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ASSESSING SOFT-BOTTOM EPIBENTHIC COMMUNITIES: METHODOLOGICAL INSIGHTS INTO DREDGING AND VIDEO SURVEYS

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ABSTRACT

The study compared two approaches, sampling using a dredge and non-invasive video surveys using a camera dredge and a video sledge, for assessing soft-bottom epibenthic communities. Sampling was conducted over a detritic muddy-sandy bottom. Altogether171 taxa were identified, with only a small subset shared among all methods. Dredging yielded the highest number of taxa, particularly small, cryptic and sediment-associated, and provided biomass data. Conversely, video-based methods detected a lower number of taxa yet could detect more vagile species and could quantify some species like sponges. Video sledge surveys provided the most extensive coverage and the highest number of habitat and community parameters. The findings indicate that dredge and video-based methodologies yield complementary ecological insights, indicating that a combination of methods should be employed for the more comprehensive monitoring and assessment.

Key words: epibenthos, soft-bottom circalittoral, dredge sampling, camera dredge, video sledge, Adriatic Sea-

VALUTAZIONE DELLE COMUNITÀ EPIBENTONICHE DEI FONDALI A SUBSTRATO MOLLE: CONSIDERAZIONI METODOLOGICHE SULLE CAMPAGNE DI CAMPIONAMENTO CON DRAGA E SULLE INDAGINI VIDEO

SINTESI

Lo studio ha confrontato il campionamento con draga e le indagini video non invasive (draga con telecamera e slitta video) per la valutazione delle comunità epibentoniche dei fondali molli. I campionamenti, effettuati su un fondale detritico fangoso-sabbioso, hanno permesso di identificare 171 taxa, con una limitata sovrapposizione tra i metodi. La draga ha rilevato il maggior numero di taxa, soprattutto specie piccole, criptiche e associate al sedimento, fornendo anche dati sulla biomassa. I metodi video hanno identificato meno taxa, ma si sono dimostrati più efficaci nel rilevare specie vagili e nel quantificare organismi importanti come le spugne. La slitta video ha inoltre garantito la maggiore copertura e la raccolta del maggior numero di informazioni su habitat e comunità. I risultati evidenziano la complementarità tra i metodi di campionamento, suggerendo l'impiego integrato di draga e tecniche video per un monitoraggio più completo degli ecosistemi bentonici.

Parole chiave: epibenthos, fondali molli circalitorali, campionamento con draga, draga con telecamera, slitta video, Adriatico

INTRODUCTION

Soft-bottom benthic habitats are among the most widespread marine environments and support diverse epibenthic assemblages composed of organisms such as sponges, molluscs, crustaceans, tunicates, echinoderms and various other mobile or sessile taxa. These communities contribute to ecosystem functioning through their roles in trophic interactions, sediment–organism relationships and habitat structuring. Their composition and spatial organisation are influenced by sediment characteristics, hydrodynamic conditions and environmental gradients, and therefore reflect both natural variability and anthropogenic disturbance (Jones, 1950; Fedra *et al.*, 1976; Eleftheriou & Moore, 2005).

In the northern Adriatic Sea, and particularly in the Gulf of Trieste, benthic communities have long been recognised as spatially heterogeneous and strongly shaped by local environmental conditions. Earlier studies described the structure and distribution of North Adriatic benthic communities (Gamulin-Brida, 1974; Fedra *et al.,* 1976), while more recent regional research has confirmed the ecological importance and variability of soft-bottom assemblages in the southern part of the Gulf of Trieste (Mavrič *et al.*, 2010). Sediment diversity and environmental gradients in this area further contribute to the complexity of benthic habitats, making reliable assessment methods particularly important for regional monitoring and management (Orlando-Bonaca *et al.,* 2012; Čermelj *et al.,* 2019).

Assessment of epibenthic communities has traditionally relied on direct sampling methods, including dredging and trawling. Such methods provide physical specimens and therefore allow detailed taxonomic identification, abundance estimates and, in some cases, biomass assessment. They are especially valuable for detecting small, cryptic and sediment-associated taxa that are difficult to identify visually (McIntyre, 1956; Eleftheriou & Moore, 2005). However, dredge-based sampling is invasive, spatially limited and affected by gear selectivity. Physical disturbance of the seabed, selective retention of organisms and possible fragmentation or loss of fragile taxa may influence the composition of the collected sample and consequently affect ecological interpretation (Hall & Harding, 1997; Kaiser *et al.*, 2000; Lindegarth *et al.*, 2000).

Non-destructive visual techniques, including towed video systems and video sledges, have increasingly been used to complement traditional sampling (Service & Golding, 2001). These approaches enable *in situ* observation of epibenthic organisms and provide information on habitat morphology, spatial distribution patterns and ecological context over larger areas than direct sampling methods. They are particularly useful for documenting larger, conspicuous, sessile and habitat-forming organisms, as well as features that are difficult to preserve in physical samples (Service & Golding, 2001; Jørgensen *et al.*, 2011; Flannery & Przeslawski, 2015). Nevertheless, video-based methods are constrained by image quality, visibility conditions and observer expertise, and usually have lower taxonomic resolution for small, cryptic or sediment-associated organisms (Service & Golding, 2001; Ierodiaconou *et al.,* 2011; Flannery & Przeslawski, 2015).

Because each sampling method favours different components of the epibenthic community, methodological bias represents a central issue in benthic biodiversity assessment. Direct sampling may better detect small and sediment-associated organisms, whereas visual methods more effectively capture larger, conspicuous and structure-forming taxa. As a result, different methods may produce different estimates of taxonomic richness, dominance structure, abundance and habitat relevance. This methodological selectivity has been recognised since early comparisons of benthic sampling techniques and remains an important consideration in modern survey design (McIntyre, 1956; Uzmann *et al.*, 1977; Bowden & Hewitt, 2012).

The integration of destructive and non-destructive approaches therefore offers a promising way to improve the completeness and reliability of epibenthic community assessments. Previous studies have shown that combining different sampling approaches can reduce uncertainty and provide a more comprehensive understanding of benthic community structure than any single method alone (Solan *et al.*, 2003; Jørgensen *et al.*, 2011; Bowden & Hewitt, 2012).

Despite these advantages, applications of video-based surveys of benthic habitats and communities, but even more comparative evaluations of physical sampling and video-based surveys remain limited, particularly for soft-bottom habitats of the northern Adriatic Sea. This kind of research is important because methodological choice can directly influence conclusions about biodiversity, dominant taxa, habitat structure and the ecological status of benthic communities and results of such studies can help us in improving new surveys and status assessments of benthic habitat types and communities and in interpreting and re-evaluating historical data mainly coming from physical sampling.

Due to this and in the scope of monitoring and assessment needs following the Marine Strategy Framework Directive and Nature Restoration Law, the present study is focusing on the comparison of two distinct sampling approaches—dredge sampling and video-based surveys (using camera-on-dredge observations and video sledge surveys)—in the epibenthic-rich soft-bottom of the Gulf of Trieste. The objectives were: (i) to compare the taxonomic composition and community information obtained by each method; (ii) to identify method-specific biases related to organism detectability, quantification and taxonomic resolution; and (iii) to evaluate the complementarity of these approaches for benthic monitoring and ecological assessment.

MATERIAL AND METHODS

Study area

The study was conducted in the Gulf of Trieste, a semi-enclosed, shallow basin with an average depth of 20 m (Trobec *et al.*, 2018). It is characterised by pronounced environmental gradients and strong seasonal variability in temperature and salinity, all being influenced by riverine inputs, atmospheric forcing, hydrodynamic processes and high levels of anthropogenic pressures (Boicurt *et al.*, 1999; Malačič & Petelin, 2001; Malačič *et al.*, 2006; Tondelli *et al.,* 2025). Water temperature analyses over the period 2001–2022 reveal that monthly mean minima occur in February (8.93 ± 0.03 °C) and maxima in August (23.56 ± 0.05 °C) and strong intra-annual variability and confirm a significant long-term warming trend of about 0.06 °C per year (Tondelli *et al.,* 2025). Salinity typically ranges between 25 and 38 PSU, with an average value of 35 PSU being among the lowest in the Mediterranean (Boicourt *et al.*, 1999; Cozzi *et al.*, 2012). River dischargers are also responsible for high nutrient and sediment supply into the Gulf and together with insolation, evaporation and periodic strong winds (bora and sirocco) affect water stratification, which contributes also to occasional events of anoxia and hypoxia (Malačič *et al.*, 2006; Zuschin & Stachowitsch, 2009).

The sampling was conducted in the south-western part of the Gulf of Trieste (northern Adriatic Sea), on the shallow circalittoral muddy-sands containing up to 30 % of pelite fraction and 45 % of biogenic detritus (Mavrič *et al.*, 2023). The bottoms are dominated by the epibenthic community of coastal detritic bottoms that transitions into the community of muddy detritic bottoms (Fedra *et al.*, 1976; Mavrič *et al.*, 2023).

Sampling design and sample processing

To evaluate methodological performance for habitat and epibenthic community assessment, three sampling approaches were applied: (i) dredge sampling, (ii) video observations using a camera mounted on the dredge (camera dredge) and (iii) video sledge surveys. Sampling was conducted on 15 stations

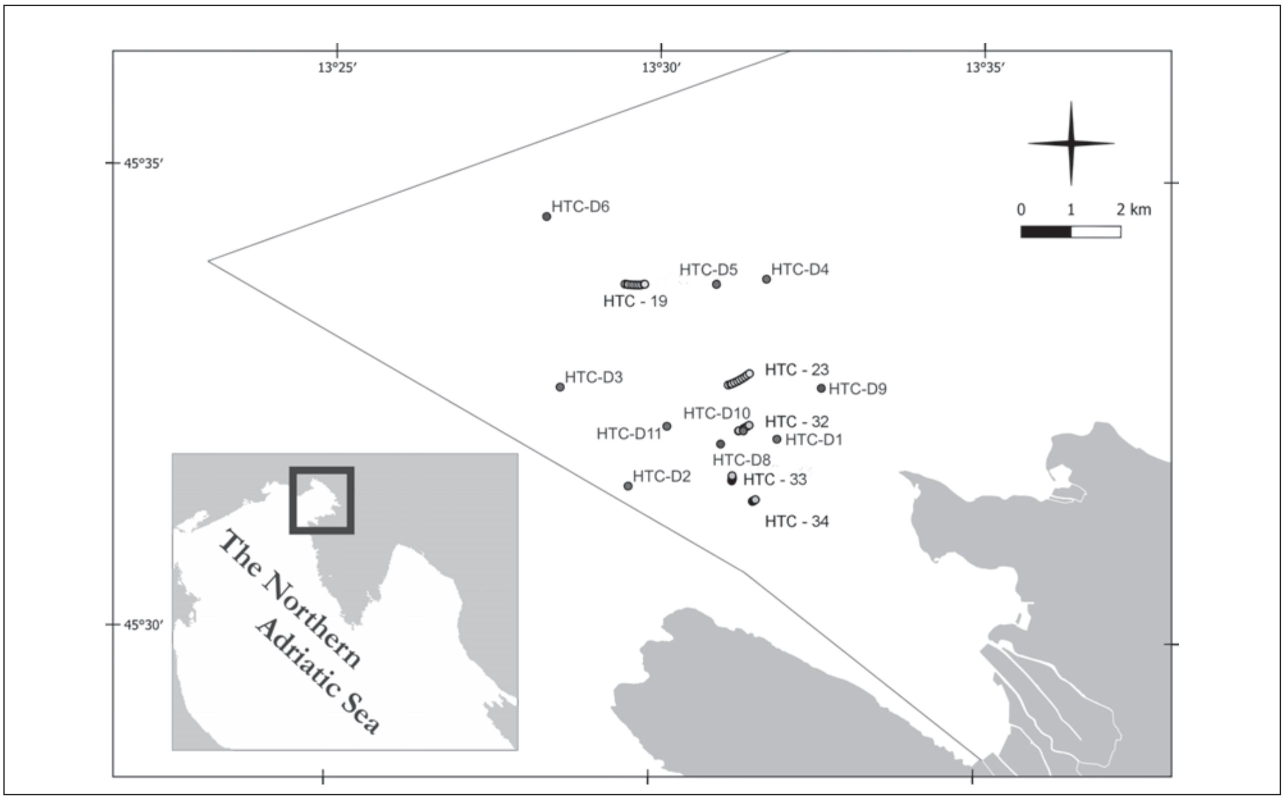

Fig. 1: Map of the areas sampled and surveyed using the dredge (labels HTC-D) and video sledge (HTC-).
Sl. 1: Zemljevid vzorčevalnih območij, pregledanih z dredžo (oznake HTC-D) in video sani (HTC-).

Tab. 1: List of transects where data for the research were collected.
Tab. 1: Seznam transektov, na katerih so bili zbrani podatki za raziskavo.

Name of the Survey	Date	Start of sampling		End of sampling		Depth (m)	Transect duration (mm:ss)	Transect lenght (m)	Speed (knots)
		LAT (N)	LON (E)	LAT (N)	LON (E)				
HTC-D1	16.02.2022	45°32.166'	13°31.804'	45°32.235'	13°31.653'	22	04:00	144	0.9
HTC-D2	22.02.2022	45°31.633'	13°29.544'	45°31.385'	13°29.465'	22	01:30	49	0.65
HTC-D3	22.02.2022	45°32.683'	13°28.477'	45°32.631'	13°28.491'	22	03:00	80	0.8
HTC-D4	9.03.2022	45°33.883'	13°31.601'	45°33.921'	13°31.619'	23	03:00	71	0.7
HTC-D5	10.03.2022	45°33.818'	13°30.837'	45°33.823'	13°30.900'	23	03:30	74	0.7
HTC-D6	14.03.2022	45°34.512'	13°28.222'	45°34.444'	13°28.178'	22	03:00	95	0.9
HTC-D8	16.03.2022	45°32.103'	13°30.945'	45°32.151'	13°30.955'	22	01:30	48	0.9
HTC-D9	21.03.2022	45°32.722'	13°32.469'	45°32.702'	13°32.419'	22	02:00	64	0.8
HTC-D10	22.03.2022	45°32.249'	13°31.289'	45°32.223'	13°31.241'	21	01:00	33	0.8
HTC-D11	22.03.2022	45°32.283'	13°30.119'	45°32.273'	13°30.059'	23	02:00	55	0.8
HTC - 19	23.03.2022	45°33.796′	13°29.508′	45°33.799′	13°29.812′	22	19:35	453	0.6
HTC - 23	24.03.2022	45°32.724′	13°31.129′	45°32.851′	13°31.453′	21	19:08	439	0.6
HTC - 32	25.03.2022	45°32.228′	13°31.300′	45°32.291′	13°31.462′	21	15:06	257	0.5
HTC - 33	28.03.2022	45°31.686′	13°31.209′	45°31.741′	13°31.214′	21	10:30	77	0.3
HTC - 34	28.03.2022	45°31.467′	13°31.533′	45°31.486′	13°31.579′	20	08:40	76	0.2

located within the circalittoral zone, with depths ranging from 20 to 25 m, where the bottom is comprised of detritic muddy-sandy sediments. Dredging and video observations using a camera mounted on the dredge were performed simultaneously on 10 transects, while video sledge surveys were performed on 5 transects adjacent to the first ones (Fig. 1, Tab. 1). All sampling approaches were conducted in the period between 16.02.2022 and 28.03.2022 (Tab. 1), to assure comparable environmental conditions. The choice of period was mainly dictated by water clarity conditions, which are usually the best between February and the beginning of April.

Dredging and camera dredging were performed using a scientific dredge with a net with openings of 20 x 23 mm, attached to a 60 cm wide metal frame (Fig. 2). On the top of the metal frame a video recording set-up was mounted, composed of a GoPro HERO 9 camera, a laser scale (two laser beams set 10 cm apart) and two video lights. This video system provided close-range observations of benthic organisms and substrate conditions along the dredge path. For each dredging, transect start and end GPS coordinates were taken, together with data on depth, time and speed of dredging. Dredging was performed for 1 to 4 minutes using the relatively constant speed

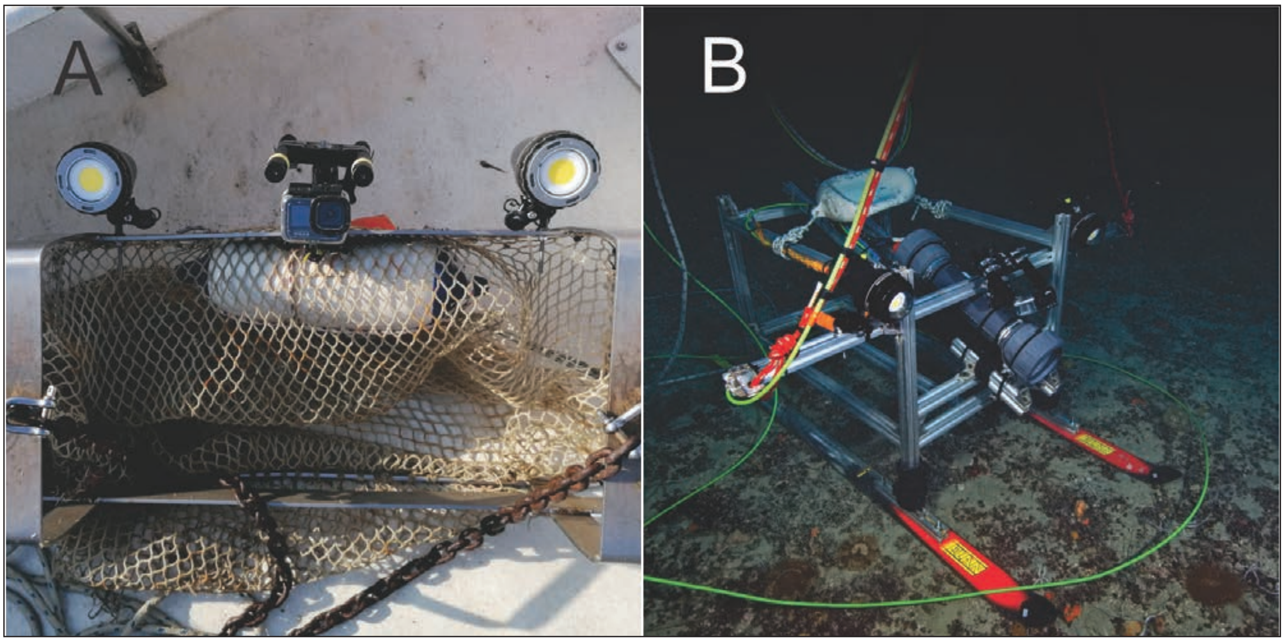

Fig. 2: Sampling devices used in the study; A – a scientific dredge, additionally equipped with a GoPro Hero camera, a laser scale and video lights, B – a video sledge equipped with three cameras, a laser scale and video lights (photo: B. Mavrič).
Sl. 2: Vzorčevalne naprave, uporabljene v raziskavi; A – znanstvena dredža, dodatno opremljena s kamero GoPro Hero, laserskim merilom in video lučmi, B – video sani, opremljene s tremi kamerami, laserskim merilom in video lučmi (foto: B. Mavrič).

between 0.65 and 0.9 knots, resulting in the length of transects between 33 and 144 meters (Tab. 1). Physical samples were transferred from the dredge into separate tanks with water for further processing on land, while video recordings were transferred from cameras to a computer for later analyses.

Video sledge system was equipped with three separate cameras, two main recording cameras (GoPro Hero 9), set at different angles and distances from the bottom to enable different views on the same positions and one IP control camera, connected with the cable to the boat above, enabling real time control of the situation underwater and survey performance. Besides the cameras the video system was complemented with one laser scale (two laser beams set 10 cm apart) and two video lights. For each survey, start, end and intermittent GPS coordinates (approximately every three minutes) were taken along the transect, together with data on depth, time and speed of survey. Active surveys lasted from around 12 to 24 minutes, with active sliding time between 9 and 20 minutes, with the speed between 0.3 and 0.6 knots, resulting in the length of the whole surveyed transects between 77 and 453 meters (Tab. 1). After the survey video recordings were transferred from cameras to a computer for later analyses.

Material collected with the dredge was firstly separated into broader taxonomical groups and weighted to the nearest g. Than specimens were determined to the lowest possible taxonomic level and counted if possible. For some taxa biometry data were measured, together with some other observations like sex, symbiotic relationships, etc.

Video material was checked on the computer. Camera dredge video transects were analysed as whole, while videos from the video sledge were separated into subtransects of around 3 min length (to match approximately the dredged transects in the area covered) and then analysed separately. Observed organisms were determined to the lowest possible taxon and counted. Besides this, other data were annotated like specimen size, behaviour and other biotic relationships (*e.g.*, presence of clumps, symbiosis), habitat appearance, bottom structure, organism distribution, etc.

Statistical analysis

Statistical analyses were performed to compare the ecological information obtained by dredge sampling, camera-on-dredge observations and video sledge surveys. Taxonomic composition was summarised as the total number of recorded taxa, the number of taxa identified to species level and the number of quantifiable taxa for each method. Mutual and method-specific taxa were visualised using a Venn diagram to assess methodological overlap and complementarity. Taxa richness was calculated as the number of quantifiable taxa per sampling unit, while abundance data were standardised as density, expressed as individuals per 100 m². For video sledge surveys, analyses were performed both for whole transects and shorter subtransects to allow comparison with the smaller spatial extent covered by dredging.

Differences in taxa richness and total density among methods were tested using Kruskal–Wallis tests, followed by Dunn's post hoc tests when appropriate. Paired Wilcoxon tests were used for direct comparisons between dredge and camera-on-dredge data collected along the same transects. Frequency of occurrence was calculated for each taxon and visualised using shade plots. Dominant taxa were identified according to mean relative density. Community composition was analysed using square-root-transformed density data, Bray–Curtis dissimilarities, nMDS ordination and PERMANOVA, with PERMDISP used to assess homogeneity of dispersion. Method performance was additionally evaluated descriptively using predefined ecological and practical criteria.

RESULTS

Application of all three methods resulted in a list of parameters we could obtain by each of them and is presented in the Table 2. Using the dredge we could assess 5 parameters, using the camera dredge 7 and with the video sledge 8 parameters out of 9 altogether. The only parameter we could assess solely with the dredge was biomass, while the video-based methods gave us insights into habitat appearances underwater, like seabed morphology, distribution patterns on the seabed, bahaviour of the organisms and their interactions, and assessment of clumps of organisms. The only three parameters we could assess with all three methods were taxonomic composition and abundance/density of organism. For this reason, we took a closer look at the performance of the three methods in assessing these three parameters.

A total of 171 mainly animal taxa were recorded across all sampling methods. Results on taxonomic composition obtained by all three methods clearly reflect differences in detection capabilities among methods. Dredge sampling recorded the highest number of taxa (129) with 104 determined to the species level. Video-based approaches recorded fewer taxa overall, the camera dredge 52 taxa out of them 39 determined to the species level and the video sledge 106 taxa with 77 species. Thirty-nine taxa were obtained by all three methods, 25 were obtained by both the dredge and the video sledge method, 8 by the camera dredge and the video sledge and 5 by the dredge and the camera dredge method. Sixty taxa were obtained solely by the dredge and 34 by the video sledge, while with the camera dredge, we obtained no exclusive taxa (Fig. 3).

The number of taxa we could quantify (density per 100 m²) were slightly lower than the number of taxa we could determine. The majority of taxa we could not count were obtained by dredging (42), while only one taxon from video-based methods was not quantifiable, namely algae *Peyssonnelia squamaria*. The highest number of countable taxa per one sampling was obtained with the video sledge over a whole length transect (55 on average) covering far more sea bottom than with the other two methods. By splitting the transect of video sledge into smaller sub-transects covering a similar area than other two methods, the number of obtained taxa per sample dropped to 33 on average which is higher than the number of taxa obtained with the camera dredge (28) and lower than 39 recorded with the dredge (Fig. 4).

Most taxa obtained by dredging belonged to molluscs (29), followed closely by poriferans (28), crustaceans (21), tunicates (15), bryozoans (12) and echinoderms (11) (Fig. 5). The most taxa-richest group obtained by both video based approaches were poriferans (17 with camera dredge and 25 with video sledge), which were in camera dredge method followed by tunicates (10), molluscs (9) echinoderms (8) and cnidar-

Tab. 2: List of parameters we could assess with the three methods.

Tab. 2: Seznam parametrov, ki smo jih lahko ocenili s tremi metodami.

Parameters	Dredge	Camera dredge	Video sledge
biomass	+	-	-
taxonomic composition	+	+	+
abundance/density	+	+	+
frequency of occurence	+	+	+
ind. size measurements	+	-	+
clumps analyses	-	+	+
species behaviour/ interactions	-	+	+
bottom morphological features	-	+	+
distribution patterns	-	+	+

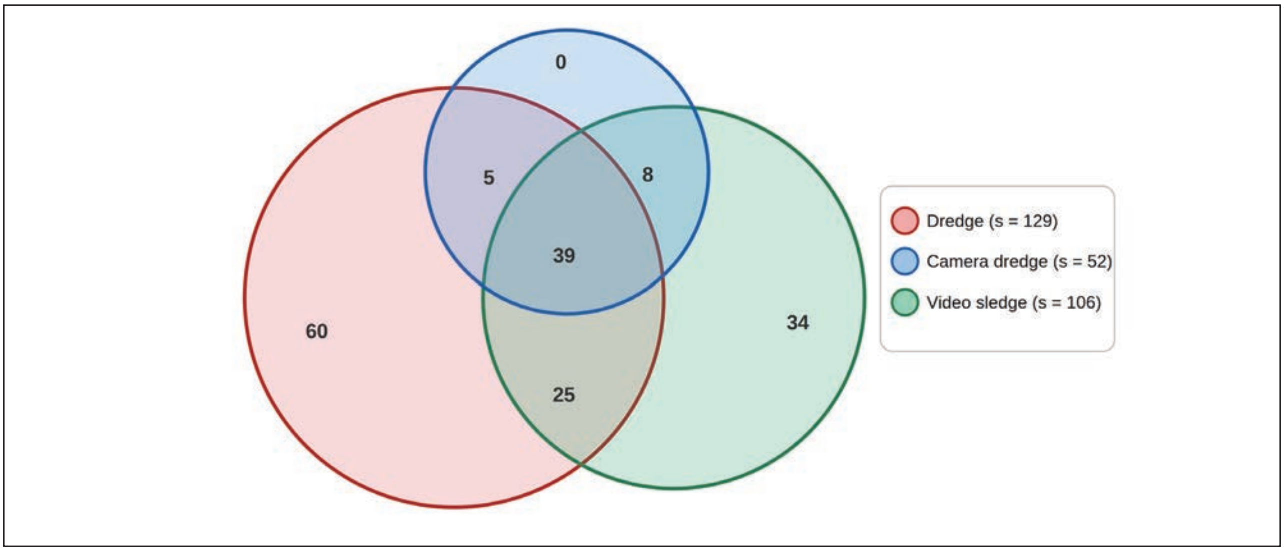

Fig. 3: Venn diagram presenting the number of taxa obtained by three methods (three differently coloured circles), split into categories based on the fact if taxa were obtained exclusively with one method (number in an area covered by only one circle), with two out of three (area covered by two circles or by all three methods (number in an area covered by all three circles).
Sl. 3: Vennov diagram prikazuje število taksonov, ugotovljenih s tremi metodami (trije različno obarvani krogi), razdeljenih v kategorije glede na to, ali so bili taksoni ugotovljeni izključno z eno metodo (število v območju, ki ga pokriva le en krog), z dvema od treh (območje, ki ga pokrivata dva kroga) ali z vsemi tremi metodami (število v območju, ki ga pokrivajo vsi trije krogi).

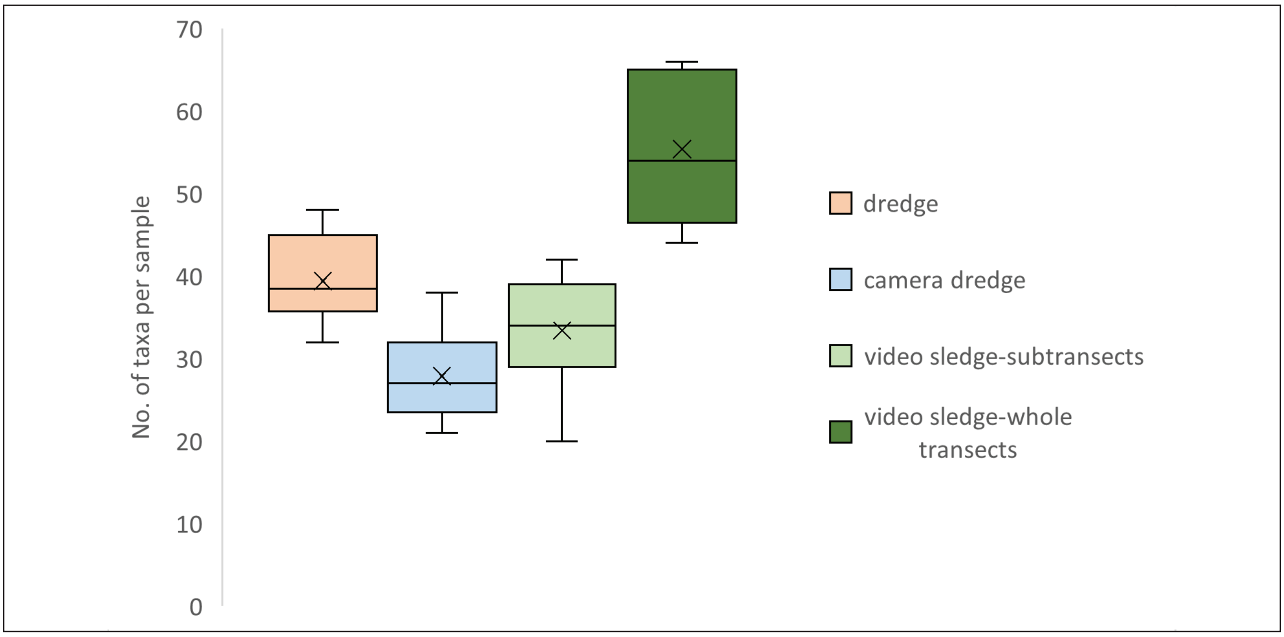

Fig. 4: The number of taxa per sample (only those for which abundance data could be obtained) presented with a box whiskers plot for method. For the video sledge two box plots were drawn, one with data obtained per subtransects and the other per whole transects recorded on one site.
Sl. 4: Število taksonov na vzorec (le tisti, za katere so bili pridobljeni podatki o abundanci) je prikazano z grafikonom kvantilov glede na metodo vzorčenja. Za video sani sta bila izrisana dva diagrama: eden s podatki, pridobljenimi na raven subtransektov, in drugi na raven celotnih transektov, posnetih na posamezni lokaciji.

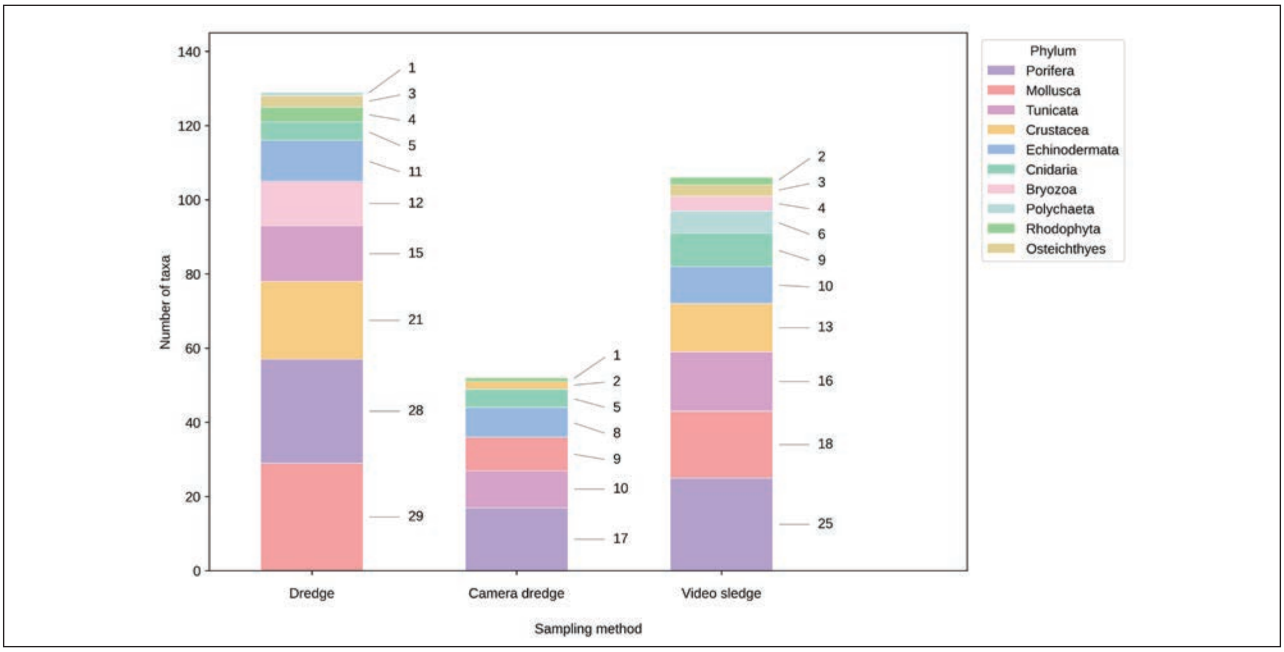

Fig. 5: The number of taxa per higher taxonomic category for each sampling method.
Sl. 5: Število taksonov na višjo taksonomsko kategorijo za vsako metodo vzorčenja.

ians (5) and in video sledge method by molluscs (18), tunicates (16), crustaceans (13), echinoderms (10) and cnidarians (9). According to this, the dredge and the video sledge sampling are more resembling. With the dredge we obtained a far higher number of mollusc, crustacean and bryozoan taxa, while with the video sledge significantly more cnidarian and polychaete taxa were recorded (Fig. 5).

Observations undertaken with the camera affixed to the dredge yielded additional information by virtue of the fact that they enabled the capture of organisms in direct proximity to the dredge's trajectory. This method often recorded taxa that were either disturbed or only partially retained during dredging, including mobile crustaceans and larger epifaunal organisms. Furthermore, it facilitated the acquisition of supplementary observations pertaining to substrate-associated fauna, which exhibited a lack of consistency in their preservation within dredge samples.

Looking at the data of frequency of occurrence, it is even more evident that not all taxa are equally detectable with all three methods (Fig. 6). There are some taxa with high frequency of occurrence obtained using video-based methods, especially video sledge, like anemone *Phymanthus pulcher,* that were never detected in dredge samples. On the other hand, there are even more examples of the taxa that were recorded in dredge samples, but hardly or not with video-based methods, especially small crab species like *Pisidia bluteli, Pilumnus spinifer* and *Ethusa mascarone*.

No statistically significant differences in recorded densities of all organisms per sample were obtained between sampling methods, although the increasing trend is evident from the camera dredge with the lowest average value (4334 ind/m^2), followed by the dredge (4733 ind/m^2) and the video sledge (6233 ind/m^2) (Fig. 7).

Analyses of the average densities of the individual taxa per sampling method revealed that in all three methods the far most dominant taxon was a brittlestar species *Ophiothrix quinquemaculata* (Fig. 8), whose relative densities were with all methods higher than 70%. With the dredge the second most dominant organism turned out to be a sea urchin *Psammechinus microtuberculatus*, followed closely by a clam *Mimachlamys varia* and by a crustacean *Paguristes eremita*. *P. microtuberculatus* was not among the 9 most dominant taxa obtained by the video sledge and it came 7th with the camera dredge. In both video-based methods the second most abundant taxon was anemone *Cereus pedunculatus*, which was only the 9th most abundant taxon in dredge samples. The third most dominant taxon with the video sledge was a sponge *Ulosa stuposa,* which came fourth with the camera sledge and could not be counted in dredge samples due to its fragmentation. The same is true also for a sponge *Mycale tunicata* which was absent from the density data from the dredge but was amongst the most abundant taxa in video-based methods. Both rounded and robust sponge species *Tethya citrina* and *Suberites domuncula* were among

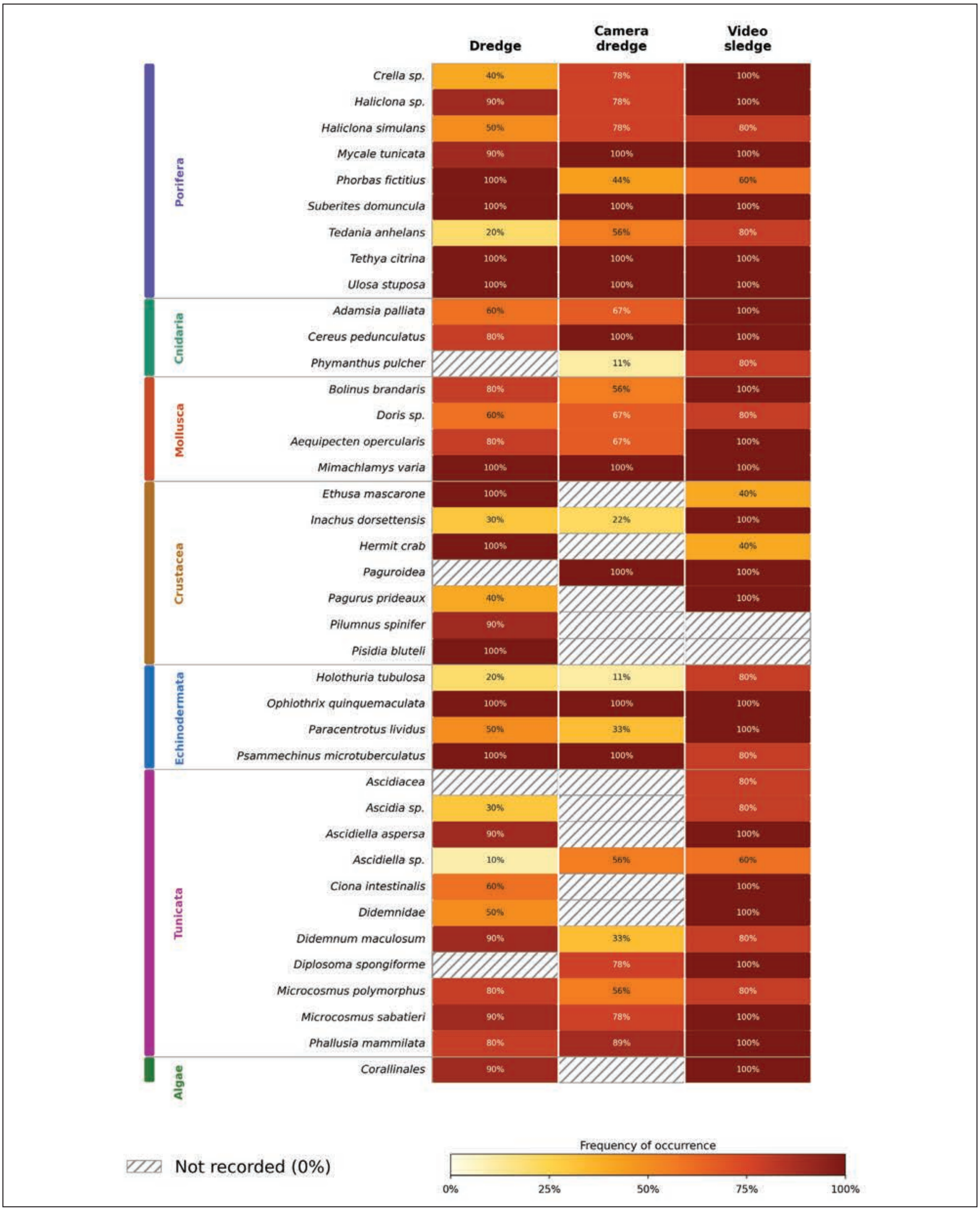

Fig. 6: A shade diagram with a frequency of occurrence of selected taxa whose occurrence was >80% in at least one of the sampling methods.
Sl. 6: Senčni diagram s frekvenco pojavljanja izbranih taksonov, katerih pojavnost je bila večja od 80 % v vsaj eni od metod vzorčenja.

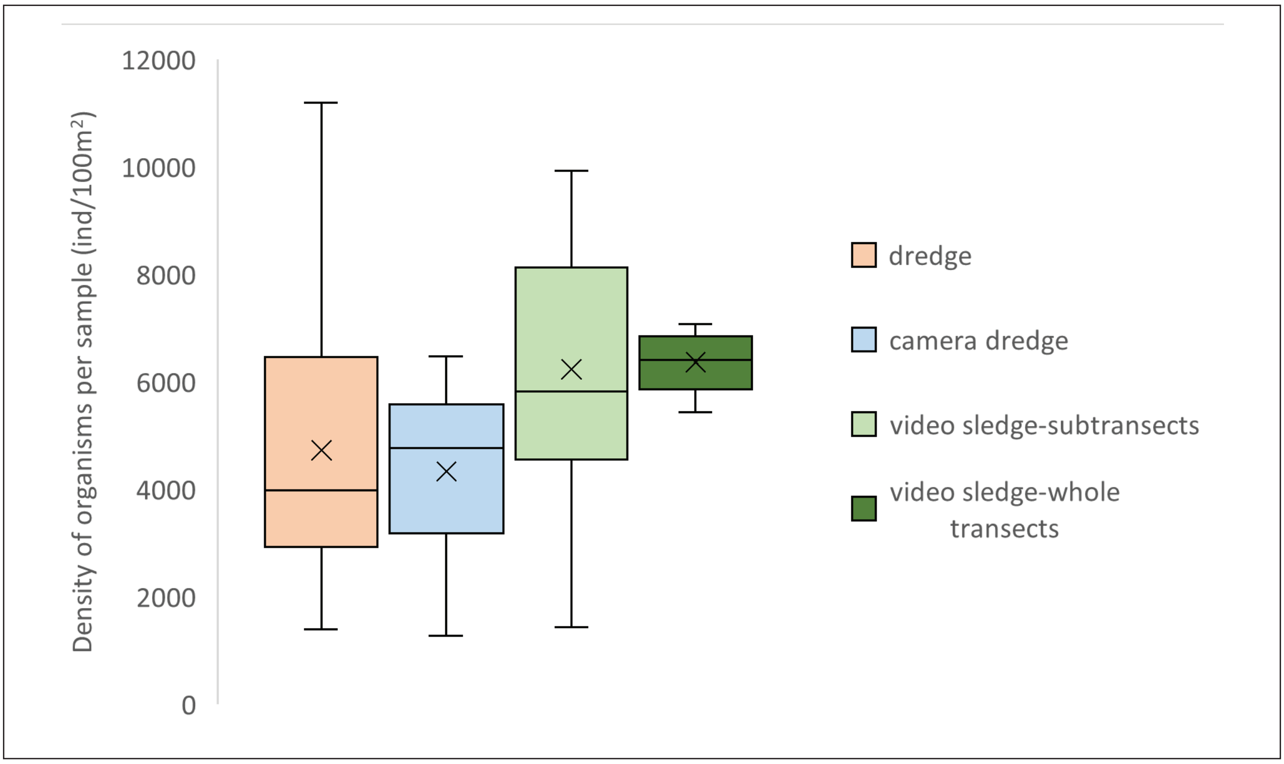

Fig. 7: Densities of organisms (ind./100m²) per sample presented with a box whiskers plot for each of the three methods. For the video sledge two box plots were drawn, one with data obtained per subtransects and the other per whole transects recorded on one site.
Sl. 7: Gostote organizmov (osebkov/100 m²) na vzorec, prikazane z grafikoni kvantilov za vsako od treh metod. Za video sani sta bila izrisana dva grafikona kvantilov, eden s podatki, pridobljenimi na podtransektih, in drugi po podatkih na celotnih transektih, posnetih na enem mestu.

the most dominant species in all three methods. There are two species recorded amongst the most abundant in dredge samples, *Paguristes eremita* and *Pisidia bluteli*, that are not among the most abundant species obtained by video-based methods. Specimens of *P. eremita* are in video-based methods mostly determined as taxon Paguroidea, which is listed amongst the most abundant taxa obtained with both methods. *Pisidia bluteli* on the other hand is a small anomuran that was not at all recorded with video-based methods.

Overall performance of the three methods was assessed based on several criteria presented in the Table 3. The video sledge turned out as the most appropriate method, especially due to its non-destructiveness, highest sampling and analyses efficiency, applicability in a broader range of soft-bottom habitats and highest number of habitat/community parameters that could be assessed. The only drawback in comparison to the dredge sampling were taxa detection and taxonomic precision and reliability, especially with smaller organisms and in cases of lower visibility, which affected video quality.

DISCUSSION

The comparison of three methods proves that dredge sampling, and video-based surveys provide substantially different yet complementary perspectives on soft-bottom epibenthic communities. Dredge sampling yielded the highest number of detected taxa, whereas video-based approaches recorded fewer taxa but provided important insights into spatial patterns and ecological context. These differences reflect inherent methodological biases related to gear selectivity and organism detectability, which have long been recognised in benthic sampling studies (McIntyre, 1956; Uzmann *et al.*, 1977).

Dredge sampling proved particularly effective in detecting small, cryptic, and sediment-associated taxa, including numerous molluscs and crustaceans. This finding is consistent with previous studies highlighting the high taxonomic resolution of destructive sampling methods (Kaiser *et al.*, 2000; Eleftheriou & Moore, 2005). However, the invasive nature of dredging, combined with its limited spatial coverage, constrains its ability to represent habitat heterogeneity and broader community structure. Furthermore, physical disturbance caused by the continuous gear usage may alter benthic assemblages and influence sample composition (Hall & Harding, 1997; Lindegarth *et al.*, 2000).

In contrast, video-based methods showed a clear tendency to detect larger, sessile, and structure-forming taxa, such as sponges and other conspicuous epibenthic organisms. These taxa are often underrepresented in dredge samples due to fragmentation, escape, or loss during sampling. Similar patterns have been reported in visual survey studies, where conspicuous organisms dominate observations (Jorgenson *et al.*, 2011; Flannery & Przeslawski, 2015). In addition, video approaches significantly improve spatial coverage and allow *in situ* assessment of habitat structure and organism interactions. However, they are inherently limited

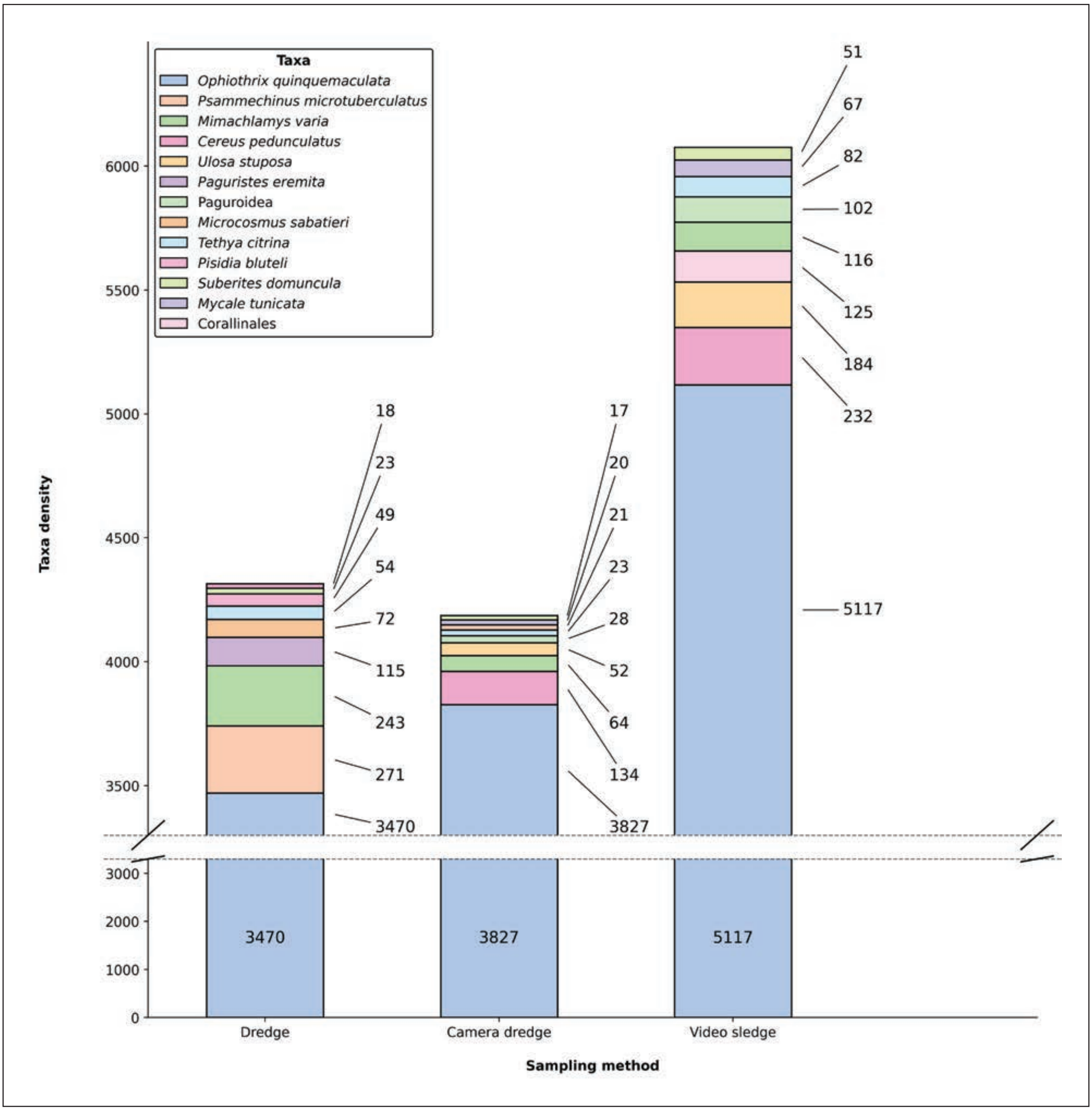

Fig. 8: Densities of individuals (ind./100m²) of the first 9 most abundant taxa for each sampling method.
Sl. 8: Gostote osebkov (osebkov/100 m²) prvih 9 najpogostejših taksonov za vsako metodo vzorčenja.

Tab. 3: Overall assessment of the performance of the three methods.
Tab. 3: Splošna ocena uspešnosti treh metod.

Criteria	Dredge	Camera dredge	Video sledge
Environmental suitability	destructive	semi-destructive	non-destructive
habitat applicability	mobile sedimentary bottoms with a low amount of pelite fraction (<30%); limited use in vulnerable and protected habitats	mobile sedimentary bottoms with a low amount of pelite fraction (<30%); limited use in vulnerable and protected habitats	all mobile sedimentary bottoms
no. of HT and community parameters	5	7	8
sampling efficiency (no. #samples/ fieldwork)	1	1	24
analyses efficiency (no. of hours/#sample)	15	8	8
taxonomy precision	high	lower	lower
taxa detection	high, including smaller cryptic species	low	lower, includes more highly vagile and retractable species
sample storage	hard/impossible (big volume, material, maintenance)	easy (digital data)	easy (digital data)
sample reassessment	hard/impossible	easy	easy

by lower taxonomic resolution and reduced detectability of small or cryptic species (Service & Golding, 2001; Ierodiaconou *et al.,* 2011).

The observed discrepancies among methods highlight the importance of sampling bias in marine benthic ecology. Each method emphasises different components of the community, resulting in method-dependent interpretations of community structure. Dredge sampling primarily captures species richness and biomass of sediment-associated, cryptic and smaller taxa, whereas video surveys emphasise the ecological role of sessile and habitat-forming organisms as well as some highly mobile or retractable. Consequently, reliance on a single method may lead to incomplete or potentially misleading ecological conclusions (Bowden & Hewitt, 2012).

A key outcome of this study is the pronounced complementarity among the two sampling approaches. Each method contributed unique information, with only partial overlap in detected taxa. Dredge sampling accounted for most unique taxa, while video-based methods identified a smaller but distinct subset not captured by dredging. This complementarity clearly indicates that no single method is sufficient for a comprehensive characterization of epibenthic communities.

The integration of destructive and non-destructive approaches therefore provides a more robust and holistic assessment by combining high taxonomic resolution with improved spatial coverage and ecological context (Solan *et al.,* 2003; Jørgensen *et al.*, 2011). Such multi-method strategies have been widely recommended in benthic research to reduce uncertainty in biodiversity estimates and strengthen ecological interpretation (Bowden & Hewitt, 2012).

These findings have direct implications for benthic monitoring programmes. While there is an increasing shift towards non-destructive video and spatially extensive methods such as video surveys, their limitations in taxonomic resolution must be acknowledged. Conversely, dredging provides detailed taxonomical information but is invasive and spatially restricted. A combined methodological framework therefore represents the most balanced approach, enabling both more precise taxonomic assessment and broader habitat evaluation, resulting in better detection of ecological changes and supporting more effective ecosystem-based management strategies. This is even more true for the northern Adriatic Sea, where previous studies have demonstrated high spatial heterogeneity and sensitivity of benthic communities to environmental gradients and human impacts (Fedra *et* *al.,* 1976; Mavrič *et al.,* 2010; Orlando-Bonaca *et al.*, 2012). The experiment with a camera mounted on the dredge did not prove sufficient combination of the two approaches, as the speed needed for a dredge to be effective turned out to be too high for a good quality of the recorded video. Besides this, the spatial extent covered in this way stayed very limited. A separate application of direct sampling and video survey thus seems the most optimal option.

The results also point to the limits of direct comparability. Comparisons among methods are inevitably influenced by differences in spatial extent, taxonomic resolution and the type of data produced by each approach. For video-based methods, image quality, visibility and observer expertise must be considered, because these factors determine whether a given taxon can be recognised and quantified at all. The next logical step is therefore the standardisation of sampling protocols and the development of analytical frameworks that allow more direct integration of physical samples and video records. Recent advances in computer vision provide an important opportunity to improve the efficiency and reproducibility of video-based benthic monitoring, particularly by reducing the bottleneck associated with manual annotation and by supporting automated detection, classification and quantification of benthic organisms in underwater imagery (Service & Golding, 2001; Ierodiaconou *et al.*, 2011; Bowden & Hewitt, 2012; Trotter *et al.*, 2025).

OCENJEVANJE EPIBENTOŠKIH ZDRUŽB MEHKEGA DNA: METODOLOŠKI VPOGLEDI V DREDŽANJE IN VIDEO PREGLEDE

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POVZETEK

Avtorji so primerjali dva pristopa k vzorčenju in oceni epibentoške združbe mehkega dna, vzorčenje z uporabo dredže ter neinvazivne preglede s kamero na dredži in z video sanmi. Vzorčenje je bilo izvedeno na detritičnem muljasto-peščenem dnu. Identificiranih je bilo 171 taksonov, pri čemer je bila med vsemi metodami skupna le manjša podmnožica. Z dredžanjem so dobili najvišje število taksonov, zlasti majhnih, kriptičnih in povezanih s sedimentom, ter podatke o biomasi. Nasprotno so z video metodama ugotovili manjše število taksonov, vendar med njimi več gibljivih vrst, številčno pa so lahko ovrednotili tudi nekatere taksone, kot so spužve. Z video pregledi so zagotovili najobsežnejšo pokritost in največje število parametrov habitata in združb. Ker se pristopa medsebojno dobro dopolnjujeta, je smiselno za celovitejše spremljanje in oceno uporabiti kombinacijo obeh.

Ključne besede: epibentos, cirkalitoral mehkega dna, dredžanje, kamera na dredži, video sani, Jadransko morje

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