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Use of a lure in visual census significantly improves probability of detecting wait-ambushing and fast cruising predatory fish

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ABSTRACT

A lure assisted, visual census, belt transect method has been developed and compared with the traditional visual census. Presentation of a lure was predicted to improve visibility of fish that are difficult to detect or identify. These include species hidden within three dimensional structures, buried in or camouflaged with the substratum, and fast swimming. A snorkeler presenting an artificial lure near the seabed along 3-m transects recorded all fish visiting the lure or present near the lure's path. Totals of 1527 lure-assisted transects and 1292 lure-absent transects intersecting a diversity of benthic habitats were carried out at thirty sites spanning the Croatian Adriatic coast in spring 2010. More than half the observed fish visited the lure, and lure presentations increased the probability of census for 76% of the 58 observed taxa. The overall significantly higher fish density at lure-assisted transects than at lure-absent transects was also significant within all common habitat types and for the entire investigated depth range ($0.25_A = 9m$). The positive effect of the lure on estimates of density was significant for 33% of taxa, including: ambush predators (*Trachinus draco*), fast moving cruise-chase predators (Sparidae), predators chasing prey from a hidden waiting position (*Coris julis* and Serranidae) or from a position of camouflaging against bare sand (Gobiidae). Adding lure presentation to regular visual census is logistically simple and flexible in the detail of its design and application.

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14 **1. Introduction**

Visual census belt transects have become a standard method for 15 quantifying the shallow benthos accessible to SCUBA or snorkeling. 16 In this method, swimmers obtain species-specific faunal densities 17 by passive visual observation of individuals present within a linear 18 belt two metres wide (Horinouchi et al., 2005). Several important 19 **O2** advantages over alternative methods have been discussed. Visual 20 census (1) is non-destructive to habitat and fauna alike (Kimmel, 21 1985), (2) can be used with DGPS navigation to eliminate inter-22 ference by physical transect marking (Schultz et al., 2009), (3) can 23 be used to compare fauna across diverse intersecting habitats, (4) 24 allows observation at small spatial scales, (5) permits simultaneous 25 video monitoring and quantification of habitat (Schultz, 2008), and 26 (6) permits recording of the habitat match at the instant an animal is observed (Schultz et al., 2009).

A survey of recently published Mediterranean visual census studies that simultaneously sampled a variety of habitats (*Posidonia*, rocks, algae, bare sediments), and for which taxon specific density data were available (Table 1), confirms that two

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functional groups generally dominate visual census belt transects: slow-moving substratum-dwelling carnivores and herbivores, and pelagic plankton-feeders (Mazzoldi and De Girolamo, 1998; Gordoa et al., 2000; Frau et al., 2003; Letourneur et al., 2003; Bonaca and Lipej, 2005). Conversely, three functional groups are rare: ambush predators, fast swimming predators (cruise-chase), and predators attacking from a hidden benthic waiting position (wait-chase). Several comparative studies have indicated that this dominance of certain species is due in part to biases inherent in the visual census method. It is proposed that this bias acts in favour of species that are visually conspicuous due e.g. to slow movement, conspicuous coloration, or lack of concealment.

For example, comparisons of visual census belt transect counts with those from quantitative sampling using rotenone have shown that abundance of small cryptobenthic microcarnivores is chronically underestimated when relying on vision alone (Brock, 1982). Lincoln Smith (1988) cautions about bias in detection due to species-specific differences in motility and size (e.g. very small sedentary fish and larger fast swimmers vs slow schoolers), and McCormick and Choat (1987) discuss the effect on the visibility of target species of behavioural interactions between fish and benthic structural complexity. In a study designed to quantify such biases, Harmelin-Vivien and Francour (1992) found that trawls successfully detected fish hidden within *Posidonia* seagrass structure, primarily ambush predators (e.g. Blenniidae, Bothidae, Gobiidae,

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Table 1

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Q3 Relative abundances (%) of feeding mode functional groups calculated from taxa specific data in five published Mediterranean visual census belt transect studies.

| Feeding mode grouping | | Mazzoldi et <mark>al. (1997)</mark> | Guidetti et al. (2000) | Letourneur et al. (2003) | Frau et al. (2003) | Bonaca and Lipej (2005) |
|-----------------------------------|------------|-------------------------------------|------------------------|--------------------------|--------------------|-------------------------|
| Benthic carnivores Mode | Prey size | | | | | |
| Ambush | Macro/meso | 0.2 | 1.0 | 1.4 | 2.9 | 2.4 |
| Wait-chase | Macro/meso | 0.6 | 1.5 | 1.6 | 4.0 | 3.9 |
| Cruise-chase | Macro/meso | 0.9 | 1.9 | 4.1 | 23.0 | 7.1 |
| Ambush | Micro | 14.2 | 2.7 | 0.7 | 4.3 | 11.9 |
| Substrate dwelling | Meso | 14.9 | 30.2 | 11.8 | 34.7 | 46.2 |
| Coris julis | | 2.9 | 13.1 | 27.0 | 19.8 | 0 |
| Herbi-/plankti-/detritivores | | 66.3 | 49.6 | 53.4 | 11.3 | 28.5 |

Scorpaenidae, Syngnathidae), but was poor in detecting fish above the seagrass canopy (mostly Sparidae), while the opposite was true for visual census. Harmelin-Vivien and Francour (1992) further found that the two methods were similar in their suitability for sampling slow swimming canopy dwelling fish and pelagic schooling planktivores, which together amounted to between 73% and 89% of the total trawl catch and 87,-98% of the total visual counts.

Studies using baits or lures indicate that their presentation can increase the probability of detecting the three underestimated groups that vary in their predation mode: cruise-chase, ambush, and wait-chase predators. Predation mode can be identified by prey search and prey approach behaviour. Cruise-chase predators search and approach by relatively fast swimming. Wait-chase predators search passively but approach by a chase resulting in relocation, while ambush predators search passively and approach with a single attack without relocation. Stationary visual census of fish assemblages using baited cameras in the shallow benthos of Mediterranean rocky reefs resulted in higher counts of cruise-chase predators as compared to surface dwelling predators, while ambush predator density remained low (Stobart et al., 2007). Schultz and Kruschel (2010) showed for a Mediterranean Zostera bed that the visibility and detectability of the ambush predator Zosterisessor ophiocephalus was positively affected by mobile bait presentation. Cardona et al. (2007), simultaneously conducting mobile experimental fishing and mobile visual census in Mediterranean Posidonia seagrass, found that a third of the visually detected taxa could be hooked, but that the majority of fish hooked (98%) were wait-chase and cruise-chase predators, these being two of the groups that are rare in visual census studies (Table 1).

We propose that presentation of a lure during visual census increases the probability of detection and census of the above three under-represented functional groups. On the other hand, the method may not increase the probability of detecting microcryptobenthic predators without additional aids such as ichthyocide application, very low transect speeds (Lincoln Smith, 1989), and manual manipulation of the substratum during the search (Beldade and Goncalves, 2007).

We predict that lure presentation elicits behaviour that increases fish visibility in two ways: (1) fish that are passive and concealed by being buried, being within a three dimensional structure, or being camouflaged are enticed out of hiding to approach and engage the lure and (2) fish that normally swim too fast for observation and identification are diverted by the lure, which slows them down and allows easier census as they approach and engage with it.

We carried out lure-assisted and lure-absent visual censuses along belt transects in locations spanning the Croatian coastline in diverse habitats, including rock, rocky-algal, bare sediment, and sediments supported by algae or seagrass. We sought answers to the following questions: (1) Does use of a lure increase the number of detected and identified fish species per transect metre?, (2) Does the use of a lure increase the relative estimated abundance of three distinct functional macro-and mesopredator groups: ambushers, cruise-chasers, and wait-chasers?, (3) Does the use of a lure have little or no effect on estimated abundance of demersal fish belonging to other functional groups, including: substratum dwelling mesopredators, ambush micropredators, herbivores, and pelagic planktivores?, (4) Does the use of a lure result in different estimated relative abundances of individual taxa, resulting in alternative perceptions of fish community structure?, (5) Is the lure presentation effect on fish abundance independent of habitat and depth?

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2. Materials and methods

2.1. Study area

The 2819 mobile, snorkel-based, visual census, belt transects were carried out at 30 study sites distributed along the entire Croatian Adriatic coast (Fig. 1).

2.2. Lure design

The artificial lure used in lure-assisted visual census was a double conical lead weight, 3 cm long, with a diameter of 0.5 cm at the center, attached to the end of a monofilament line and presented in a vertical position. The upper hand-held end of the monofilament was wrapped around a piece of styrofoam (locally called a "tunja"). Along the length of the monofilament, lead spheres of 2.5 mm diameter were placed at one metre intervals to serve as markers allowing for depth measurements (Fig. 2). In lure-absent transects,



Fig. 1. Study site location map. The thirty sampling sites (**■**) at which lure-assisted and lure-absent visual census transects were conducted.

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Fig. 2. Lure design. Schematic diagram showing components and deployment of the lure.

the lure line was briefly deployed outside the transect to record 136 depth. 137

2.3. Mobile lure presentation 138

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At each location the same individual observer (Kruschel) con-130 ducted 50-100 short visual census belt transects in 60-120 min 140 of swimming at the surface. For each transect, the snorkeler posi-141 tioned the lure at approximately 5 cm above the surface of the 142 substratum and moved at a constant speed of approximately 143 0.3 m s^{-1} for 10 s (approximately 3 m distance). The snorkeler, 144 looking down, observed and identified all fish in the cuboid 145 water column defined as lying within 1m either side of the 146 lure line's path and extending upward to the observer's eyes 147 148 (Fig. 2).

Short transects were used in this study because its purpose 149 included visually quantifying benthic habitat in addition to iden-150 tifying fish and recording their behaviour. It was not possible for a single observer to perform all three activities simultaneously within longer unmarked transects. Longer transects can be used with this method if habitat is not simultaneously quantified, or if habitat is quantified videographically or with a second diver during the fish sampling (Schultz et al., 2009) or later using tape measures or other tools (Bonaca and Lipej, 2005).

The transects were established randomly within an area extend-158 ing from shore to approximately 9m depth within each study 159 location. Distinct taxa were identified either as individuals or as 160 observational groups of one to 1000 individuals of the same taxon. 161 162 For each species in each group, the actual number of individuals was counted for a group size of up to 20 fish, and for numbers 163 higher than 20 estimates were made in increments of 10 for a group 164 size of up to 100 fish, then in increments of 100 to the maximum 165 observed group size of 1000. After completion of the 10s presen-166 tation and observation period, the following data were recorded 167 with pencil on a PVC pipe worn around the snorkeler's wrist: fish 168 taxon, number of individuals and groups, behavioural response(s) 169 to the lure (none, visit, chase, physical contact), and the visually 170 estimated proportional cover of all present basic habitat types, 171 including: rock (R), which can be bare (Rb), covered with algal turf 172 (Rt), or supporting an algal canopy (Rv), bare sediment (U), algae 173 on sediment (A), Posidonia oceanica (P), Cymodocea nodosa (C), and 174 Zostera noltii (N). Lure-absent transects were executed in exactly 175 176 the same way except without recording any lure-related fish behaviour.

2.4 *Lure interactions*

A fish was considered present if it was observed within the previously defined observational zone. A present fish's visit was defined as a single movement orientated towards the lure. Chase was two or more movements towards the moving lure. Physical interaction was any physical contact with the lure by mouth.

2.5. Feeding mode category identification

Feeding modes were classified as herbivory, omnivory, planktivory, and carnivory, and the last was further categorized by a combination of prey size (micro-, meso-, macro) and predation mode, utilizing published information (Froese and Pauly, 2000; Jardas, 1996; Bell and Harmelin-Vivien, 1983).

Predation mode was based on distinct differences in two types of behaviour: (1) the search behaviour before prey is detected and (2) the approach behaviour after the prey is detected. Waitchase predators searched passively (waited motionless, often from a hidden position or camouflaged against the substratum) and approached by making on average more than two movements towards the prey, which was quantified based on our own lure interaction observations, our field observations of natural predatory behaviour, and on descriptions in the literature, including the database Fishbase (Froese and Pauly, 2000). Cruise-chase predators searched actively (fast cruising above the benthos) and approached by making on average more than two movements towards the prey. Ambush predators searched passively (waited motionless, often from a position hidden inside a three dimensional structure or one of being buried and/or camouflaged against the substratum) and approached on average with less than two movements towards the prey (for quantification see above). Substratum dwelling predators searched actively, slowly moving near the benthic substratum, and their approach was not defined by the number of movements towards the prey. Coris julis exhibited mixed prey search behaviour which made it difficult to assign to any one of the feeding mode categories. C. julis is the most common labrid in the Mediterranean (Gordoa et al., 2000), and our study (Table 2) and other similar studies (Table 1) illustrate this and the variation in observed location of numerical dominance. Placing C. julis in any of the potentially suitable feeding mode categories would obscure the effect that lure presentation has on the other members within. So, overall we felt it necessary to confine C. julis to its own category.

Trophic grouping was determined according to diet and food item information given by the database Fishbase (Froese and Pauly, 2000), and in Mediterranean studies (Sala, 2004) which enabled the trophic group information of Guidetti and Sala (2007) to be approximately quantified.

2.6. Data analysis

Statistical hypotheses were tested using generalized linear models, assuming Poisson family and logarithm link for counts of individual species, and Gaussian family with identity link for counts within functional groups. Analyses of deviance were generally conducted twice, using individuals or groups as the response variable. Ninety-six percent of all groups comprised 10 individuals or fewer, 77% of one individual. For statistical tests of lure effect, however, the appropriate unit of replication within a transect is probably the group, since individuals within a group are not independent. Probability values are presented only for the group results. While differences in results between the two types of test were generally small, they were substantial for Atherina and unidentified juveniles <3 cm (group size 1–1000), for which opposite lure effects were observed when analyzing groups vs individuals.

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Table 2

Analysis of deviance p-values and lure-assisted/lure-absent mean abundance ratios for taxa observed at least five times.

| | Predation mode | Feeding mode | Prey size | р | Abundance ratio |
|--------------------------------------|-------------------|--------------|------------|---|-----------------|
| All fish | | | | $<2.2 \times 10^{-16}$ | 1.9 |
| Adult fish | | | | | |
| Coris julis | Unidentified | Carnivore | Macro/meso | 2.20×10^{-16} | 4 .1 |
| Diplodus annularis | Cruise-chase | Carnivore | Meso | 2.20×10^{-16} | 3.7 |
| Trachinus draco | Ambush | Carnivore | Macro/meso | $\textbf{3.40}\times \textbf{10}^{-10}$ | Lure |
| Diplodus vulgaris | Cruise-chase | Carnivore | Meso | 6.20×10^{-10} | 3.3 |
| Spicara maena | ~ | Planktivore | | $1.0 	imes 10^{-9}$ | 10.2 |
| Serranus hepatus | Wait-chase | Carnivore | Macro/meso | 1.80×10^{-8} | 5.2 |
| Gobius niger | Wait-chase | Carnivore | Meso | 1.90×10^{-6} | 2.8 |
| Serranus cabrilla | Wait-chase | Carnivore | Macro/meso | 2.20×10^{-6} | 8.9 |
| Gobius spec. | Wait-chase | Carnivore | Meso | $4.80 	imes 10^{-5}$ | 2.2 |
| Serranus scriba | Wait-chase | Carnivore | Macro/meso | 0.00015 | 1.9 |
| Lithognathus mormyrus | Dwelling | Carnivore | Meso | 0.00073 | Lure |
| Oblada melanura | ~ | Planktivore | | 0.0069 | 1.9 |
| Pagrus pagrus | Cruise-chase | Carnivore | Macro/meso | 0.0083 | Lure |
| Diplodus puntazzo | Cruise-chase | Carnivore | Meso | 0.01 | Lure |
| Boops boops | ~ | Planktivore | | 0.01 | 7.6 |
| Pomatoschistus bathi | Ambush | Carnivore | Micro | 0.014 | 2.9 |
| Atherina spec. | ~ | Planktivore | | 0.029 | -1.4 |
| Gobius bucchichi | Ambush | Carnivore | Micro | 0.034 | 1.1 |
| Symphodus cinereus | Dwelling | Carnivore | Meso | 0.056 | 1.2 |
| Chromis chromis | A - | Planktivore | | 0.059 | 1.8 |
| Callionymus pusillus | Ambush | Carnivore | Micro | 0.076 | 3.4 |
| Gobius cruentatus | Wait-chase | Carnivore | Meso | 0.12 | 1.8 |
| Gobius geniporus | Wait-chase | Carnivore | Meso | 0.14 | 1.7 |
| Symphodus ocellatus | Dwelling | Carnivore | Meso | 0.16 | 1.1 |
| Sarpa salpa | ~ | Herbivore | | 0.19 | 1.4 |
| Parablennius sanguinolentus | | Herbivore | | 0.22 | 5.1 |
| Symphodus rostratus | Dwelling | Carnivore | Meso | 0.26 | -2.5 |
| Symphodus mediterraneus | Dwelling | Carnivore | Meso | 0.32 | 1.6 |
| Triperygion spec. | Ambush | Carnivore | Micro | 0.39 | -1.4 |
| Pomatoschistus marmoratus | Ambush | Carnivore | Micro | 0.40 | 1.2 |
| Parablennius tentacularis | Ambush | Carnivore | Micro | 0.46 | -1.7 |
| Gobius fallax | Ambush | Carnivore | Micro | 0.61 | -1.7 |
| Parablennius rouxi | Ambush | Carnivore | Micro | 0.73 | 1.3 |
| Symphodus roissali | Dwelling | Carnivore | Meso | 0.76 | 1.1 |
| Symphodus tinca | Dwelling | Carnivore | Meso | 0.99 | 1 |
| Juvenile fish | ~ | | | | |
| Gobiids | Wait-chase/ambush | Carnivore | Meso/micro | 1.80×10^{-6} | 2.7 |
| Coris julis | Wait-chase | Carnivore | Meso/micro | 0.11 | 33 |
| Diplodus | Cruise-chase | Carnivore | Meso/micro | 0.2 | 1.2 |
| Unidentified | 0 | Planktivore | | 0.0014 | -1.7 |

3. Results

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3.1. Lure-assisted visual census

A total of 1527 lure-assisted visual census transects, each 3 m 239 long, yielded 3284 observations of groups (mean 2.15 per tran-240 sect), of which 57% (1862) responded to the lure by visiting it. A 241 total of 1593 of the individual visiting fish followed the lure, while 242 only 108 fish engaged in physical contact with the lure. In compar-243 ison, a total of 1292 lure-absent visual census transects resulted 244 in 1473 groups (1.14 per transect). The total number of censused 245 groups, resulting from pooling lure-assisted and lure-absent tran-246 sects, was 4757 while the total number of individual fish (including 247 non-independent observations of individuals within groups) was 248 12,765, of which 4549 were censused at lure-absent transects (3.5 249 per transect) and 8216 at lure-assisted transects (5.4 per transect). 250

3.2. Total and species-specific effects of lure on fish densities

The mean number of fish groups per lure transect was 2.15, nearly twice as high as along lure-absent transects (1.13), and the difference in means was highly significant (Table 2). Fourteen of the fifty-eight identified adult fish taxa (adult fish only) had a lower mean abundance along lure-assisted transects as compared with lure-absent transects. This difference, however, was significant for only one adult taxon, *Atherina* spp., when calculated from group counts, and for a group of mixed unidentified juvenile taxa <3 cm in length (Table 2). In contrast forty-four of the fifty-eight identified fish taxa (76%) were more abundant in lure-assisted transects than in lure-absent transects, and the difference was significant for one third (35%, 20 adult taxa) and for juvenile Gobiidae (Table 2).

3.3. Species specific *behavioural* responses to the lure

Lure presentation increased detectability of certain fish taxa. Trachinus draco, a species observed to be burrowing into bare sand leaving only the eyes uncovered, were never seen at lure-absent transects, but were censused in 3.5% of the lure-assisted transects (Table 2) intersecting open patches of bare sand. T. draco was censused in 51% of those locations (21 of 30 total) that offered bare sand (1.5-44% of the total seabed intersected). T. draco most commonly (83%) responded with a single sudden movement emerging from the sand combined with a single attempt to attack the lure (thus was an ambush predator). Serranidae hid between and under rocks (Serranus scriba), within clumps of algae (S. cabrilla), or hovered within/over Posidonia (S. scriba) and Cymodocea or bare sand (S. hepatus). Of those visiting the lure, 67% followed it, of which 11% physically contacted the lure (wait-chase predators). The labrid, *C. julis*, exhibited a mixed search behaviour. Some individuals searched while moving fast near the substratum, others arrived at the lure from a concealed position. Regardless of the search behaviour, approach of the lure was almost always (95%)

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Table 3

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Q4 Analysis of deviance *p*-values and lure-assisted/lure-absent mean abundance ratios for feeding mode and trophic groupings.

| Feeding mode grouping | g | р | Abundance ratio | | |
|------------------------------|------------|--------------------------|-----------------|--|--|
| Benthic carnivores | | | | | |
| Predation mode | Prey size | | | | |
| Ambush | Macro/meso | 1.9e-10 | 2.7 | | |
| Wait-chase | Macro/meso | $<\!2.2 \times 10^{-16}$ | 2.4 | | |
| Cruise-chase | Macro/meso | $<\!2.2 \times 10^{-16}$ | 2.7 | | |
| Ambush | Micro | 0.066 | 1.2 | | |
| Substrate dwelling | Meso | 0.076 | 1.1 | | |
| Coris julis | | <2.2 × 10 ⁻¹⁶ | 4.3 | | |
| Herbi-/plankti-/detritiv | /ores | 0.048 | 1.2 | | |
| | | | | | |
| Trophic grouping | | р | Abundance ratio | | |
| Large piscivores | | 2.6e <mark>-09</mark> | 28 | | |
| Small piscivores | | 1.4e-14 | 2.8 | | |
| Invertebrate feeders | | <2.2 × 10 ⁻¹⁶ | 2.2 | | |
| Microinvertebrate feed | ers | 0.00012 | 1.3 | | |
| Herbi-/plankti-/detritivores | | 0.081 | 1.2 | | |

a persistent chase, and occasionally (4.5%) large males succeeded in physical contact with the lure. All the above chase predators (*Serranus*, *C. julis*) were significantly more abundant (by a factor of two to four) in lure-assisted vs lure-absent transects (Table 2), regardless of whether calculated as groups or individuals.

Presentation of a lure increased the probability of detecting fish 288 that are potentially already visible to an observer. The likelihood 280 of noticing gobiids that are not buried and in plain view on bare 200 sands was significantly increased (2.2-2.8 times) in lure-assisted 201 transects (Gobius niger, G. spp., small/juvenile gobiids; Table 2). 292 The most common response to the lure in *Gobius* > 3 cm was a 293 behavioural switch from motionless waiting on the sand's surface 294 to approaching and chasing the lure while making repeated 295 attempts to attack it. In contrast, very small/juvenile gobiids 296 (<3 cm) more often switched from motionless waiting to fleeing 297 from the approaching lure. The probability of detecting highly 298 conspicuous but fast swimming fish was significantly increased 299 in lure-assisted transects: Diplodus annularis (3.7 times), Diplodus 300 vulgaris (3.2 times), *Diplodus puntazzo* (only at lures), Pagrus pagrus 301 (only at lures), Dicentrarchus labrax (only at lures), Sparus aurata 302 303 (only at lures) (Table 2). The sparids D. annularis (mostly over Posidonia) and D. vulgaris (mostly over rocky and sandy ground) 304 were aggressive chasers of the lure with D. annularis regularly 305 attempting to physically attack it. **P.** puntazzo and P. pagrus 306 became more detectable through their brief visits to the lure, 307 which diverted them in their movement and slowed them down, 308 while they never chased the lure. Addition of a lure had a significant 309 effect on two microcarnivorous ambush predator species, Gobius 310 bucchichi, the largest and least cryptic, and Pomatoschistus bathi, 311 312 a well carmouflaged but not a concealed species. However, lure had no effect on the truly cryptic (hidden inside the substratum) 313 Blennidae, yet the effect on the entire feeding mode category was 314 almost significant (Tables 2 and 3). The lure had no significant 315 effect on the probability of detecting herbivores (Sarpa salpa and 316 Parablennius sanguinolentus). Pomatoschistus and Callionymus, well 317 camouflaged but in potentially plain view, became visible to the 318 observer due to their motion of fleeing from the approaching lure, 319 while Parablennius rouxi was observed once to visit and briefly 320 chase the lure. A mixed response was seen within the planktivores. 321 Atherina, the by far most numerous, was observed also to be most 322 pelagic and to form the largest groups (up to 1000 individuals). 323 Atherina showed almost no response to the lure, only 5% of the 324 observed individuals/groups chased the lure and only briefly. 325 All other planktivores (except for Atherina and Chromis chromis) 326 327 were significantly more abundant (groups and individuals) at 328 lure-assisted transects (increases ranged from 1.8 to 10.2) and

lure-absent transects



Fig. 3. Feeding mode community structure. Relative abundances of benthic predator feeding mode categories at lure-absent and lure-assisted transects calculated from observational group data.

all showed substantial positive behavioural responses: 86% of *Spicara maena*, 44% of *Oblada melanura*, 23% of *C. chromis*, and 18% of *Boops boops* exhibited persistent chasing behaviour, although they were less attracted to the actual lure at the lower end of the monofilament than to the smaller depth markings along the line.

3.4. Effect of lure on feeding modes

Three feeding mode categories of benthic macro- and mesocarnivorous predators, including ambush, cruise-chase, and wait-chase, were highly significantly more likely to be detected, and had higher counts of observational groups and individuals at lure-assisted transects than at lure-absent transects (Table 3). The same was true for *C. julis*, the most abundant benthic carnivore (Table 3). Microcarnivorous ambush predators and mesocarnivorous substratum-dwelling predators were also more often detected and more numerous at lure-assisted transects (but these differences were not quite significant). Herbivores, omnivores, and planktivores appeared in significantly higher numbers at lureassisted transects, but the chance of detecting groups of these fish was only barely significantly higher during lure presentation (Table 3).

3.5. Effect of lure on taxa

The differential responses of taxa to the lure resulted in altered relative abundances. This in turn altered the estimated proportions of benthic predator categories within the community when comparing lure-assisted transects to lure-absent transects; large ambush predators, wait-chase predators, and cruise chase predators increased in proportion, while small ambush and substratum dwelling predators decreased (Fig. 3). Lure application also altered our perception of trophic community structure; the proportion of piscivores and invertebrate feeders increased and that of microinvertebrate feeders and herbi-, omni-, and planktivores decreased (Fig. 4).

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Fig. 4. Trophic community structure. Relative abundances of trophic groupings at lure-absent and Jure-assisted transects calculated from observational group data.

Table 4

Analysis of deviance *p*-values and lure-assisted/lure-absent mean abundance ratios for all taxa observed in distinct habitats and combinations thereof, and within depth zones.

| | р | Abundance ratio | |
|-------------------|------------------------|-----------------|--|
| Groundcover | | | |
| U (bare sand) | 1.4×10^{-11} | 3.1 | |
| R (rock) | 4.5×10^{-9} | 1.6 | |
| RU | $1.3 	imes 10^{-6}$ | 1.8 | |
| P (Posidonia) | 6.3 × 10 ⁻⁶ | 3.0 | |
| A (algae on sand) | 0.0021 | 5.5 | |
| UA | 0.0026 | 2.5 | |
| C (Cymodocea) | 0.0032 | 1.9 | |
| UC | 0.020 | 2.1 | |
| RUA | 0.024 | 2.9 | |
| Depth zone | | | |
| 0.25–1.5 m | 0.0044 | 1.2 | |
| >1.5-3 m | 1.3×10^{-7} | 1.6 | |
| >3-4.5 m | $8.1 	imes 10^{-11}$ | 3.3 | |
| >4.5-6 m | $1.4 	imes 10^{-10}$ | 3.9 | |
| >6-9 m | 0.00063 | 3.1 | |
| | | | |

Table 5

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Analysis of variance of the effect of lure, habitat, and depth on fish group abundance.

| | Df | SumSq | MeanSq | F value | p value |
|-----------|------|---------|--------|---------|----------|
| Depth | 4 | 43.7 | 10.93 | 2.2 | 0.07 |
| Lure | 1 | 708.8 | 708.8 | 140 | <2.0e-16 |
| Habitat | 23 | 795.3 | 34.58 | 6.8 | <2.0e-16 |
| Residuals | 2787 | 14156.2 | 5.08 | | · · · |

3.6. Depth and habitat specific effects of lure application

The 2819 visual census transects intersected pure seabed covers of rocks (R), bare sediments (U), algae vegetated sediments (A), and seagrass [*Posidonia* (P), *Cymodocea* (C), *Z. noltii* (N)], as well as fifteen combinations thereof (Table 4). Fish abundance was higher along lure-assisted transects than along lure-absent transects for sixteen of these twenty-one, and the difference was significant for eleven, including five common pure groundcover types (R, U, A, P, and C, Table 4). Mean fish abundance was higher at lure-assisted transects than at lure-absent transects across the entire depth range sampled (0.25_{A} -9 m, Table 4). While fish abundance significantly differed across habitats independently of the lure effect, depth did not have such a lure independent effect (Table 5).

4. Discussion

Our results are consistent with our five general predictions. Lure presentation had a significantly positive effect on overall observational group and individual fish density. The lure effect was different across taxa and across feeding mode categories. Taxon-specific lure effects resulted in altered relative abundances of taxa, and in changed proportions of feeding mode categories and trophic groupings calculated from data acquired by the two alternative methods. This consequently altered our perception of fish community structure. Lure effects on group counts and individual counts of fish were independent of habitat and depth.

Moreover, although the overall increase in independent fish observations and fish density in lure-assisted census was seen in three quarters of the observed fish taxa, the largest portion of that increase was due to the strongly positive response of large ambush predators (T. draco), wait-chase predators (Gobiidae and Serranidae), cruise-chase predators (Sparidae), and the solitary labrid *C. julis*. All these responded to the presented lure as predicted; ambush and wait-chase predators were lured out from a passive search position in a concealed situation (within a three dimensional structure, buried in sediment, or cryptically concealed), and fast swimming cruise-chase predators slowed down or even approached the lure, which made their detection and identification more likely. The only unexpected result was displayed by very small gobiids as well as Callionymus pusillus; their increased chance of being detected was mostly caused by a negative (fleeing) response to the approaching lure.

Our results are consistent with known behavioural strategies used by these species for foraging. *C. julis* has been described as a sedentary species (Lejeune, 1987) and a solitary one, particularly during their foraging which involves monitoring the success of other species (e.g. *Mullus*) followed by joining them and scavenging their discovered food (De Pirro et al., 1999). This monitoring behaviour, combined with territoriality in males, would be sufficient to explain the large increase in numbers in the lure-assisted census, which resulted from individual *C. julis* approaching by fast chasing from a concealed location.

The three Croatian Adriatic species in the genus *Serranus* are reported as mostly sedentary species (Jardas, 1996) relying on sedentary or motionless search strategies usually combined with concealment, which would reduce their detection probability in a non-lure visual census. Gibran (2007), in his detailed behavioural study of tropical serranids, identifies sit-and-wait and ambush hunting as the two search strategies of more sedentary species, but even more mobile larger species seemed to prefer motionless hovering and waiting to active swimming when searching for prey. Serranids generally rely on a keen visual sense and prey tracking is preferably done by movement of the eyes rather than the body.

T. draco is a classic ambush predator (Creutzberg and Witte, 1989), and according to our experience very unlikely to be detected in a traditional visual census, while we have shown by

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lure presentation that it is reliably present in its preferred habitat (bare sand patches). Its low detection probability is borne out by the fact that it has been reported thus far in only one published visual census study investigating sand habitats in shallow Mediterranean waters, where it is considered to be widespread and common on sand (Portillo Strempel et al., 2008).

Our results indicate that lure-absent visual census significantly underestimates abundance of several species, resulting in a distorted perception of fish community structure. This includes gobiids generally, which are a species-rich and numerically dominant group in many shallow waters in the Mediterranean (Malavasi et al., 2005; Franco et al., 2006). This makes them, and especially their juveniles, an important potential prey for fish (Froese and Pauly, 2000) but even more so of nektonic cephalopods (Castro and Guerra, 1990). Planktivores exhibited a mixed response to lure presentation, ranging from significantly negative (*Atherina*, juvenile fish <3 cm) to significantly positive (*S. maena*, *C. chromis*, *O. melanura*), the last being primarily attracted to the monofilament line and/or the attached depth markers.

Our data further verified that the increased fish counts in the lure-assisted census were not significantly different at different depths. Lure presentation was effective across the entire depth range studied as well as in all common types of seabed comprising pure or mixed stands of bare and vegetated rock, bare and vegetated sand, and seagrass (Table 4). This habitat-independent effectiveness makes lure assisted visual census suitable for comparative studies, which rely on observed differences in relative fish abundance across sampled localities rather than absolute abundances.

Visual census methods also yield unrealistic estimates of abso-453 lute abundance. This criticism, however, applies to virtually all 454 census methods. For example individuals may be counted that 455 were not previously present within the sampled area (the tran-456 sect belt), but moved into the area in response to the presence of 457 the diver or snorkeler (Watson and Harvey, 2007). Such experi-458 menter or equipment effects are difficult to control, make estimates 459 of absolute abundance per unit area problematic, and are present 460 whether or not the census is lure-assisted. With or without lures, 461 when using visual census in comparative studies (of habitats, geo-462 graphical locations, depths, coastal uses, seasons, time of day, etc.), 463 estimates of absolute abundance are not necessary, and these 464 comparisons will be valid as long as any experimenter or equip-465 ment effects are similar across treatment levels (Peterson and 466 Black, 1994). Any biases associated with lure use per se, if they 467 exist, are to be weighed against the disadvantage of underesti-468 469 mating or missing entirely certain taxa or functional groups, e.g. piscivorous ambush predators (T. draco in our study) or large pis-470 civores in general (others observed only in lure-assisted census 471 included Scorpaena scrofa, P. pagrus, and D. labrax). The fact that 472 lure-assisted visual census belt transects allow a more complete 473 sampling of taxonomic and functional richness make them a desir-474 able tool in community-level studies at any spatial and temporal 475 scale. 476

Our data show that the effect of habitat on species abundance is 477 independent of the effect of lure presentation (Table 5). This indi-478 cates that habitats do not equally contribute to fish abundance in 479 the shallow Adriatic and suggests a need for further evaluation of 480 the relative importance of benthic habitat on fish abundance and 481 diversity on several spatial scales in the Adriatic Sea. Such research 482 is urgently needed in the development of a network of marine pro-483 tected areas (MPAs) in the Mediterranean bioregion and elsewhere 484 in the ongoing effort to meet the worldwide goal of 10% marine area 485 coverage (Convention on Biological Diversity, 2006). The identifica-486 tion and the subsequent monitoring of such MPAs requires time and 487 needs cost efficient methods, such as lure-assisted visual census, 488 489 suitable for censusing and monitoring diverse taxa and functional groups across a range of physical and biological contexts.

5. Conclusions

Lure-assisted visual census of belt transects offers a more complete representation of fish communities present in shallow Adriatic environments than does the non-lure assisted alternative. Non-lure visual counts, while adequate in assessing slow moving and conspicuous fish, may underestimate or completely miss a substantial portion of the physically present but hiding, camouflaged, and fast swimming fish. On the other hand, lure assisted visual counts were equally adequate in assessing slow moving herbivores and benthic and pelagic predators but in addition succeeded in detecting a larger portion of the physically present ambush-, waitchase-, and cruise-chase predators. Lure-assisted visual census is less likely to fail to detect present taxa or to underestimate the presence of others, so might enable a more realistic analysis of fish community structure. The observed independence of the lure's effect from habitat and depth provides assurance that our method is suitable for comparative studies. The details of the method's transect arrangement and lure application are flexible and limited only by the needs and creativity of the potential user.

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