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A new design of multi-mesh survey gillnets to sample fish community in the Adriatic Sea

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Three types of multi-mesh benthic survey gillnets were tested for their performance in the uniform muddy bottom habitat of the Bay of Piran. We describe the compared methods, present their positive and negative aspects and suggest a sampling design that could be used with different research goals. The research sampling was performed in winter in the years from 2010 to 2012. The sampling site is situated close to a sea bass rearing fish farm in the Northern Adriatic Sea. With the Nordic 1.5 type nets 5 species were detected compared to the 23 and 20 species detected with the Adriatic 2.5 and 5.0 nets. In the Nordic 1.5 type nets only demersal species were caught and even for those a much greater sampling effort would be required to reach a representative sample. On the other hand, both the Adriatic type nets also caught benthopelagic and pelagic species, and a correlation between net height and size of fish in these two nets was detected. While both the Adriatic type nets proved successful in achieving a representative sample of fish assemblage, the Adriatic 2.5 nets performed better in terms of CPUE and as such also reached a better cost-benefit ratio.

Key words: fish, gillnets, marine reserves, community composition, marine aquaculture

INTRODUCTION

In the Bay of Piran and especially in the Portorož Fisheries Reserve no study of fish community structure has been performed so far although marine fish monitoring programme has been performed in Slovenia since 1995. The perspective of fish monitoring has extended from being mainly focused on stock development to include anthropogenic effects on fish assemblage structure, biodiversity and protection (APPELBERG *et al.*, 2003). A research has been launched in 2010 in the Portorož Fisheries Reserve to determine the effect of the fish farm on wild fish assemblage and its seasonal variability (hereafter CRP).

No single method can reliably depict the composition of an actual fish assemblage; each method induces its own biases (HARMELIN-VIVIEN & FRANCOUR, 1992). Standardized techniques for long-term monitoring and predictions of the size and productive capacity of fish populations, as well as continuous control of their health in a wide context thus are required (NEUMAN *et al*., 1997). In recent years the visual census methods have become widely used (SAMOILYS & CARLOS, 2000; HARMELIN-VIVIEN *et al*., 2008; FERNANDEZ-JOVER *et al*., 2008; DEMPSTER *et al*., 2002; ŠEGVIĆ BUBIĆ *et al*., 2011; VALLE *et al*., 2007). On the other hand, the bottom otter trawl net is also commonly used in marine fish research and monitoring (MACHIAS *et al*., 2004; Mrv otb[1], Medits[2], SoleMon[3]). However, when low visibility prevents the use of visual counts and the buoys, mooring blocs and ropes prevent the use of conventional fishing gear close to the fish farm, a different approach is needed.

In the Eastern Adriatic, littoral fish assemblages are examined and fish resources monitored by multiple sets of trammel nets (MATIĆ-SKOKO *et al*., 2011; STAGLIČIĆ *et al*., 2011). These nets and their biological impact have been studied on different occasions by JARDAS & PALLAORO (1991a, 1991b) in the Croatian coastal seas. In the Baltic Sea both, population monitoring and collection of fish for analytical purposes are done by means of fishing using established methods – gillnets and fyke nets (THORESSON, 1996; NEUMAN *et al*., 1997). Besides, freshwater lake and accumulation monitoring throughout Europe is done with the Nordic 1.5 multi-mesh survey gillnets defined in the European Standard (SIST EN 14757: 2005). Considering these information, the results of a preliminary sampling and interviews with the local fishermen a new type of nets named Adriatic 5.0 was designed. These nets were used in the CRP survey with success and were put forward as a possible candidate for marine fish monitoring (PENGAL, 2013).

Detection of methodological biases is of prime importance and can be achieved by comparing different sampling techniques (HARMELIN-VIVIEN & FRANCOUR, 1992). Our preliminary samplings did not give enough data to prove the inefficiency of the Nordic 1.5 nets under the specific restraints and conditions of the survey. Secondly, the use of the Adriatic 5.0 nets raised a question of optimal net height in terms of cost-benefit ratio (PENGAL, 2013). Thirdly, studies including simultaneous diurnal fish sampling with different gears help us to understand, when it is profitable to use a certain method and how the methods can supplement each other (OLIN & MALINEN, 2003). Consequently, we decided to test the three net types potentially useful for monitoring.

The goal of this survey was to develop a new, Adriatic type of benthic multi-mesh survey gillnet by adapting the Nordic 1.5 and Coastal survey nets used in Europe to suit the specific conditions and constraints of our study area and purpose. These survey nets were not only designed to estimate the impact of aquaculture on the wild fish assemblage where environmental and anthropogenic factors prevent the use of conventional fishing methods and visual counts, but they also enable population monitoring and sampling of fish in all the oligotrophic coastal seas with low visibility and unstructured bottom.

MATERIAL AND METHODS

Sampling site

The studied area is situated in the southern part of the shallow Gulf of Trieste, which is the northern most part of the Adriatic Sea (Fig. 1). The sampling site is specific in that the fish farm lies within the Portorož Fisheries Reserve inside the Bay of Piran. The Bay of Piran is a 7 km long and 5 km wide submerged valley of the Dragonja River. Its bottom is gently dropping towards the open sea to depths of up to 20 m. Larger part of the bay belongs to the infralittoral zone with typical flat muddy bottom, composed of clayey silt (OGORELEC *et al*., 1991), while the rest of the habitat types are limited to small dispersed areas (LIPEJ *et al*., 2005).

The sampling location at the fish farm Fonda is located on the southern side of the Seča peninsula, in front of the Sečovlje saltpans (Fig. 1). The fish farm encompasses an area of 4 hectares with an annual production of approximately 50 tons of the European sea bass, *Dicentrarchus labrax*. The fish farm impacts the benthic community in the form of uneaten fish food or fish feces, but only up to a few tens of meters (GREGO *et al*., 2009). The nets were set right next

[1] Monitoring of fishery resources with bottom otter trawl
[2] International bottom trawl survey in the Mediterranean
[3] Rapido trawl survey in the Northern Adriatic Sea

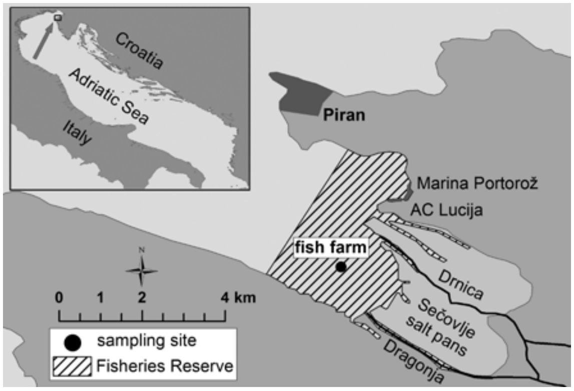

Fig. 1. The sampling site in the Piran Bay and the location in the Adriatic Sea. Cartography and Map Design: FRIS, 2013. Map Source: GURS, 2009

to the mariculture area limits which means less than 100 m from the cages. The water depth at sampling was 12,35 m ± 0,35 m and the sea temperature in the sampling period was 14,42 ± 1,51°C.

Sampling methods

Estimates of wild fish populations are subject to method specific biases and limitations (HARMELIN-VIVIEN *et al*., 1985). A decision was made to test the Nordic 1.5 survey nets because they have already been used in freshwater research in Slovenia and so they were readily available. Moreover, the Nordic 1.5 survey nets were developed to enable the acquisition of the best possible data when sampling all freshwater fish species in Scandinavian countries (APPELBERG *et al*., 2000), whereas their modification was suggested as an alternative method for monitoring the Baltic Sea (APPELBERG *et al*., 2003).

The benthic Nordic 1.5 survey nets are 30 m long and 1.5 m deep, composed of 12 2.5 m long panels with different mesh sizes (Table 1; SIST EN 14757: 2005).

The Adriatic survey nets were designed by studying and adapting the different types of multi-mesh survey gillnets in use throughout Europe. These nets are 200 m long with 10 panels, each 20 m long and with different mesh sizes (Table 1). In comparison to the Nordic 1.5 nets the Adriatic type nets lack 2 of the smaller mesh sizes (5 mm and 8 mm), in some panels thicker or thinner nylon thread is used and the panels have a slightly different mesh sizes that were selected according to their availability on the market. Two types of the Adriatic nets were tested in the survey, differing only in their height which is 5 m and 2.5 m (named Adriatic 5.0 and Adriatic 2.5).

Sampling design

For our purpose of comparing the three different net types, the most widely distributed habitat and depth stratum was selected although it is not the most densely populated. The nets were set at the depth of 12 to 13 m. On the basis of preliminary study we decided to do all the sampling in November and December when the abundance was said to be very low for this area, and thus the minimum required effort to reach a representative sample, even at times of low abundance, could be determined. Further to the protocol, nets have to be set at the sampling location in the 2 hour period before sundown and lifted in the 2 hour period after sunrise. This limits the preying on and decomposition of the caught fish on the one hand, and encompasses the diurnal migration time of most fish species on the other.

To compare the different net types, the nets were set on 4 different occasions at a predetermined sampling location around the fish farm

Table 1. Comparison of the arrangement, mesh sizes and nylon diameters in the two types of survey gillnets used in the survey. The adaptations are marked in grey

Nordic 1.5 Survey net (SIST EN 14757: 2005**)**												
mesh size [mm]	43	19.5	6.25	10	55	8	12.5	24	15.5	5	35	29
nylon diameter [mm]	0.20	0.15	0.10	0.13	0.23	0.10	0.13	0.16	0.15	0.10	0.20	0.16
Adriatic Survey net												
mesh size [mm]	42	20	6.5	10	55	/	12	24	16	/	35	30
nylon diameter [mm]	0.20	0.15	0.10	0.10	0.25	/	0.12	0.18	0.15	/	0.20	0.18

following the protocol. During the setting of the nets, exposure time, position of the nets and abiotic factors important for fish ecology were recorded. Caught fish were determined to species level, measured to the nearest millimeter (total length – TL) and weighed. In total, 14 Nordic 1.5 type nets and 4 of each of the Adriatic 2.5 and Adriatic 5.0 type nets were set. The mean exposure time was 16.6, 17.1 and 16.9 hours for the Nordic 1.5, the Adriatic 2.5 and the Adriatic 5.0 type nets respectively. The 5 mm and 8 mm mesh size panels in the Nordic 1.5 nets were omitted from the analysis of the results, and only the mesh sizes corresponding to those in the Adriatic type nets were compared.

The species composition was compared in terms of presence, incidence, length-frequency distribution and environmental category. The environmental categories were defined as demersal, pelagic and benthopelagic. The length and biomass structure of the catch were inspected by arranging all the recorded species in three size classes according to their maximum known length. Furthermore, for all the three net types the catch per unit of effort (CPUE) was calculated in terms of abundance (NPUE – number per unit of effort) and biomass (BPUE – biomass per unit of effort) for all panels, nets and sampling occasions. Because of the uneven vertical fish distribution we could not use the surface but rather selected 100 m and one day (24 h) as our unit of effort. The CPUE parameters were calculated to 24 h to remove any bias due to diurnal fish migrations. The consequence of small sample sizes is large variability of results, so non-parametric significance tests were chosen as the most appropriate for statistical analysis. We used SPSS program to test the results with the chi-square test of homogeneity and the Man-Whitney-Wilcoxon test.

RESULTS

In total, 29 fish belonging to 5 species and weighing 1.12 kg were collected from the Nordic 1.5 type nets, 176 fish belonging to 23 species, weighing 12.57 kg from the Adriatic 2.5 and 190 fish belonging to 20 species, weighing 36.06 kg from the Adriatic 5.0 type nets. For the Nordic 1.5 type nets only abundance and biomass in terms of CPUE were compared.

Species and size composition

In the study 31 species were recorded, out of which 13 species were represented by only 1 individual and another 10 species were represented by less than 10 individuals (Table 2). The mean number of species per sampling was equal (11 species) for both the Adriatic type nets, but only 1 for the Nordic 1.5. The cumulative number of species is presented in Fig. 2.

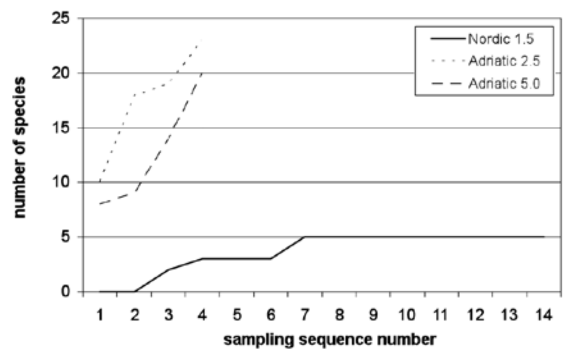

Fig. 2. Cumulative number of species in the catch of the three net types

In the Nordic 1.5 nets predominantly smaller and more abundant species were caught (Table 2). As expected, most of the caught species were demersal, but we also detected exceedingly high number of pelagic species in the Adriatic type nets (Fig. 3). With the exception of *E. encrasicolus* all the pelagic species (80%) were only present in 25% of the samplings with

Fig. 3. Proportion of demersal and pelagic fish species in the catch from the three net types

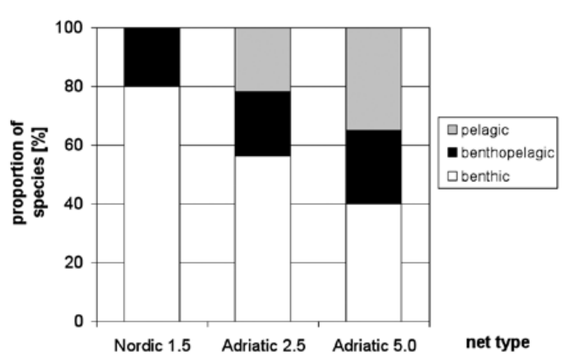

Table 2. The list of A (abundance in n° of individuals) and P (proportion of abundance in %) for the species caught with each net Type

	Nordic 1.5		Adriatic 2.5		Adriatic 5.0	
Species	**A**	**P**	**A**	**P**	**A**	**P**
Alosa fallax	0	0.00	0	0.00	1	0.53
Atherina boyeri	17	58.62	45	25.57	53	27.89
Atherina hepsetus	0	0.00	1	0.57	0	0.00
Boops boops	0	0.00	2	1.14	5	2.63
Buglossidium luteum	0	0.00	4	2.27	0	0.00
Campogramma glaycos	0	0.00	1	0.57	1	0.53
Chelidonichthys lucerna	0	0.00	0	0.00	4	2.11
Chelon labrosus	0	0.00	2	1.14	1	0.53
Dicentrarchus labrax	0	0.00	6	3.41	22	11.58
Diplodus annularis	3	10.34	29	16.48	2	1.05
Engraulis encrasicolus	0	0.00	31	17.61	14	7.37
Gobius niger	2	6.90	11	6.25	7	3.68
Liza aurata	0	0.00	6	3.41	41	21.58
Liza ramado	0	0.00	0	0.00	2	1.05
Merlangius merlangus	6	20.69	18	10.23	12	6.32
Mullus barbatus	0	0.00	1	0.57	0	0.00
Mullus surmuletus	0	0.00	1	0.57	0	0.00
Pagellus acarne	0	0.00	0	0.00	1	0.53
Pagellus erythrinus	0	0.00	4	2.27	2	1.05
Pomatoschistus sp.	0	0.00	0	0.00	1	0.53
Sardina pilchardus	0	0.00	0	0.00	1	0.53
Sarpa salpa	0	0.00	1	0.57	0	0.00
Sciaena umbra	0	0.00	1	0.57	0	0.00
Scorpaena porcus	0	0.00	1	0.57	0	0.00
Serranus hepatus	1	3.45	0	0.00	1	0.53
Solea solea	0	0.00	1	0.57	0	0.00
Sparus aurata	0	0.00	2	1.14	0	0.00
Sprattus sprattus	0	0.00	0	0.00	1	0.53
Torpedo marmorata	0	0.00	6	3.41	0	0.00
Trachurus mediterraneus	0	0.00	1	0.57	18	9.47
Trachurus trachurus	0	0.00	1	0.57	0	0.00
TOTAL	**29**	**100.00**	**176**	**100.00**	**190**	**100.00**

the Adriatic 2.5 nets, whereas in the Adriatic 5.0 nets 42.86% of pelagic species were constantly present in the catch and 57.14% were rare, present only in 25% of the samplings.

The difference in species environmental category was confirmed by a chi-square analysis for the Nordic type nets with a significance level of $\alpha < 0.001$. The same comparison of both the Adriatic type nets only confirmed the difference when we tested the proportion of abundance for the species of the different environmental categories, but not for the species number itself. The significance for the first instance was $\alpha < 0.001$ and for the second $\alpha < 0.2$.

With the Nordic 1.5 type nets no fish were caught in the two largest mesh panels. Because of the low abundance in the Nordic 1.5 type nets, the length-frequency distribution was analyzed in 20 mm length-classes (Fig. 4). The distributions were similar in that all of the nets showed at least two peaks in abundance of length-classes.

With the difference in relative fishing effort between net types in mind, the absolute frequen-

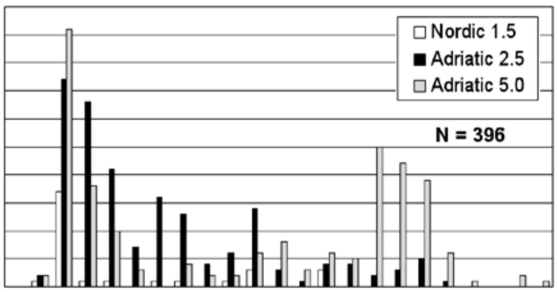

Fig. 4. Length-frequency distribution of the catch in all three types of survey nets used

cies were extrapolated to NPUE with 100 m and 24 hours as the unit of effort. Hence, the ratio of frequencies between the nets was expected to be 1.5 : 2.5 : 5.0. However, due to the uneven distribution of fish in the water column this is not so. In most of the length classes (72.22%) the frequencies were relatively higher than expected in the Adriatic 2.5 compared to the Nordic 1.5 nets. On the other hand, the comparison of the Adriatic 5.0 and the Nordic 1.5 nets showed a superior performance of the first for the larger length classes and of the second for the smaller length classes. The comparison between both the Adriatic type nets confirmed the better relative efficiency of the Adriatic 5.0 nets in sampling the larger length classes. On the one side, we found that overall the Adriatic 2.5 nets caught more fish in 71.43% of the length classes. In contrast, the Adriatic 5.0 nets performed better than expected in all of the largest third of the length classes. However, the positive deviations in large length classes for the Adriatic 5.0 nets were much smaller than the negative deviations in small length classes, so the overall performance was better with the Adriatic 2.5 nets.

The Mann-Whitney-Wilcoxon test, carried out on absolute total lengths of individuals, confirms the observed difference in frequency distributions between all the three net types with significance level of $\alpha < 0.001$.

When analyzing the length-frequency distributions, a correlation between size of fish and net height was detected. To check this correlation all the caught species were arranged in three size classes according to their maximum length. This analysis showed that the Nordic 1.5 type nets mostly caught small species with limited mobility (Fig. 5). Both the Adriatic type nets caught a similar proportion of species from all the three size classes with the most even distribution recorded in the Adriatic 2.5 type nets. Taking into account the abundance of the individuals for each species, similar results as with the proportion of species were determined for the Nordic 1.5 and the Adriatic 5.0 type nets. On the contrary, the Adriatic 2.5 nets showed quite a different result with very few medium size individuals and a large proportion of individuals belonging to the small species.

A chi-square test of homogeneity on the number of species in each length class confirms the difference between the Nordic 1.5 and the Adriatic 2.5 nets (significance level $\alpha < 0.001$), but fails to do so when comparing both the Adriatic type nets (significance level $\alpha < 0.3$). However, when the number of individuals in the species length categories is taken into account, the difference is significant ($\alpha < 0.001$) in both of the above comparisons.

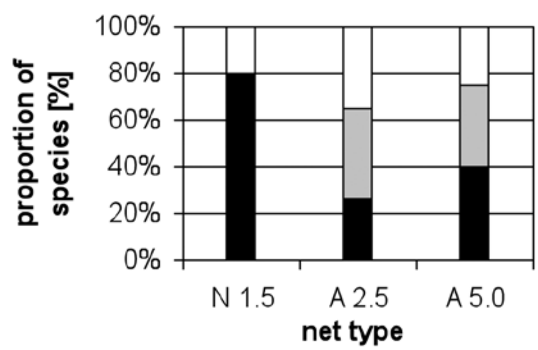

Fig. 5. Proportion of caught species from the three size classes for the three net types

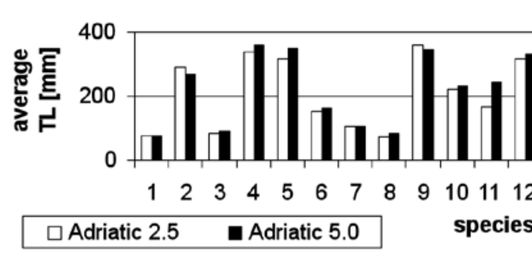

Fig. 6. Mean total length of individuals by species and net type. Numbers represent the following species: 1 – A. boyeri, 2 – B. boops, 3 – C. glaycos, 4 – C. labrosus, 5 – D. labrax, 6 – D. annularis, 7 – E. encrasicolus, 8 – G. niger, 9 – L. aurata, 10 – M. merlangus, 11 – P. erythrinus, 12 – T. mediterraneus

Additional analysis by species revealed that of the 12 species caught in both the Adriatic type nets, 75% had higher mean total length and 91.67% species had higher mean biomass in the Adriatic 5.0 nets (Fig. 6). This analysis was not possible for the Nordic 1.5 type nets due to their low total abundance by species.

Catch per unit of effort (CPUE)

The small number of samples resulted in high variability of NPUE and BPUE, so the analysis of means had to be considered with caution and information from individual values and trends had to be relied on (Fig. 7 and Table 3). Standard deviation of NPUE in all the three net types was similar, whereas large differences were detected in standard deviations of BPUE with the Nordic 1.5 nets varying the least and the Adriatic 5.0 nets showing the largest variations (Table 3). The Nordic 1.5 nets reached the minimum calculated values of both, the NPUE and BPUE, since we found them to be empty on several occasions. The maximum calculated NPUE (54.99 ind.) value was reached by the Adriatic 2.5 nets and the maximum calculated BPUE (4.14 kg) value by the Adriatic 5.0 nets.

A significant difference (α=0.018 and α=0.007) was confirmed for the NPUE and BPUE respectively by a Mann-Whitney-Wilcoxon test of the difference between the Nordic 1.5 and the Adriatic 2.5 type nets. On the other hand, the difference between both the Adriatic type nets was significant only for the BPUE (α=0.043), whereas for the NPUE it was completely rejected (α=1.0).

When comparing the NPUE by mesh panel we found that the Nordic 1.5 and the Adriatic 2.5 nets achieved similar success in the smallest four panels. In the same panels the Adriatic 5.0 nets showed lower NPUE. The transition occured between size 16 mm and 20 mm mesh panels, after which both the Adriatic net types reached higher NPUEs compared to the Nordic 1.5. Similar results were calculated when comparing the BPUE by mesh panel. All the three net types achieved similar success in the small mesh size panels. The Adriatic 5.0 nets started with relatively low BPUE compared to the Adriatic 2.5 net type, but increased their performance with increasing mesh sizes. The Nordic 1.5 type nets were catching comparatively well up to the mesh size 16 mm, but declined drastically in relative success after that. The Adriatic 2.5 nets caught better with the smaller mesh panels and worse with the larger mesh panels compared to the Adriatic 5.0 nets, although the difference was not pronounced.

Additionally, CPUE for each caught species was calculated in the Adriatic type nets to

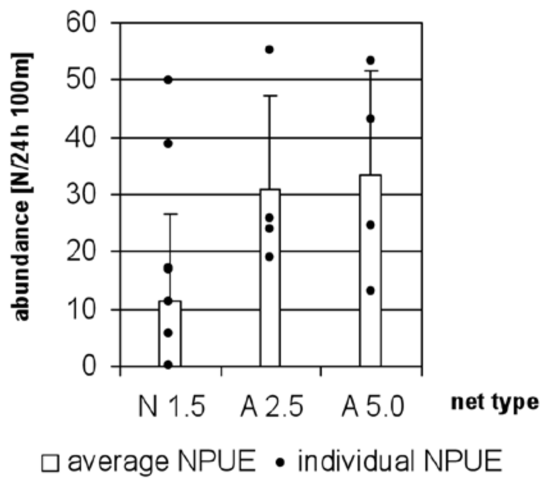

Fig. 7. Mean NPUE for the three types of nets. The error bars represent positive standard deviation and dots represent individual values

Table 3. Catch per 100 m of net and day (24 hrs) in terms of mean abundance and biomass with standard deviation and variance

Net type	mean NPUE [N $24h^{-1}$ $100m^{-1}$]	SD	σ^2	mean BPUE [kg $24h^{-1}$ $100m^{-1}$]	SD	σ^2
Nordic 1.5	11.50	15.23	231.95	0.44	0.65	0.43
Adriatic 2.5	30.85	16.35	267.18	2.20	1.32	1.74
Adriatic 5.0	33.46	18.14	329.06	6.36	3.61	13.01

see if any of the caught large species was to be expected in the Nordic 1.5 type nets. Of the 6 species that were expected but not actually caught, 2 were benthic, 1 was benthopelagic and 3 were pelagic.

DISCUSSION

In abundance studies certain restrictions and priorities must be made depending on the demands of the statistical tests and according to cost-efficiency analyses (NEUMAN *et al*., 1997). In this study, the relative effort applied with the Nordic 1.5 type nets was only half of that applied with the Adriatic type nets in terms of net length.

Sampling strategy

The result of fish sampling using passive gears to a large extent is determined by water temperature, life history and time for spawning of specific fish species (SIST EN 14757: 2005). The horizontal distribution is mostly influenced by habitat heterogeneity and meteorological factors. The sampling period therefore has to be chosen in such a way that each single species is neither over- nor under-represented in the catch (SIST EN 14757: 2005). Fish activity changes diurnally (HELFMAN, 1981) and affects the encounter probability in passive gears (OLIN & MALINEN, 2003). Migrations of various types between shelter locations, where they rest, and feeding grounds are a major element of the transition periods (HOBSON *et al*., 1972). On the other hand, the longer the nets are in the water, the more chance exists for the caught fish to degrade or be fed on by predators, so the exposure time should be as short as possible. Consequently, the protocol, set in our research, requires that all the sampling activity has to be completed and the sampling team has to leave the sampling site 1 hour before sunset and arrive at the site no sooner than 30 minutes after sunrise.

Because of their small size the Nordic 1.5 type nets are easy to handle on the water and take less emptying time. In our experience, a team of 6 people can successfully process 15 nets per day. However, the total catch of fish from the Nordic 1.5 type nets shows that to reach a representative sample of fish in a given marine area the effort would have to be far too great and spread over at least 5 nights to be appropriate for regular monitoring or comparative study. The sampling strategy based on repeated sampling of the same stations over six nights, have in some areas shown to cause depletion of local fish populations during fishing (APPELBERG *et al*., 2003). The nets are also expensive and only available from one known distributor in Europe.

On the other hand, because the netting used in the Adriatic survey nets is also used in commercial fishery, these nets can be ordered from any local net distributor. Their size and wider netting availability further result in their lower market values. Handling can be a problem in bad weather or with inexperienced staff. Further to handling, the collecting of fish obviously takes longer for the Adriatic type nets and so 2 nets per day is the most a team of 6 people can successfully process. For all the net types tearing presents a dilemma in terms of spending valuable research time for sewing vs. spending funds on obtaining new nets. The problem also arises with setting the limit when a net is torn to the level at which its catchability is overly affected.

Species and size composition

The Nordic 1.5 type nets correspond to 9% and 4.5% of the net surface of the Adriatic 2.5 and 5.0 nets, so the relative effort of one net night is much higher for the Adriatic type nets and this should be kept in mind throughout the results analysis. In combination with the preliminary sampling results the slow rise of cumulative number of species in the Nordic 1.5 type nets suggests that there are additional benthic species these nets could record. However, the minimum required sampling effort to detect them would have to be much greater and only further research could determine it. All of the species caught with Nordic type nets were also caught with the Adriatic type nets. Conversely, there were 10 species caught only with the Adriatic 2.5 nets and 6 species only with the Adriatic 5.0 nets. These results show that the Nordic 1.5

type nets are selective for a limited set of species and as such cannot give a sound estimate of the whole fish community in the specific conditions of our sampling area.

A comparison with the list of species from the Fisheries Resources Monitoring Programme (MARČETA, 2012; hereafter: FRM) indicates the potential of the Adriatic type nets to reach a representative sample of species with only a small increase in sampling effort and a stratified sampling strategy. Overall, there are 18 species (50% of all recorded with FRM) that were not detected with the Adriatic type nets and this is attributable to the fact that the FRM has been performed in the open sea, whereas our sampling location is deep inside the bay. Excluding rare species from the FRM list only 7 species remain that we did not detect. On the other hand, there are 13 species that we caught in the Adriatic type nets, but are not on the FRM list. So, despite the fact that we did not reach an asymptote of cumulative number of species with either of the Adriatic type nets, the comparison with the FRM list of common species in Slovenian coastal seas suggests that we could reach the platform with very few additional samplings.

Fish are usually not randomly distributed over a lake (APPELBERG *et al*., 2000) which also holds true for the marine environment. There is a correlation between net height and proportion of demersal and pelagic species in the catch. In the 12 m water column of the surveyed location the three net types cover different proportions of the column which has a great effect on the difference of the catch quantity and composition. Because benthopelagic and pelagic species swim higher in the water column they were caught in the Adriatic type nets, but not in the lower Nordic 1.5 type. To quantify the difference between the Adriatic type nets and to determine the minimum sampling effort for monitoring, additional sampling is needed, at least to a degree that the cumulative number of species levels off.

The size of fish caught in multi-mesh gillnets is strongly dependent on mesh size combination used (APPELBERG *et al*., 2003). The size distribution estimates are skewed because small individuals move less and when encounter the net are caught less effectively due to slower speed and lower flexibility of small mesh sizes (OLIN & MALINEN, 2003). In all but one panel the length interval of fish was larger in both the Adriatic type nets than in the Nordic 1.5 type, which suggests that the smaller length classes are caught with equal success in both net types. However, the detailed analysis of fish length by species has shown a possible correlation of size of caught species and the net height, with the Nordic 1.5 type nets catching the smallest species.

The length-frequency distribution analysis confirms the suggested correlation by showing that the frequency of larger length classes is relatively higher for the Adriatic type nets. This confirms that the vertical distribution of species in the water column prevents the Nordic 1.5 type nets from reliably estimating species and size composition of fish community in the marine environment. Furthermore, the differences in the Adriatic type nets are small and only suggest a correlation which could be detected by a survey specifically designed for this purpose.

To sum up, in the Nordic 1.5 type nets predominantly demersal, small and species that are common in Slovenian coastal seas (BIOS, 2012) were caught. On the other hand, the Adriatic type nets also caught considerable amount of pelagic, larger and rare species, which results in better estimate of fish community structure in terms of species and length distribution. The Nordic 1.5 type nets are not suitable to determine the species composition of marine fish community in the specific conditions of the Gulf of Trieste because they are selective for a limited set of fish species and sizes. Finally, the Adriatic nets proved to be more successful in determining the fish community structure in the specific conditions of the muddy bottom habitat of the research area. The Adriatic 2.5 type nets achieved the optimal results in most of the analyses. All of the conducted analyses confirmed that distribution of fish in the water column has a significant effect on the performance of the different net types. Thus, when the goal of a survey is to estimate a whole fish community, either benthic sampling with the Adriatic 5.0 nets or concurrent benthic and pelagic application of the Adriatic 2.5 nets would probably result in the best estimate. Nevertheless, to develop a monitoring programme based on sampling with multi-mesh survey nets, additional experimental sampling is needed. This survey gives a good starting point on the research questions to be answered and a sound base on which effective design of such surveys can be developed.

Catch per unit of effort (CPUE)

The comparison of CPUE shows that the Adriatic 2.5 nets are the most effective. The Nordic 1.5 nets scored the worst, beating only the Adriatic 5.0 nets in terms of mean NPUE. With the exception of mean BPUE the Adriatic 2.5 nets preformed best in all other mean CPUE comparisons against both the other net types. In between were the Adriatic 5.0 nets that sampled the worst in terms of mean NPUE. The only difference between the Adriatic type nets is in the net height, so if the fish were uniformly distributed in the water column, we would expect the CPUE to be equal for both the Adriatic type nets. However, the CPUE relationship indicates that there was a corridor in the water column where most of the fish were caught and that its upper limit was around 2.5 m above the bottom. Additional comparison sampling is advised to determine the optimum height of the Adriatic sampling nets so that the best cost-benefit ratio would be achieved.

Further analysis of CPUE per mesh panel confirmed the differential catchability of fish size classes between the net types. The CPUE data by panel shows that the Nordic 1.5 type nets caught the small size classes quite well but performed considerably worse concerning the large classes, which means they give a biased estimate of the sampled fish community. The difference between the Adriatic type nets is less pronounced. Though the Adriatic 2.5 nets generally perform better in both NPUE and BPUE as far as the smaller mesh panels are considered, the BPUE is higher for the Adriatic 5.0 nets in the larger mesh panels. The NPUE of larger mesh panels is similar for both Adriatic net types. These results suggest that larger mesh panels perform better in the higher nets but further research would be required to determine if this trend in fact exists.

CONCLUSIONS

Overall, our survey proves that the Nordic 1.5 type nets are not suitable for fish community research in the specific conditions of homogenous flat muddy bottom habitat. They underperformed in all the comparative analyses against the Adriatic type nets. On the other hand, we failed to confirm significant differences between both of the Adriatic net types in almost all of the comparisons. Our data indicates that the Adriatic 5.0 nets are more effective in catching larger and pelagic fish, whereas the Adriatic 2.5 nets perform better in terms of CPUE and as such also reach a better cost-benefit ratio. This makes them the method of choice for monitoring purposes although we suggest a combination of benthic and pelagic applications for wider species coverage.

Finally, the Adriatic nets proved to be effective in determining the fish community structure in the specific conditions of our survey. Our results give a good starting point for focusing future research effort by raising specific questions and indicating difficulties encountered during the survey.

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REFERENCES

APPELBERG, M., G. JOHANSSON & S.F. HAMRIN. 2000. Swedish standard methods for sampling freshwater fish with multi-mesh gillnets. Fiskeriverket Information, 1. 33 pp.

APPELBERG, M., M. HOLMQVIST & G. FORSGREN. 2003. An alternative strategy for coastal fish monitoring in the Baltic Sea. ICES Annual Science Conference, Tallinn, Estonia, 24-27. Sep. pp. 13.

DEMPSTER, T., P. SANCHEZ-JEREZ, J.T. BAYLE-SEMPERE, F. GIMENEZ-CASALDUERO & C. VALLE. 2002. Attraction of wild fish to sea-cage fish farms in the south-western Mediterranean Sea: spatial and short-term temporal variability. Mar. Ecol. Prog. Ser., 242: 237-252.

FERNANDEZ-JOVER, D., P. SANCHEZ-JEREZ, J.T. BAYLE-SEMPERE, C. VALLE & T. DEMPSTER. 2008. Seasonal patterns and diets of wild fish assemblages associated with Mediterranean coastal fish farms. ICES J. Mar. Sci., 65:1153-1160.

GREGO, M., M. DE TROCH, J. FORTE & A. MALEJ. 2009. Main meiofauna taxa as an indicator for assessing the spatial and seasonal impact of fish farming. Mar. Pollut. Bull., 58(8):1178–1186.

HARMELIN-VIVIEN, M., J. HARMELIN, C. CHAUVET, C. DUVAL, R. GALZIN, P. LEJEUNE, G. BARNABÉ, F. BLANC, R. CHEVALIER, J. DUCLERC & G. LASSERRE. 1985. Evaluation visuelle des peuplements et populations de poissons : méthodes et problèmes (Visual evaluation of fish communities and populations: methods and problems). Rev. Ecol., 40:467-539.

HARMELIN-VIVIEN, M.L. & P. FRANCOUR. 1992. Trawling or visual censuses? Methodological bias in the assessment offish populations in seagrass beds. P.S.Z.N.I.: Mar. Ecol., 13(1): 41-51.

HARMELIN-VIVIEN, M., L. LE DIRÉACH, J. BAYLE-SEMPRE, E. CHARBONNEL, J.A. GARCÍA-CHARTON, D. ODY, A. PÉREZ-RUZAFA, O. REÑONES, P. SÁNCHEZ-JEREZ & C. VALLE. 2008. Gradients of abundance and biomass across reserve boundaries in six Mediterranean marine protected areas: Evidence of fish spillover? Biol. Conserv., 141(2008):1829-1839.

HELFMAN, G. S., 1981. Twilight activities and temporal structure in a freshwater fish community. Can. J. Fish. Aquat. Sci., 38: 1405-1420.

HOBSON, E.S. 1972. Activity of Hawaiian reef fishes during the evening and morning transitions between daylight and darkness. Fish. B.-NOAA, 70(3):715-740.

JARDAS, I. & A. PALLAORO. 1991a. Usporedba lovina mreža poponica različite veličine oka mahe. Morsko ribarstvo, 1/43:5–12.

JARDAS, I. & A. PALLAORO. 1991b. Biološka štetnost lova poponicom. Morsko ribarstvo, 3/43:98–102.

LIPEJ, L., M. ORLANDO BONACA & T. MAKOVEC. 2005. Raziskovanje biodiverzitete v slovenskem morju (Biodiversity research in the Slovenian sea). National Institute of Piran. Marine Biology Station, pp. 136.

MACHIAS, A., I. KARAKASSIS, M. LABROPOUPOU, S. SOMARAKIS, K.N. PAPADOPOULOU & C. PAPACONSTANTINOU. 2004. Changes in wild fish assemblages after the establishment of a fish farming zone in an oligotrophic marine ecosystem. Est. Coast. Shelf Sci., 60:771-779.

MARČETA, B. 2012. In: Marčeta, B. (Editor). BIOS database. Fisheries Research Institute of Slovenia. 1995–(accessed 2013 Jan).

MATIĆ-SKOKO, S., N. STAGLIČIĆ, M. KRALJEVIĆ, A. PALLAORO, P. TUTMAN, B. DRAGIČEVIĆ, R. GRGIČEVIĆ & J. DULČIĆ. 2011. Effectiveness of conventional management in Mediterranean type artisanal fisheries. Est. Coast Shelf Sci., 91:314–324.

NEUMAN, E., O. SANDSTRÖM & O. THORESSON. 1997. Guidelines for coastal fish monitoring. National Board of Fisheries, Institute of Coastal Research, pp. 45.

OGORELEC, B., M. MIŠIČ & J. FAGANELI. 1991. Marine geology of the Gulf of Trieste (northern Adriatic): Sedimentological aspects. Mar. Geol., 99: 79–92.

OLIN, M. & T. MALINEN. 2003. Comparison of gillnet and trawl in diurnal fish community sampling. Hydrobiologia, 506–509: 443-449.

PENGAL, P. 2013. Vpliv marikulture na ribje združbe v Portoroškem ribolovnem rezervatu (Effect of mariculture on the fish assemblages in the Portorož Fisheries Reserve. Ph.D.Thesis. Univerza v Ljubljani, Biotehniška fakulteta, pp. 108.

SAMOILYS, M.A. & G. CARLOS. 2000. Determining methods of underwater visual census for estimating the abundance of coral reef fishes. Environ. Biol. Fish., 57: 289-304.

SIST EN 14757:2005. Water quality - Sampling of fish with multi-mesh gillnets. ICS 13.060.70; 65.150, pp. 34.

STAGLIČIĆ, N., S. MATIĆ-SKOKO, A. PALLAORO, R. GRGIČEVIĆ, M. KRALJEVIĆ, P. TUTMAN, B. DRAGIČEVIĆ & J. DULČIĆ. 2011. Long-term trends in the structure of eastern Adriatic littoral fish assemblages: Consequences for fisheries management. Est. Coast Shelf Sci., 94:263–271.

ŠEGVIĆ BUBIĆ, T., L. GRUBIŠIĆ, V. TIČINA & I. KATAVIĆ. 2011. Temporal and spatial variability of pelagic wild fish assemblages around Atlantic bluefin tuna *Thunnus thynnus* farms in the eastern Adriatic Sea. J. Fish Biol., 78:78-97.

THORESSON, G. 1996. Guideliness for coastal fish monitoring. Kustrapport, pp. 35.

VALLE, C., J.T. BAYLE-SEMPERE, T. DEMPSTER, P. SANCHEZ-JEREZ & F. GIMENEZ-CASALDUERO. 2007. Temporal variability of wild fish assemblages associated with a sea-cage fish farm in the south-western Mediterranean Sea. Est. Coast. Shelf Sci., 72: 299-307.

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Novi dizajn istraživačkih mreža stajačicama za uzorkovanje riba u Jadranskom moru

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SAŽETAK

Tri vrste jednostrukih mreža stajačica različitih veličina oka su testirane na uniformnom muljevitom dnu Piranskog zaljeva. U radu su opisane i uspoređene metode, predstavljeni njihovi pozitivni i negativni aspekti te predložen plan uzorkovanja koji bi se mogao koristiti za različite istraživačke ciljeve. Istraživačko uzorkovanje se odvijalo zimi u razdoblju od 2010. do 2012. godine, a uzorkovalo se u neposrednoj blizini uzgajališta lubina u sjevernom dijelu Jadranskog mora. U Nordijskom 1.5 tipu mreža nađeno je 5 vrsta organizama, u odnosu na 23 u Jadranskom 2.5, te 20 vrsta nađenih u Jadranskom 5.0 tipu mreže. Nadalje, u Nordijskom 1.5 tipu mreže su uhvaćene samo pridnene vrste organizama, s tim da je do reprezentativnog uzorka bilo puno teže doći. S druge strane, u oba Jadranska tipa mreža su nađene bentopelagične i pelagične vrste riba, te je utvrđena korelacija između visine mreže i veličine riba. Premda se s obje vrste mreža Jadranskog tipa relativno lako došlo do reprezentativnog uzorka, Jadranska 2.5 mreža je dala bolje rezultate s obzirom na CPUE te tako postigla bolji omjer uloženog i dobivenog.

Ključne riječi: ribe, jednostruke mreže stajačice, morski rezervati, sastav zajednice, marikultura