</i> (ADJ, DEV) Pate - <i>Parablennius tentacularis</i>	Poma - <i>Pomatoschistus marmoratus</i> (NAT)	<b>Serranidae</b> Seca - <i>Serranus cabrilla</i> Sehe - <i>Serranus hepatus</i> Sesc - <i>Serranus scriba</i>
<b>Bothidae</b> Bopo - <i>Bothus podas</i> (ADJ, DEV)	<b>Labridae</b> Coju - <i>Coris julis</i> Lavi - <i>Labrus viridis</i> (ADJ) Syci - <i>Symphodus cinereus</i> Sydo - <i>Symphodus doderleini</i> Symed - <i>Symphodus mediterraneus</i> Symela - <i>Symphodus melanocercus</i> Syoc - <i>Symphodus ocellatus</i> Syroi - <i>Symphodus roissali</i> Syros - <i>Symphodus rostratus</i>	<b>Sparidae</b> Bobo - <i>Boops boops</i> Dian - <i>Diplodus annularis</i> Dipu - <i>Diplodus puntazzo</i> Disa - <i>Diplodus sargus</i> Divu - <i>Diplodus vulgaris</i> Limo - <i>Lithognathus mormyrus</i> (DEV, NAT) Obme - <i>Oblada melanura</i> Sasa - <i>Sarpa salpa</i> Syte - <i>Syngnathus</i> sp. Syty - <i>Syngnathus typhle</i>
<b>Callionymidae</b> Capu - <i>Callionymus pusillus</i>		
<b>Centracanthidae</b> Spma - <i>Spicara maena</i> Spsm - <i>Spicara smaris</i> (NAT, ADJ)	Syti - <i>Symphodus tinca</i> Thpa - <i>Thalassoma pavo</i>	
	<b>Mugilidae (unidentified)</b>	
	<b>Mullidae</b> Muba - <i>Mullus barbatus</i> Musu - <i>Mullus surmuletus</i> (DEV, NAT)	<b>Trachinidae</b> Trdr - <i>Trachinus draco</i>
		<b>Tripterygiidae (unidentified)</b>

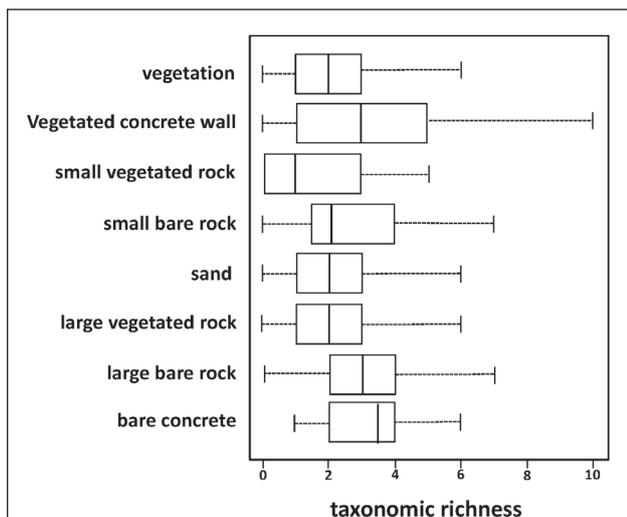
**Hypothesis 6:** Sites belonging to the same level of development will not cluster together based on the relative abundance of the observed species.

Sampling sites do not consistently cluster according to their association with one of the three developmental levels (Fig. 5). Neither do they consistently cluster by geographical closeness. Sites that are by definition geographically very close, as are developed and adjacent sites, show no clear pattern of similarity. Some adjacent/developed site-pairs are very far apart in the dendrogram, examples are adjacent and developed sites within locations Zaton and Trogir. Others are as close as predicted in Bray distance, like within the location Muline (for geographical position of all locations see Tab. 1a). Natu-

ral sites are not consistently clustering by geographical distance either. Natural sites in Slano and at U. Kobiljak are hundreds of kilometers of coastline apart but close in Bray distance, while natural sites in Tkon and U. Kablin which are both on the Island of Pašman are not close in Bray distance (Tab. 1a and Fig. 5).

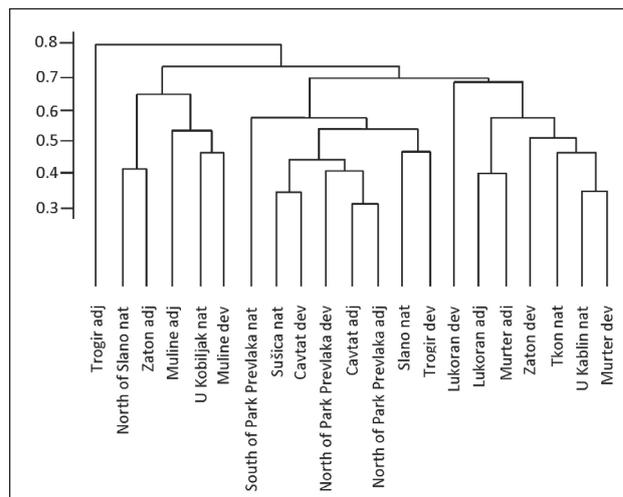
## DISCUSSION

We did not detect significant differences in total fish abundance across sites of different development levels. Four species were significantly more abundant than any of the other taxa. A rank abundance curve (Fig. 2) shows that the total combined abundance of these four spe-



**Fig. 4: Fish taxonomic richness within major habitat types pooled across the 21 sites investigated.**  
**Sl. 4: Taksonomska pestrost rib v glavnih habitatnih tipih, združenih v 21 raziskanih lokalitetah.**

cies exceeded 900 individuals while the total combined abundance of the remaining species was lower than 700 individuals. Of these four species, *D. annularis*, *D. vulgaris* and *C. julis* are very mobile fish and known to be aggressive mesopredators (Kruschel & Schultz, 2012) while the fourth, *C. chromis*, is a schooling planktivore known to aggregate, when in the shallow waters, over transitions between rocks and sediments (Guidetti, 2000). We did discover differences in the relative abundance across developmental levels for these species. *C. julis* dominates rocky shores adjacent to developments where it is 3.9 times more abundant than in pristine and developed sites. As a wait-chase predator it may prefer the more frequent transitions from complex (vegetated rocks, vegetation) to more open habitats (bare rocks, sand) of which the adjacent sites offer more than the other two levels of development (Fig. 2). *D. annularis* is 2.7 times more abundant at developed than at natural sites. This seems surprising since developed sites offer less vegetation, especially *P. oceanica*. However, seawalls sharply border sediments, bare or vegetated, often covered with the seagrass *C. nodosa* and neighboring rocks are small. This combination should be attractive to *D. annularis*, a species attracted to vegetation and sand but rarely seen on complex rocky-reef bottoms (Bauchot & Hureau, 1990; Macpherson, 1994; Froese & Pauly, 2012). *D. vulgaris* is also more abundant at developed sites than natural sites, indicating that seawalls probably resemble rocky cliffs and larger boulder surfaces sufficiently to attract this species and may offer less competition with the ecologically similar *D. puntazzo* and *D. sargus*, which are generally in popula-



**Fig. 5: Dendrogram of taxonomical communities at the sampled sites based on pairwise Bray distances.**  
**Sl. 5: Dendrogram taksonomskih združb na raziskanih lokalitetah na temelju parnih Brayevih razdalj.**

tion decline, especially in developed areas with higher local fishing pressure. According to Sala and Ballesteros (1997) the three rocky-reef *Diplodus* species are known to coexist in pristine sites by differential habitat and depth preferences (*D. vulgaris* and *D. sargus*) but also by differential prey use within the same habitats and depths (*D. vulgaris* and *D. puntazzo*). It is likely that the decline of *D. sargus* and *D. puntazzo* due to overfishing has released *D. vulgaris* from its competitive restrictions. Likewise, *C. chromis* may prefer developed and adjacent sites because of the lower abundance of large piscivorous fish in heavier fished areas. Another reason for increased *C. chromis* in developed sites may be the greater availability of particulate organic matter (POM) in the water column, including plankton and anthropogenic particles, e.g. from sewage and run-off, which is typical for areas with higher human population densities (Guidetti et al., 2002).

We found no significant differences in taxonomic richness, diversity or evenness across sites of different developmental level. Two obvious observations support this homogeneity across sites - they are all dominated by the same four species, resulting in similarly low evenness and very few species are unique to a particular level of development. Almost all species are everywhere but in similarly low numbers, resulting in similar species richness and number of effective species. The overwhelming dominance by four species at all sites may indicate that natural sites are similarly degraded as developed sites by factors other than development so that some taxa have effectively been excluded while a few other species dominate all sites. Another reason for a relatively similar suite of taxa could be the negative

method bias against observing cryptic and epibenthic species such as Gobiidae, Blenniidae and Tryterigiidae (Lipej & Orlando-Bonaca, 2006; Kovačić *et al.*, 2012) in dense vegetation on rocks, of which there is more available in natural than in developed sites.

Increasing dominance of small predators may be due to favourable habitat changes or because of predator/competitor release and the associated trophic cascades. Trophic cascades have been extensively studied in tropical reefs with varying conclusions, e.g. Casey *et al.* (2017) found no evidence for it in the very complex Great Barrier Reef context, while Stier *et al.* (2017) found that overall abundance of taxa and the alpha diversity were reduced as a result of top-predator loss and mesopredator release, although beta diversity remained unchanged. A recent publication by Nagelkerken *et al.* (2017) clearly shows that the collapse of large predator populations combined with resource enrichment can foster behavioural changes in already common mesopredators towards more aggressive risk-taking, eventually resulting in a clear dominance by such taxa and an associated loss of biodiversity in the community. In short, predator loss and associated widespread disruptions of 'normal' species interactions significantly reduces biodiversity. The possibility of such complex scenarios has gotten less attention in the Mediterranean/Adriatic. We suspect that the three highly dominant mesopredators in our study, *C. julis*, *D. vulgaris* and *D. annularis*, may indicate a similar top-down/eutrophication mediated change in community structure in the Croatian Adriatic infralittoral belt.

Yet, fish assemblages across developmental levels were not identical, 10% of the 52 identified taxa were unique to one level of development and another 17% avoided one level of development. However, 62% of all species contributed less than 10 individuals across all sites (Fig. 2) so we must consider that detectability of all of these species is low and that total lack of observation for any one species may indicate a general under-sampling, especially considering the relatively small overall area sampled. In general stationary lure methods are positively biased towards any mobile predators and negatively biased against any sedentary fish whereas mobile lure-methods do not have that bias (Murphy & Jenkins, 2010; Kruschel & Schultz, 2010 b). Every fish-census method, including all visual ones, is biased. There is intrinsic bias because of fish traits (size, colour, behaviour) especially in the context of habitat traits (complexity, color). Extrinsic bias is due to method specifics (Edgar *et al.*, 2004; Lowry *et al.*, 2012; Kruschel & Schultz, 2012). Guidetti *et al.* (2005) compared stationary and strip-transect visual-census methods at breakwaters and concluded that in very heterogeneous habitats or at discrete structures such as seawalls and artificial reefs, point methods are more feasible. Harmelin Vivien *et al.* (1985) and Bohnsack & Bannerot (1986) concur with this preference. We generally agree

with this view but recommend fish counts along short and random mobile lure-assisted transects (3-5 m) over stationary counts, because the former allow for a larger number of random and independent samples than the latter. Mobile short lure transects are less likely to result in errors due to species interferences and double counts, typical for the stationary counts. At the same time short mobile lure-transects allow the monitoring of behavioral differences e.g. in aggressivity, predation mode, and dominance. Random and short mobile lure-transects can be applied equally in homogeneous habitat patches and in heterogeneous habitat mosaics and within discrete areas (less than 100m) or across large sampling sites (> 1000 m) (Kruschel & Schultz, 2012).

We found a few significant differences in the relative proportions across the six main shared habitat types and some obvious trends across development levels (Fig. 2). All the main structural components are represented in all levels of development – large vegetated and bare rock surfaces, small vegetated and bare rock surfaces, vegetation on sand, and bare sand. The most significant proportional differences between developed sites and adjacent/natural sites are due to the removal of the rocky reef by seawalls and the associated shortening of the investigated littoral slope between the shoreline and 7 m depth. However, we also found differences between adjacent and natural sites. Adjacent sites harbor lower proportions of canopy vegetation as they have less large algae attached to rocks and boulders and less vegetation, algae and seagrass, anchored in sand. This difference between adjacent and pristine natural sites may be due to two major stressors in developed areas – higher incident of urchin barrens and low water clarity due to pollution and sediment mobilization at developed shores. In the scope of an extensive and long term visual-census throughout the Croatian Adriatic, we have observed urchin barrens everywhere at developed and pristine natural sites but we see an association with areas of high fishing pressure causing a lack of urchin predation due to declining abundances of predators, e.g. *D. sargus*, *D. putazzo*, *Sparus aurata* (Guidetti & Dulčić, 2007; Rustici *et al.*, 2017 and therein). Another trigger of urchin barrens seems to be nutrient pollution, probably due to the changes in algal composition from slow growing brown algae, e.g. *Cystoseira* species, to opportunistic fast growing algae, e.g. green algae, which may be more efficiently digested by urchins (Piazzi & Ceccherelli, 2017 and therein). Both stressors, overfishing and nutrient rich waste water are higher in developed than in pristine locations.

Fish species richness did differ across main habitat types: large vegetated boulders had significantly fewer species than bare seawalls but did not differ in species richness from vegetated seawalls (Fig. 4). Considering that canopy vegetation on rock is the preferred habitat of various cryptobenthic fish, a more detailed study addressing the difficulties of counting cryptobenthic

species within vegetation in a regular visual census should be considered to further test this hypothesis but we would recommend benign methods which are non-destructive to the habitat and non-consumptive to the fishes (Orlando-Bonaca & Lipej, 2007; Kovačić et al., 2012).

Overall, fish community structure based on relative abundances of all species differed very little between sites across three levels of development, and existing differences were not consistent across all sites. We also found no evidence that latitude (*contra* Guidetti & Dulčić, 2007) or smaller-scale geographical distances cause consistent similarity patterns. One reason for the lack of consistent and obvious differences between the extremes – pristine natural vs. seawall sites could be related to the fact that different communities can be observed at sheltered vs. wave exposed sides of seawalls. The landward, sheltered, seawall-side attracts different communities, including invasive species (Guidetti, 2004; Bulleri & Airoldi, 2005; Vaselli et al., 2008). The communities of the seaward and exposed side of a seawall are more similar to natural reefs than at the landward side with significantly more *D. vulgaris* and less *C. chromis* and *Oblada melanura* (Clynick, 2006; Pizzolon et al., 2007). A multitude of yet not investigated factors, including fishing intensity, natural predation intensities and other biological interactions, as well as details in habitat composition are possible candidates to interact, positively or negatively, with development-level effects. In this study we casually observed that the occurrence and abundance of planktivorous fish, e.g. *C. chromis* and *Atherina* sp. strongly varied with wave exposure and the presence of particulate organic matter at seawall sites, while the presence of fisherman discarding fish offal into the water at developed sites caused unusually high abundances of cruising predators and substrate-dwelling fish. These observations offer direct explanations why spatially close sites such as developed and adjacent sites may be unexpectedly dissimilar or too similar. The adjacent and developed (concrete wall) sites of North Prevlaka were similar most likely due to the unusual and widespread accumulation of POM, while the adjacent and developed sites of Lukoran were distinct from each

other, most likely due to regular offal feedings as a point source pollution at the seawall site only.

## CONCLUSIONS

Using a stationary lure results in observing higher fish abundance and taxonomic richness compared to the non-lure treatment, a result that corroborates the reports from previous mobile lure-assisted studies. We discovered little evidence that natural, adjacent and developed sites support different fish communities, instead there was variability within all levels. We have reason to believe, that without gathering information about the quality and quantity of many other variables at each site, true differences in fish communities due to the level of development may remain masked. We also suggest to use a long-term monitoring approach to address hypotheses related to the impact of urbanization. Nevertheless, our study does not indicate that lightly developed sites typical of the Croatian Adriatic are obviously less likely to support typical Adriatic fish communities than more natural sites. 73% of the 52 taxa observed within this relatively small scale study were present at all investigated sites, but in low numbers. We suspect that overall fish communities become lower in evenness as top predatory fish taxa decline, which allows smaller and already widespread common mesopredators to dominate and become more aggressive. This predation/competition release and associated mesopredator increase in relative abundance is likely to have far reaching top-down effects on the entire community. To understand this and other region-wide declines, the interplay between fishing pressure, habitat changes, eutrophication and interrupted species-interactions needs to be better understood in the Croatian Adriatic. Overall we conclude that the typically small scale concrete wall developments embedded into expansive undeveloped shorelines, as targeted in this study, do not directly cause major disruptions of natural near-shore fish assemblages. They can instead provide additional structure that constitutes fish habitats and their presence is, according to our study, not associated with a general local decline of fish richness in their immediate surrounding.

## ALI SE RIBJE ZDRUŽBE NA LOKALITETAH Z BETONSKIMI STENAMI RAZLIKUJEJO OD TISTIH V NARAVNEM SKALNATEM OKOLJU?

*Claudia KRUSCHEL & Julia HARRAS*

University of Zadar, Department of Ecology, Agronomy and Aquaculture &  
CIMMAR – Center for Interdisciplinary Marine and Maritime Research, 23000 Zadar, Croatia  
e-mail: ckrusche@unizd.hr

*Irmgard BLINDOW*

Biological Station Hiddensee, Ernst-Moritz Arndt University Greifswald, Biologienweg 15, 18565 Kloster/Hiddensee, Germany

*Stewart T. SCHULTZ*

University of Zadar, Department of Ecology, Agronomy and Aquaculture &  
CIMMAR – Center for Interdisciplinary Marine and Maritime Research, 23000 Zadar, Croatia

### POVZETEK

*Urbani razvoj zmanjšuje biodiverzitetu. Po ovrednotenju opazovalnih metod z uporabo vabe smo nadaljevali s testiranjem hipoteze, da se struktura ribje združbe spremeni, ko naravno in raznoliko skalnato okolje nadomestijo manj kompleksne navpične trdne površine. Taksonomske ribje kazalce, pridobljene z naravnega skalnatega okolja, smo primerjali s tistimi iz okolja betonskih sten ter naravnimi skalnatimi okolji, ki mejijo na razvojno spremembo. Ribje združbe so se med lokalitetami s tremi različnimi fazami razvoja le malo razlikovale, poleg tega pa te razlike niso bile ugotovljene na vseh lokalitetah. Avtorji menijo, da v hrvaškem delu Jadrana značilne navpične betonske stene manjših razsežnosti ne povzročajo večjih motenj v obrežnih ribjih združbah.*

**Ključne besede:** ribja združba, opazovalni census z uporabo vabe, skalnato dno, betonske stene, urbanizacija, plenilski vpliv

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