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Towed underwater television towards the quantification of Norway lobster, squat lobsters and sea pens in the Adriatic Sea

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Norway lobster, Nephrops norvegicus, *is of great commercial importance throughout the NE Atlantic and Mediterranean, where it lives in burrows within muddy sediments. In several European countries it is assessed by means of towed underwater TV techniques. These are particularly suited to* N. norvegicus *because, for a number of reasons, the application of common fishery-dependent stock-assessment methods is not thorough for this species. The TV-based methodology relies on the fact that a known surface area of seabed is visually assessed and the number of* N. norvegicus *burrows, whose features are distinct, can be counted and their inhabitants quantified. It follows that, in theory, the same can be done for other organisms or key ecological features which appear on the footage. This study reports the results of the underwater television surveys (2009 and 2010) carried out jointly by Italy and Croatia in the Pomo/Jabuka pits, an area of the Adriatic Sea important for its* N. norvegicus *fishery and its hake nursery grounds. The obtained footage allowed quantification of the density of* N. norvegicus *in the area and the acquisition of estimates of the abundances of the squat lobster,* Munida rutllanti *and the sea pen* Funiculina quadrangularis. *The concurrent quantification of trawling activity from the footage has allowed us to place our results in the context of an ecosystem approach to fisheries management.*

Key words: towed UWTV, Norway lobster, squat lobster, sea pen, Adriatic Sea

INTRODUCTION

Norway lobster, *Nephrops norvegicus*, is of great commercial importance throughout the NE Atlantic and Mediterranean.

In the Adriatic Sea *N. norvegicus* ranks first of all crustacean species exploited in terms of value, and second in terms of weight, with a decreasing trend in catches since 1993 (VRGOČ *et al*., 2004). It burrows within muddy sediments at depths between *cca* 50 m and 400 m (ARTEGIANI *et al*., 1979), making the Pomo/Jabuka pits (200 – 270 m) very important fishing grounds in the Adriatic Sea (FROGLIA & GRAMITTO, 1988; FROGLIA *et al*., 1997; MORELLO *et al*., 2007). The western Adriatic Sea trawling grounds have been classified as fully exploited to overexploited with respect to *N. norvegicus* (SARDÀ *et al*., 1998). Furthermore, the Pomo/Jabuka pits, with their particular topography, bottom-sediment composition (fine muddy, sloping down to 270 m) and oceanography fine mud also comprise the main nursery grounds of the commercially important European hake *Merluccius merluccius* (ŽUPANOVIĆ & JARDAS, 1986). For these reasons, the Pomo/Jabuka pits have been the subject of many discussions aimed at establishing them as an area closed to bottom trawling (e.g. ADRIAMED, 2008; DE JUAN & LLEONART, 2010). In this context, careful management of the Pomo/Jabuka pits ground and their main resources are crucial, especially because two mixed-species trawling fleets from two different countries (Italy and Croatia) fish there regularly. Furthermore, the Italian and Croatian grounds share important common characteristics and the *N. norvegicus* populations are, to some extent, interdependent because of larval exchange.

In several European countries *N. norvegicus* is assessed by means of towed underwater cameras (UWTV). This technique is particularly suited to *N. norvegicus* because, for a number of reasons, traditional fishery-dependent stock-assessment methods (e.g. use of catch and CPUE trends or analytical methods such as VPA, LCA and yield-per-recruit analysis) are considered not exhaustive for this species (MORELLO *et al*., 2007). Furthermore this species is caught in fishing gear only when it emerges from its burrow, and emergence may vary with time of day, season, animal size, sex, and reproductive status; thus the fishery exploits the population selectively and in a different manner according to sex and season (MORELLO *et al*., 2009).

The UWTV methodology relies on the fact that a known surface area of seabed is visually assessed and the number of *N. norvegicus* burrows, whose features are distinct, can be counted and their inhabitants quantified. Burrow densities (burrows x m^{-2}) can be used as an index of stock abundance.

This technique, which was pioneered in Scotland, has become the standard method of assessment for NE Atlantic stocks and has received detailed attention in a series of ICES (International Council for the Exploration of the Sea) workshops aimed at standardising methodologies and quantifying the uncertainties associated with the method (CAMPBELL *et al*., 2009).

The Adriatic Pomo/Jabuka pits ground has been the subject of detailed *Nephrops*-centric studies throughout the years (for a summary see MORELLO *et al*., 2007). Pioneering research on *N. norvegicus* ecology and burrows derives both from the former Yugoslavia and Italy (KARLOVAC, 1953; CRNKOVIĆ, 1968; FROGLIA *et al*., 1997), but the stocks have never been the subject of a systematic assessment before the present study.

In May 2009 and August 2010, ISMAR – CNR of Ancona (Italy) and IOF of Split (Croatia) joined forces, under the auspices of the FAO – AdriaMed project (Scientific Cooperation to Support Responsible Fisheries in the Adriatic Sea), in order to carry out an evaluation of the *N. norvegicus* stock in the Pomo/Jabuka pits using the towed UWTV methodology.

The recording of underwater footage using a system set up for the quantification of anything included within the field of view of the camera, lends itself nicely to the collection of corollary ecological data, potentially producing datasets that could be used in the context of an ecosystem approach to fisheries management. The footage could be useful towards carrying out quantitative or semi-quantitative assessments of those species that share the habitat with *N.*

norvegicus. In particular, the assessment of sea pens by means of UWTV has recently been the object of OSPAR (Oslo and Paris Conventions for the protection of the marine environment of the North-East Atlantic) attention, and ICES SGNEPS (Study Group on *Nephrops* Surveys) determined that further studies are needed to determine the potential of such approach (ICES, 2010).

Thus, in order to contribute to the development of this topic, in the Adriatic Sea, the UWTV methodology was used not only to determine *N. norvegicus* burrow densities but also to gain estimates of the abundance of the sea pen *Funiculina quadrangularis* and of the squat lobsters, *Munida* spp.

The sea pen *F. quadrangularis* is distributed throughout the western Atlantic and Mediterranean Sea and often shares its habitat with *N. norvegicus*; it is considered a species sensitive to physical disturbance (e.g. trawling activities; SARDÀ *et al*., 2004; GREATHEAD *et al.,* 2007).

On the other hand the quantification of the squat lobsters *Munida* spp. could be relevant in this area because since 2000, a newcomer, *Munida rutllanti*, made its first appearance in the Pomo/Jabuka pits and in just a few years almost replaced the native, dominant, *M. intermedia* (FROGLIA *et al*., 2010).

Finally, the footage collected in this area was used to quantify the trawl tracks towards developing a proxy for fishing effort which could be incorporated into future assessments on *N. norvegicus*.

MATERIAL AND METHODS

The study area covers all of the Pomo/Jabuka pits, in the central Adriatic Sea, with a total area of about 4800 km^2 (Fig. 1). The UWTV stations were assigned to the study area following a stratified random sampling design with strata defined according to (i) depth: shallow (< 200 m) and deep (> 200 m), and (ii) fishing intensity (this is defined indirectly using the 12 nm line

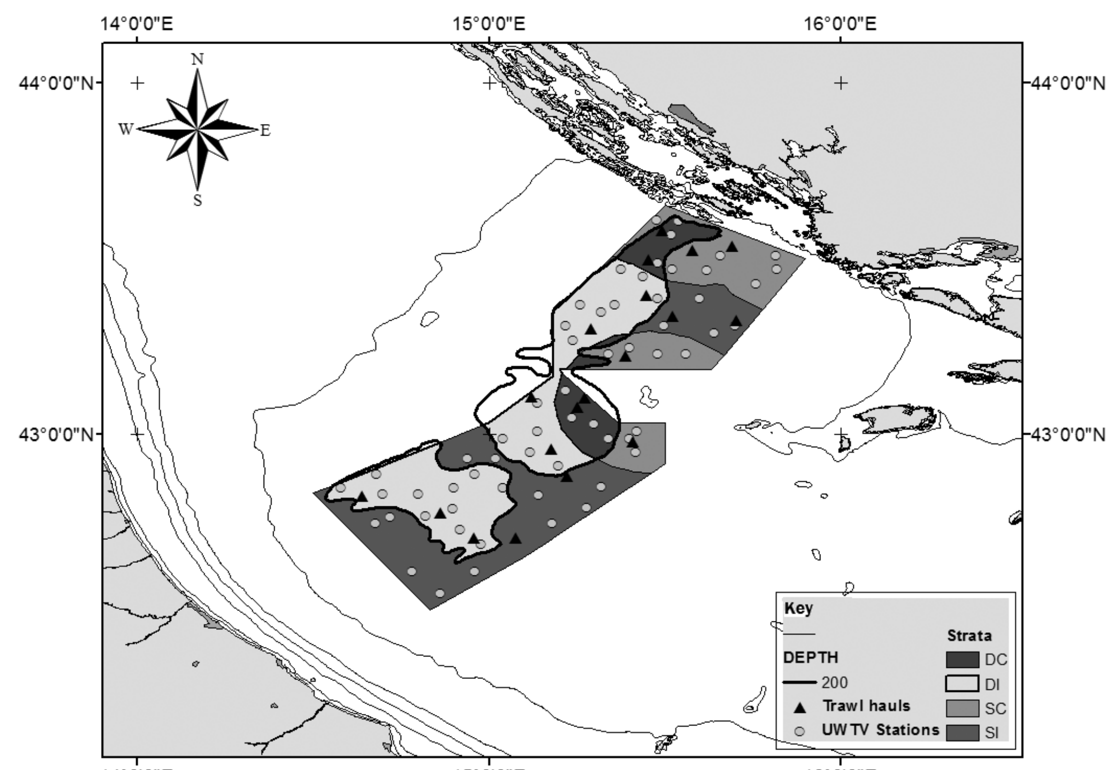

Fig. 1. Survey design: DC = deep Croatian territorial waters, DI = deep international waters, SC = shallow Croatian territorial waters, SI = shallow international waters

delimiting Croatian territorial waters as a proxy based on the hypothesis that less boats operate within the Croatian territory; Fig. 1).

This subdivision resulted in 4 distinct strata:

1. DC: deep Croatian territorial waters
2. DI: deep international waters;
3. SC: shallow Croatian territorial waters; and
4. SI: shallow international waters.

The number of stations per stratum was determined proportionally to the surface area of the stratum for a total of 60 stations.

The UWTV camera (Kongsberg Simrad OE 1364 colour camera) was mounted on a sledge towed on the sea bed at a speed of 1 knot. The field of view of the camera was fixed at 80 cm width. The position of the sledge at each minute was recorded by means of a custom-made data-logger synchronised with the camera deck unit. Each UWTV station entailed an effective towing time of *cca* 20 minutes. The UWTV tows were carried out during day time on board RV Dallaporta (LOA 35.30 m, 258 GT, 1100 HP), on 5-27 May in 2009 and on 6-28 August in 2010.

Analysis of VHS footage and *N. norvegicus* burrow identification and quantification were carried out following ICES protocols (ICES, 2008) by 4 readers in 2009 and 3 readers in 2010; a minimum of 8 ‘good’ (easy to read) minutes per station was fixed as a threshold to accept the validity of each station. Owing to the fact that any resulting burrow count comprises both those burrows that are wholly in the field of view and those that extend from the field of view to adjacent unseen sea bed, a correction factor related to the “edge effect” was calculated for each stratum separately and applied to the data. The edge effect correction was calculated following the ICES “Two pass counting method” (ICES 2010).

The same methodology (with the exception of the edge effect calculation) was applied to *Munida* spp. and *F. quandrangularis*.

In all cases, data regarding absolute numbers per tow and average densities per tow and stratum were obtained.

Trawling activity was quantified by counting the number of trawl tracks (visible as deep furrows caused by the dragging of otter doors) in the footage and using them as a proxy of fishing intensity.

Statistical analyses were conducted separately on the data obtained for the two surveys accounting for the fact that they were carried out in two different seasons (spring 2009 and summer 2010). ANOVA and post-hoc Tukey HSD tests were used to analyse log-transformed data meeting the required assumptions. Trawl track densities were also tested for differences between the two surveys. According to the original plan the 2010 survey was supposed to take place during the closed season (month of August) for the Italian fleet, thus the idea was to observe a different situation than that of a standard fishing month (May 2009). Unfortunately in 2010 the closure was only partial as some important Italian fleets were allowed to fish for socio-economic reasons.

Burrows, *Munida* spp. and *F. quadrangularis* densities were tested for correlation with trawl tracks.

RESULTS

The mean densities (n x m^{-2}) with standard deviation obtained from the footage, for *N. norvegicus* burrows, *Munida* spp., *F. quadrangularis* and trawl tracks, for each stratum in May 2009 and August 2010 are summarised in Table 1, together with the number of valid UWTV stations and the total surface of the seabed inspected (m^2). With regard to *N. norvegicus* burrow densities, percentage “edge effect” corrections, applied to each stratum are shown in Table 2.

In May 2009 *N. norvegicus* burrows densities were significantly higher in DC than DI (ANOVA $F(3,45) = 4.528$, $p = 0.007$; Tukey HSD test $p = 0.015$; Fig. 2A), while in August 2010 no significant differences among strata were found (Fig. 2B).

On a semi-quantitative scale of abundance (ICES, 2010), *Munida* spp. could be classified as abundant (found in almost all frames, in multiples) in 2009, whilst in 2010 it was abundant in some areas but only occasional (*cca* 12 individuals per 10 minute run) in others (Fig. 3A and B).

In May 2009, densities of *Munida* spp. were significantly higher in DC than all other strata

Table 1. Mean density (and standard deviation) of Nephrops norvegicus burrows, Munida spp., Funiculina quandrangularis and trawl tracks counted for each of the four substrata of the 2009 and 2010 surveys of the Pomo/Jabuka pits, Adriatic Sea. Notes: DC = deep Croatian territorial waters, DI = deep international waters, SC = shallow Croatian territorial waters, SI = shallow international waters

Sub-stratum	*Nephrops norvegicus* burrows·m^{-2}	*Munida spp.* number·m^{-2}	*Funiculina quadrangularis* number·m^{-2}	Trawl tracks·m^{-2}	Tot. SA viewed (m^2)	No. stations
			2009			
DC	1.247 (0.457)	0.335 (0.108)	0.001 (0.002)	0.033 (0.026)	1621.30	7
DI	0.898 (0.248)	0.147 (0.084)	0.001 (0.001)	0.043 (0.013)	5265.91	21
SC	1.236 (0.298)	0.169 (0.139)	0.001 (0.003)	0.039 (0.028)	2840.24	12
SI	0.953 (0.265)	0.156 (0.126)	0.016 (0.031)	0.038 (0.019)	2209.96	9
			2010			
DC	1.140 (0.438)	0.147 (0.136)	0.001 (0.001)	0.023 (0.017)	1677.12	7
DI	1.022 (0.269)	0.084 (0.181)	0.001 (0.002)	0.032 (0.019)	4876.12	20
SC	1.347 (0.427)	0.003 (0.006)	0.003 (0.010)	0.043 (0.023)	3126.54	13
SI	1.201 (0.320)	0.004 (0.009)	0.004 (0.011)	0.029 (0.020)	3008.40	12

Table 2. Percentage "edge effect" correction obtained by means of the ICES "Two pass counting method" in 2009 and 2010 footage for each of the four strata: DC = deep Croatian territorial waters, DI = deep international waters, SC = shallow Croatian territorial waters, SI = shallow international waters

Year	DC	SC	DI	SI
2009	27.25%	23.31%	19.92%	16.1%
2010	15.60%	19.53%	18.40%	14.03%

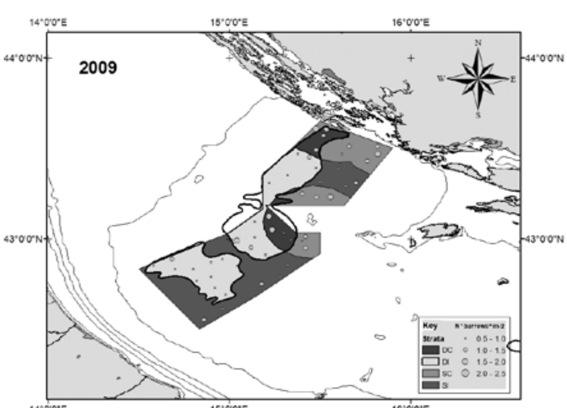

*Fig. 2. A) densities of Nephrops norvegicus burrows (number * m-2) obtained for each UWTV station in May 2009*

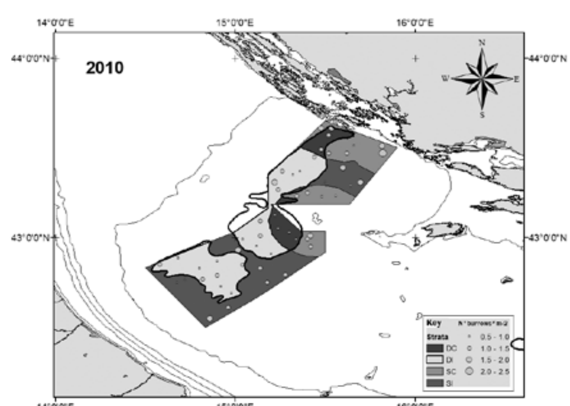

*Fig. 2. B) densities of Nephrops norvegicus burrows (number * m-2) obtained for each UWTV station in August 2010*

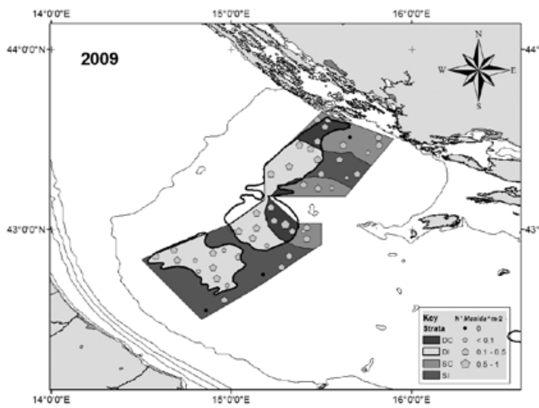

*Fig. 3. A) densities of Munida spp. (number * m-2) obtained for each UWTV station in May 2009*

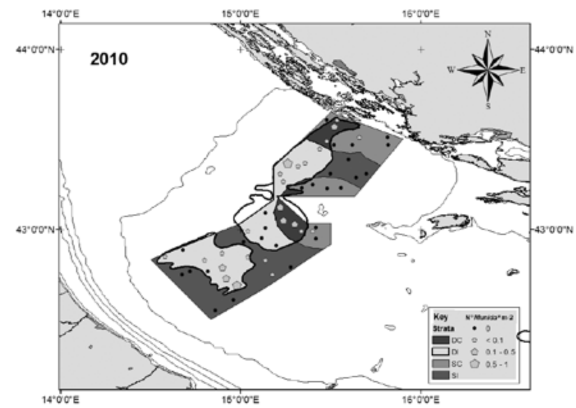

*Fig. 3. B) densities of Munida spp. (number * m-2) obtained for each UWTV station in August 2010*

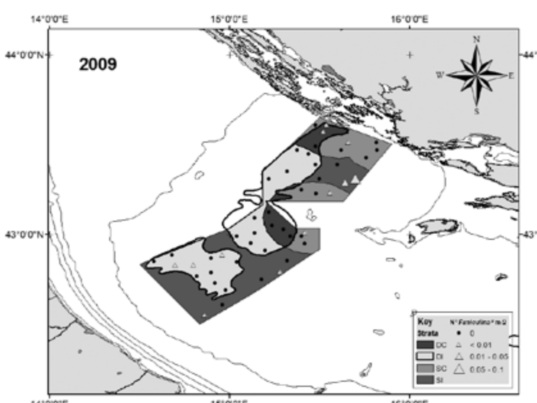

*Fig. 4. A) densities of Funiculina quadrangularis (number * m-2) obtained for each UWTV station in May 2009*

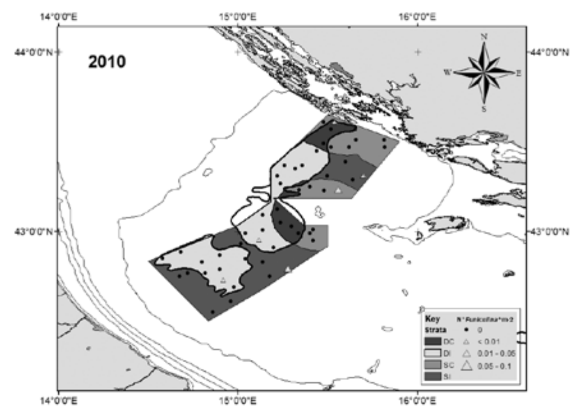

*Fig. 4. B) densities of Funiculina quadrangularis (number * m-2) obtained for each UWTV station in August 2010*

Table 3. Trawl tracks densities versus Nephrops norvegicus burrows, Munida spp. and Funiculina quadrangularis densities: r and p (in brackets) values; no significant correlations were found

Year	N	*Nephrops norvegicus* burrows	*Munida spp.*	*Funiculina quadrangularis*
2009	49	-0.2297 (0.112)	-0.2132 (0.141)	0.0004 (0.998)
2010	52	-0.0066 (0.963)	0.0183 (0.898)	-0.1987 (0.158)

(ANOVA $F(3,45) = 5.126$, $p = 0.004$; Tukey HSD test $p < 0.005$; Fig. 3A), while values of densities obtained for August 2010 did not respect the homogeneity of variances assumption.

Funiculina quadrangularis, on the other hand, was rare (1-5 individuals per 10 minute run) everywhere (Fig. 4A and B). The number of the sea-pens was very low in both years and performed poorly in any comparative analyses.

Both in 2009 and 2010, no significant differences were found in the densities of trawl tracks among strata (Fig. 5A and B); furthermore no significant differences between 2009 and 2010 were noticed.

There were no significant correlations between the density of trawl tracks and those of *N. norvegicus* burrows, *Munida* spp. and *F. quadrangularis* (Table 3).

DISCUSSION

The 2009 and 2010 surveys were exceptional in that the UWTV methodology was extended for the first time to both Croatian and Italian waters. It was therefore important that the analytical approach for the Pomo/Jabuka data was standardised and that the criteria developed in the ICES workshops were applied consistently to the analysis. This effort was done primarily with the aim of making this approach the standard method of *N. norvegicus* abundance estimation in the Adriatic Sea, as it is in the NE Atlantic and the North Sea.

Furthermore the footage produced by the *N. norvegicus* UWTV assessment survey of the Pomo/Jabuka pits (Adriatic Sea) in 2009 and 2010 allowed the quantification of the squat lobsters *Munida* spp., the sea pen *F. quadrangularis* and topographic features (trawl tracks) other than the target *N. norvegicus* burrows, even under poor visibility conditions. In this particular case, the reason why these identifications were possible was related to the ease of recognition of the considered organisms and of the seabed features taken into account: the uniqueness of the squat lobsters shape and their relatively large size, the prior knowledge of the distribution of *F. quadrangularis* compared with other sea pens in the area, together with its large, distinctive and easily recognisable structure, and the distinctiveness of otter door furrows on the seabed. The extent to which footage from UWTV surveys for *N. norvegicus* is suitable for other ecological purposes greatly depends on the organisms/features to be quantified (i.e. their distinctiveness, their relative size and their habits), the quality of footage and the degree of expertise of the viewer. When all these conditions are met simultaneously, this allows for the assessment of accessory species of choice along with the production of quantitative distribution maps even in a historic context if UWTV footage were to be available (ICES, 2010).

CONCLUSIONS

ICES (2011) stated that the use of UWTV footage originally acquired in order to assess *N. norvegicus* populations, should be integrated with further research to establish a better understanding of the relationship between local densities and overall status of other species (sea pens in particular); comparisons between areas impacted by *N. norvegicus* fisheries and unfished areas could be helpful toward this intent.

The quantification of the trawl tracks in the area was trialed with the aim of developing a proxy for fishing effort which could be incorporated into future assessments on *N. norvegicus*. A significantly lower number of tracks was expected in August 2010, in DI and SI strata, because of the closure of trawl fisheries for part of the Italian fleet in that month; but actually the closure that usually takes place in August for harbours from Trieste to Bari, was delayed to September for two of the Adriatic Italian fleets (Pescara and Ortona) which currently fish in the Jabuka Pit area, therefore results obtained are not conclusive. Furthermore, the time of persistence of trawl tracks on the sea bed is not known for this area. Other studies have been carried out on the use of UWTV systems for the quantification of otter doors tracks and estimates of their persistence (SMITH *et al*., 2007), but probably the latter depends greatly on the dynamic conditions of the area and its sedimentology. The use of VMS (Vessel Monitoring System) tracks in conjunction of trawl tracks observations and burrow counts would be useful in order to determine how the vessels exploit the different areas of the fishing ground. Use of VMS signals in order to define UWTV (RUSSO et al., 2013) survey areas and the location of survey stations has already been trialed in other areas like North and South Minch or Devil's Hole in the UK (ICES, 2010); accounting for the fishing effort to whom different areas are subjected, this could in fact be useful in the a priori definition of the strata in this type of survey.

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SAŽETAK

Škamp (*Nephrops norvegicus*) je izuzetno važna gospodarska vrsta koja obitava u rupama u muljevitom sedimentu diljem sjeverno-istočnog Atlantika i Mediterana. Obzirom da uobičajene metode procjene bioloških resursa koje se zasnivaju na ribolovu nisu u potpunosti pogodne za ovu vrstu, nekoliko Europskih zemalja procjene populacije škampa obavlja korištenjem povlačne podvodne kamere. Ova metodologija bazira se na činjenici da škamp u sedimentu iskapa rupe karakterističnog izgleda koje se determiniraju i prebrojavaju vizualnim pregledom snimke dobivene povlačenjem podvodne kamere preko određene površine morskog dna. Teoretski, ova metodologija se može primijeniti i za procjene drugih vrsta ili ekoloških parametara koji su zabilježeni na snimkama. Ova studija iznosi rezultate istraživanja podvodnom kamerom (2009. i 2010. godine) koje su zajednički proveli Italija i Hrvatska na području Jabučke kotline u Jadranskom moru. Ovo područje koje se intenzivno gospodarski iskorištava značajno je kao glavno mrijestilište i rastilište većeg broja pridnenih vrsta, posebno škampa i oslića (*Merluccius merluccius*) Na osnovu dobivenih snimki izrađena je procjena brojnosti i biomase škampa, kao i procjena brojnosti hlapića (*Munida rutllanti*) i morskog pera (*Funiculina quadrangularis*). Istodobna procjena tragova koćarenja zabilježenih na snimkama omogućila nam je da ove rezultate stavimo u kontekst ekosustavnog pristupa gospodarenju bioloških resursa mora.

Ključne riječi: podvodna kamera, UWTV, škamp, hlapić, morsko pero, Jadransko more