ACTA ZOOLOGICA BULGARICA
Acta zool. bulg., Suppl. 7, 2014: 19-25

Macroinvertebrates of the Marine Edge and Fore-Delta of Kyliya Branch of the Danube River

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Abstract: The paper presents results of a long-term investigation on macroinvertebrate species composition that was carried out at the marine edge and fore-delta of Kyliya branch of the Danube River. Uneven distribution of invertebrates in the different areas was established. The mixing zone, where fresh and sea water come in contact, was found to be the most uninhabited zone. It was characterised by hydrological and hydrophysical stress. Only few of the invertebrate species could survive and exist inside the "disaster area" that had originated there. Growth of the species richness was registered from the open marine areas towards the desalinated water bodies of the marine edge of the delta. Regardless of the increase in species richness that was registered, we found a reduction of Polychaeta, Amphipoda and other Crustacea. In addition, there was an increase in Gastropoda, Oligochaeta and Insecta from the marine areas towards the desalinated water bodies of the marine edge. The changes in the structure of the invertebrate complexes corresponded to the change of salinity: domination of freshwater fauna was typical in the brackish waters, while towards the sea the share of Ponto-Caspian and marine species increased. Moreover, a reduction in the share of filter-feeders and an increase in predators were registered from the sea towards the freshwater bodies.

Keywords: Macroinvertebrates, fore-delta, salinity, species composition

Introduction

The delta of the Danube River is a typical delta of extension with the open marine edge that passes into the fore-delta, where there is a rather fast transition from the hydrological balance of the river branches into the hydrodynamic balance of the sea (Chystykov *et al.* 2000). That is an area of active interaction of the river and the sea waters, characterised by the stress of hydrological and hydrochemical processes, as well as the space-time dynamics of biotopes and biocoenoses. The fore-delta is characterised by the most intense hydrodynamic and hydrochemical situation. Unloading of suspended matters with associated contaminants occurs in waters with salinity of 2–6‰ (Berlinsky *et al*. 2010, Bogatova 2009). Here is the area of the so-called "critical salinity of biological processes" (5–8‰) (Khlebovich 1974, Romanenko 2001, Fedorov, Gilmanov 1980). Only few organisms are adapted for life in such waters. Among them, in particular, are the typical Danube Delta representatives of the relict Ponto-Caspian complex. They are descendants of the inhabitants of the ancient Sarmatian Sea which was isolated from the World Ocean and consequently was desalinated. These organisms have survived in the estuaries of the rivers of the Azov-Black-Sea basin, the Aral and Caspian seas.

The studies devoted to the research of freshwater organisms in the transitional area between fresh and sea waters are few. For the Ukrainian part of the estuary beach of the Danube River, these are the works of Markovskyi (1955), Polishchuk (1974), Kharchenko *et al.* (1994) and Kharchenko,

Liashenko (1996). However, the available data, in our opinion, does not shed enough light on the distribution of macroinvertebrates in the area of mixing of fresh and salty water at the marine edge and the fore-delta of the Danube River, which is the area of the contact of the sea and river communities, and the horohalinicum area of critical salinity. The purpose of this work was to replenish this omission by studying the species composition and describing the features of the structure of macroinvertebrate complexes of the marine edge of the delta and the fore-delta of the Kyliya branch of the Danube River.

Material and Methods

The materials of the long-term (2003–2012) study on macroinvertebrates in the boundary areas of the river delta and the coastal waters were utilised in this work. A diagrammatic map with the sampling stations is presented in Fig. 1. The collection and analysis of the materials was conducted using common hydrobiological techniques (Romanenko 2006). Benthic samples were collected by sectional bottom-grab (10×10 cm), epifauna – by a scraper (5 cm wide), phytophilous fauna – through washing of plants. A total of 700 samples was collected and processed. The similarity of the species composition of macrofauna was determined using the Soerensen index in the BioDiversityPro program (James, McCulloch 1990). The Ponto-Caspian complexes of macroinvertebrates, the marine taxa, including the Mediterranean species and the wide-spread sea organisms, as well as the freshwater species, were identified in the composition of the macrofauna (Moroz 1993, Liashenko *et al*. 2012).

Description of the basic types of bottom sediments and the dominating species of macrophytes, as well as measurement of depth, oxygen content in the surface layer (by oxygen analyzer "AZhA-101M"), the pH–value (by pH-metre "pH-301") and the total salinity (by conductometer "HANNA HI 9835") were carried out at each sampling station.

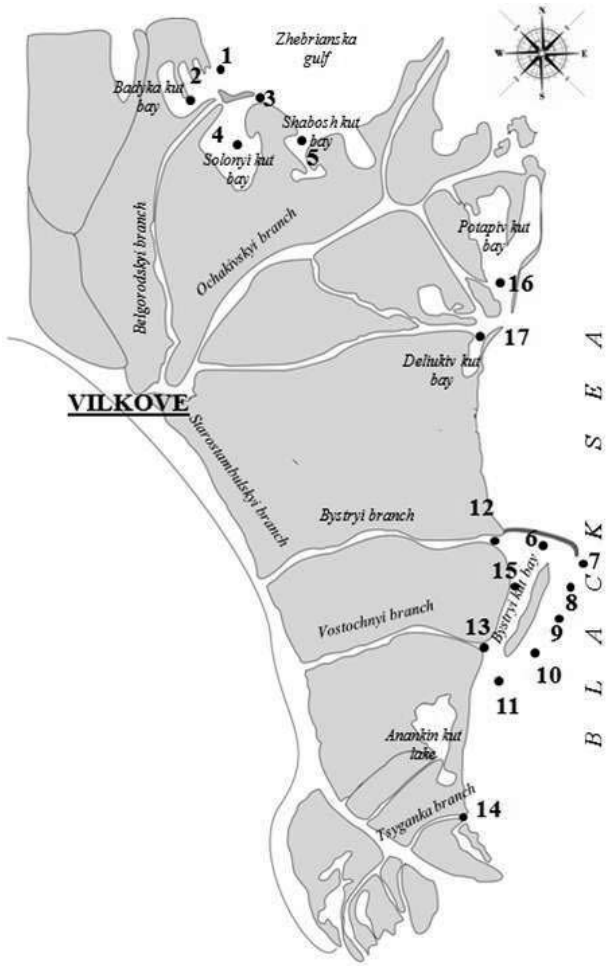

Fig. 1. Schematic map of the sampling sites. Legend: Stations 1, 2 – Badyka Kut Bay, Stations 3, 4 – Solonyi Kut Bay, Station (St.) 5 – Shabosh Kut Bay, St. 6 – marine canal of deep water fairway between the Danube River and the Black Sea, St. 7 – the sea near the top of protective dam of the marine approach canal, St. 8 – the sea across Ptashyna Kosa Island (near Bystryi branch), St. 9 – the sea across Ptashyna Kosa Island (middle), St. 10 – the sea across Ptashyna Kosa Island (near Vostochnyi branch), St. 11 – shallow area between Vostochnyi branch and Tsyganka branch, St. 12 – the mouth of Bystryi branch, St. 13 – the mouth of Vostochnyi branch, St. 14 – the mouth of Tsyganka branch, St. 15 – Bystryi Kut Bay, St. 16 – Potapiv Kut Bay, St. 17 – Deliukiv Kut Bay

Results and Discussion

The basins and water areas of the marine edge of the northern and eastern part of the Kyliya branch of the Danube River differed by hydrochemical parameters, the sediment type and by the characteristic of the biotopes (Table 1). With highest salinity (mesohaline up to 12‰) were the bays in the north of the delta where the sea influence dominated. Reduction in salinity was reported in the region of the inflow of the Belgorodskyi branch, in the Solonyi Kut and Badyka Kut bays. The eastern coast (except for the sea edge of the protective dam of the marine canal where the maximum salinity reaches 12.64‰), on the contrary, was under the prevailing influence of the most active branches, which considerably freshened the coastal water areas. Oligo-mezohaline waters were dominant there, transforming into hypoha-

line in the branches. Mainly freshwater was recorded in the brackish Deliukov Kut and Potapov Kut bays. A certain influence on the salinity balance of the marine edge and the fore-delta line was exerted by positive and negative setup phenomena (Michaylov 2004); however, they were mainly short-term and they did not change the general picture of the salinity in the investigated water areas.

The majority of the investigated water areas were shallow. The maximum depth seldom reached 2 m (in the bays of the Zhebrianska Gulf). On average these areas made up 0.3–0.5 metres in the freshwater bays, and the maximum magnitudes (up to 1.5 m) were observed only during the periods of the increased water quantities in the Danube River. The depths of the estuary sections of the branches were stable; the maximum values were recorded along the waterway – about 3 m. The area of the marine canal, where the depths reached 6–7 m, was the deepest one.

Three types of bottom substrata predominated in the investigated areas: sands in the marine edge, silted sands in the brackish-water bays, grey silts in the branches and black (rich of organic) substrata in the freshwater bays. Sands and shell limestone dominated at the marine stations and the mouths of the Zhebrianska Gulf bays into the sea. From the middle of the bays grey silts appeared, which together with black silts covered the bottom at the tops of the bays. In addition, silted sands occurred occasionally at this place as well. Bottom sediments in the marine approach canal were represented basically by silted sands and grey silts. The estuary sections of the branches had bottom sediments of the same type, composed of silted sands and grey silts. Sandy bottom sediments predominated in the sea in front of Ptashyna Kosa Island (St. 8-10), while only a negligible sedimentation was reported on the shoals below the Vostochnyi branch where a new spit (St. 11) had risen. Some grey and black silts, with a considerable admixture of detritus, predominated in the freshwater Potapiv Kut and Delyukiv Kut bays. Silted sands dominated in the Bystryi Kut Bay along its entire extent. Grey silts dominated along some sections of the bay (the Bystryi and Vostochnyi branches), and sands dominated near the Ptashyna Kosa Island.

The thickets of helophytes, with domination of *Phragmites australis* (Cav.) Trin. ex. Steud and submerged plants with domination of *Potamogeton pectinatus* L. and *P. perfoliatus* L., prevailed at the majority of the stations. A mass development of plants with floating leaves was recorded in the freshwater bays. Vegetation was absent (Table 1) from the sections of the marine edge and in the marine approach canal (St. 6-11).

As a whole, it is necessary to point out that it was possible to distinguish three biotopes that were having certain characteristics: brackish-water bays in the northern part (St. 1–5), the mouths of the branches and the desalinated bays of the east coast (St. 6, 12–17), and the sea section from the spike of the protective dam of the marine approach canal to the shoals between the Vostochnyi and Tsyganka branches (St. 7–11).

The macrofauna was represented by 327 species of invertebrates (Fig. 2), including 179 that belong to the zoobenthos, 139 that belong to the epifauna, and 237 species that could be classified as phytophilous fauna. The total species richness of macrozoobenthos of the Lower Danube River was represented by 288 species according to the materials of the international expeditions carried out under the aegis of the Danube commission (Joint Danube Survey 2002, Joint Danube Survey 2 2008, and Joint Danube Delta Survey (Liashenko, Zorina-Sakharova 2012). When collating a list of the most common species, using personal long-term observations and literature data (Markovskyi 1955, Polishchuk 1974, Moroz 1983, Sheliag-Sosonko 1999, Kharchenko *et al*. 2006, Liashenko, Zorina-Sakharova 2009) from the estuary region of the Danube River and the adjacent lakes, beginning from Markovskyi's work (1955), it could be stated that this figure was at least twice as large. According to the Romanian experts (Danube Delta 2006), no less than 290 species of the bottom invertebrates and 353 phytophilous species inhabit the delta. Chironomidae, Oligochaeta, Gastropoda, Gammaridae and Bivalvia were the most richly represented in the samples of the marine edge, as well as in the entire Lower Danube River (Joint Danube Survey 2002, Joint Danube Survey 2 2008).

The results of the analysis of the similarity of macroinvertebrate species composition in the water bodies of the beach are represented in Fig. 3. It was possible to single out several groups of the stations characterised by the generality of the spe-

Table 1. Biotope characteristics of the investigated water areas

Legend: in brackets – an average arithmetic, S – sand, SS – silted sand, SL – shell limenstone, GS – grey silt, BS – black silt, T – tree, St – stone; He – helophytes, Sp – submerged plants, Fl – vegetation with floating leaves.

№ st.	Salinity, ‰	Prevailing depth, m	Types of bottom substrata	Substrata of epifauna	Ecological groups of vegetation
1	2.91-9.00 (6.51)	0.50	S, SL	T	SP
2	0.96-9.95 (3.51)	1.50	SS, SL, GS, BS	T	HE, SP
3	2.20-8.82 (5.39)	1.80	S, SS, SL	T	SP
4	0.19-7.61 (4.41)	1.50	SS, SL, GS, BS	T	HE, SP
5	2.69-12.00 (7.25)	1.50	S, SL, GS	T	SP
6	0.17-1.48 (0.57)	3.00	SS, GS	ST	–
7	0.46-12.64 (3.66)	7.00	SS, GS	ST	–
8	0.44-3.05 (1.43)	1.50	S	T	–
9	1.54	1.50	S	–	–
10	1.08	1.50	S	–	–
11	0.21-1.35 (0.59)	1.50	S, SS	–	–
12	0.17-0.72 (0.29)	3.00	SS, GS	T	HE, SP
13	0.18-0.57 (0.25)	3.00	SS, GS	T	HE, SP
14	0.18-3.73 (0.71)	3.00	SS, GS	T	HE, SP
15	0.17-4.72 (0.81)	1.50	S, SS, GS	T	HE, SP
16	0.19-1.04 (0.72)	1.50	GS, BS	T	HE, FL
17	0.18-0.75 (0.28)	1.50	GS, BS	T	HE, FL

Table 2. Structural characteristics of macrofauna

Indexes	Groups of station=invertebrates complexes (numbers of stations)			
	I (St. 8–11)	II (St. 1, 3, 5, 7)	III (St. 2, 4, 6)	VI (St. 12–17)
Taxonomical structure, (species richness)				
Bivalvia	4% (1)	6% (6)	2% (3)	3% (8)
Gastropoda	–	1% (1)	7% (10)	14% (41)
Oligochaeta	4% (1)	15% (13)	17% (25)	14% (39)
Polychaeta	13% (3)	7% (6)	5% (7)	1% (3)
Amphipoda	39% (9)	17% (15)	10% (15)	10% (29)
Other Crustacea	17% (4)	17% (15)	10% (14)	5% (13)
Chironomidae	17% (4)	13% (11)	23% (33)	18% (51)
Other Insecta	4% (1)	13% (11)	17% (24)	29% (84)
Other species	–	10% (9)	8% (12)	7% (20)
Total species richness	23	87	143	288
Structure by origin, (species richness)				
Ponto-Caspian fauna	48% (11)	30% (26)	15% (21)	14% (39)
Mediterranean fauna	13% (3)	15% (13)	9% (13)	2% (5)
Freshwater fauna	39% (9)	51% (44)	71% (102)	82% (237)
Invader species	–	5% (4)	5% (7)	2% (7)

cies structure of macroinvertebrate complexes, the generalised characteristics of which is presented in Table 2.

The first group included taxa that were most advanced in the sea stations, but being under the influence of the runoff of the Bystryi branch (St. 9 and 10, 8 and 11) with low levels of the similarity of the species composition among themselves (up to 38%). Zoobenthos complexes characterised by low species richness (from four to 17 species per station)

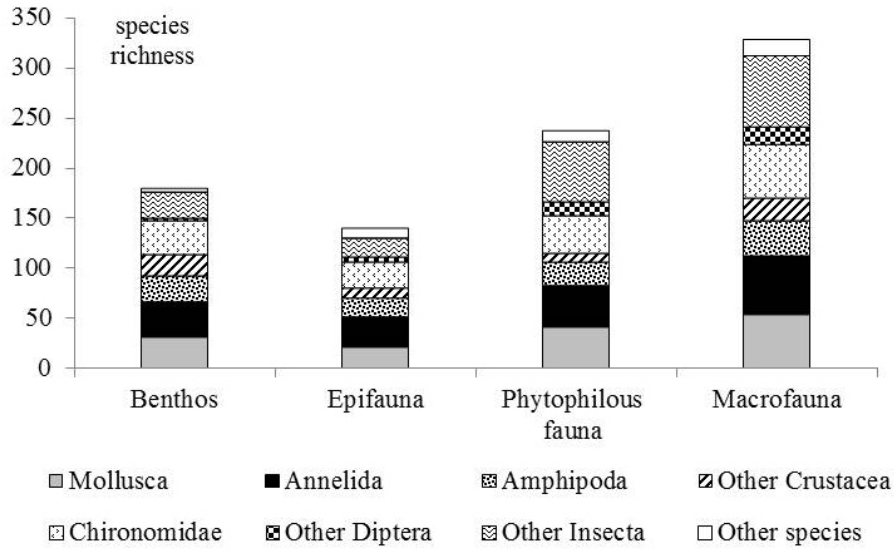

Fig. 2. Taxonomic structure of the macroinvertebrate biotic complexes

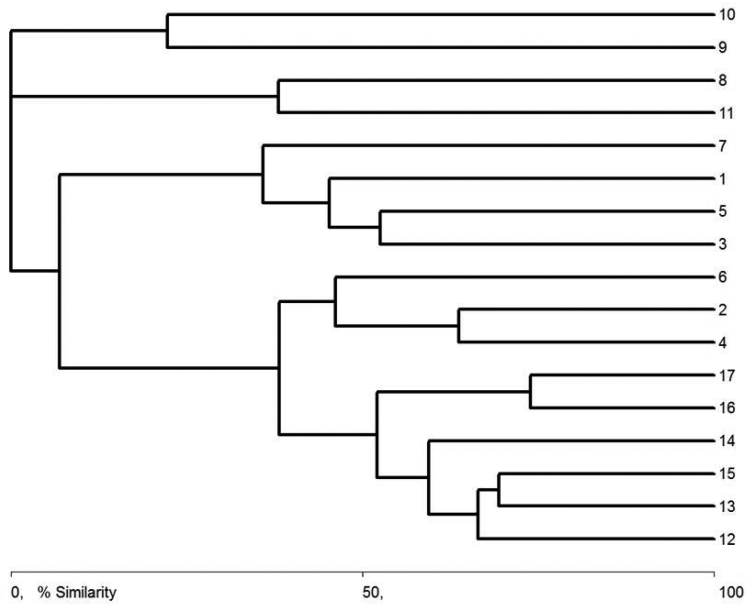

Fig. 3. Dendrogram of the similarity of the macroinvertebrate species composition (according to the Soerensen index)

developed there, in the conditions of a strong wave influence on the mainly sandy bottoms. The greatest number of species (within this group) was reported at the sea section being the closest to the Bystryi branch (St. 8). Crustacea of the Ponto-Caspian relic fauna prevailed (11 species) and *P. maeoticus* Sowinskyi occurred most often. The Mediterranean complex was represented by the bivalvian *Abra ovata* (Philippi), gammarid *Bathyporeia guilliamsoniana* Bate and polychaet Neretidae. Only the oligochaet *Isochaetides michaelseni* (Lastockin), heteropteran *Micronecta griseola* Kirkaldy and three species larvae of Chironomidae from the freshwater fauna were recorded.

The second group included stations 1, 3, 5 and 7, located in the mouths of the bays of the northern part of the marine edge and the bay of the marine canal (Fig. 1). The levels of similarity of the species composition of macrofauna were higher there (36–53%). These sampling sites were characterised by high salinity (up to 12.64‰), small depths and mainly sandy-silty habitats. The poorly developed vegetation was represented mainly by submerged species, developing at the entries of the bays and

at the places that were protected from the influence of the wave action by coastal spits. No plants were discovered in the bay of the marine canal, but organisms of epifauna intensively developed on the stony filling of the protective dam (St. 7). The increase in the variety of biotopes lead to the increase in the general species richness: we recorded 87 species of macrofauna. Among them 30 species of Crustacea, half of which were Amphipoda. Annelida was represented by six species of Polychaeta and 13 species of Oligochaeta. In addition, seven species of Mollusca and 22 Insecta species, of which 11 belong to the family of Chironomidae, were most variously represented. The species preferring meso-euhaline water habitats were registered on these stations: Bivalvia - *A. ovata* (Philippi), *Anadara inaequivalvis* (Bruguiere), *Cardium edule* L., *Mytillus galloprovincialis* Lamarck; Izopoda *Idotea baltica* Audouin, *I. ostroumovi* (Sowinsky) and *Sphaeroma serratum* (Fabr.); Gammaridae - *Gammarus aequicauda* Martynov, Bryozoa - *Conopeum seurati* (Canu), Polychaeta - *Polydora ciliata limicola* (Ionson). The species tolerating large changes in salinity occurred widely at these stations: worms of the genera *Nereis* and *Paranais*; the amphipods *Corophium volutator* (Pallas) and *P. maeoticus* Sowinskyi; species from Mysidacea - *Mesopodopsis slabberi* (van Beneden), Decapoda - *Palaemon elegans* Rathke and *Rhithropanopeus harrisii tridentata* Maitland, and Cirripedia - *Ballanus improvisus* Linne. The representatives of the Ponto-Caspian complex (77%), which were represented mainly by Gammaridae and Cumacea, prevailed in the bottom communities. The representatives of the Mediterranean fauna (13 species) occurred widely. Among them *I. baltica, C. volutator* and *G. aequicauda* were the most common species. The invader species *B. improvisus, R. harrisii tridentata*, *P. ciliata limicola* and *A. inaequivalvis* occurred regularly. The latter species was recorded only in the benthos and the others were in all groupings.

The third group consisted of stations 2, 4 and 6, or the inner water areas of Badyka Kut and Solonyi Kut and the bay of the marine approach canal. The similarity levels of the macrofauna species composition were higher (46–64%) in comparison with the previous stations. Moreover, the sedimentation of bottom substrata was greater there, while the average and maximum magnitudes of salinity were lower. The development of helophytes and submerged vegetation was reported at stations 2 and 4 (Table 1). The macrofauna was represented by 143 species. Freshwater Bivalvia and Gastropoda, Oligochaeta, larvae of Odonata, Trichoptera, Ephemeroptera were found in this area in addition to the species inhabiting the sections adjacent to the sea. The fauna of Chironomidae was also more various. The richness of the Mediterranean and Ponto-Caspian complexes of organisms did not appear to change in comparison with the previous group of stations. The number of freshwater species increased more than twice, reaching 102 species, and made up 71% of the general species richness (143 species) of this group of stations.

The fourth and largest group included the remaining stations: the mouth sections of branches and the freshwater bays (stations 12–17). These stations were characterised by high levels of similarity of the species composition of macrofauna (52–74%), low salinity with mainly hypo-oligohaline waters, a wide variety of substrata and the representativeness of macrophytes (Table 1), and as a consequence of such a high habitat variety, the greatest richness of species. The macrofauna of stations 12–17 included 288 invertebrate species. The species of the freshwater complex (237 species) dominated among the invertebrates: Gastropoda, Oligochaeta and Insecta. From those belonging to the Mediterranean fauna, the genus *Nereis* (Polychaeta) and *C. volutator* (Corophiidae) occurred everywhere. The molluscs *A. ovata* and *B. reticulatum*, gammarids *G. aequicauda,* decapod *P. elegans* were reported at some stations. The species richness of the Ponto-Caspian fauna was the greatest here (36 species) and it was determined by a considerable variety of Amphipoda, however, their share as compared with the previous complexes of invertebrates was the smallest (14%).

Generally over the distance in some kilometres from the open sea areas to the freshwater basins and waterways of the marine edge of the delta, a considerable growth (by more than an order of a magnitude) of the macrofauna species richness was recorded. Four complexes of macroinvertebrates were identified, having characteristic structural differences. A reduction in the share of Polychaeta, Amphipoda and the other Crustacea and an increase in Gastropoda, Oligochaeta and Insecta were reported from the sea water areas towards the water bodies

of the desalinated coast (complexes of macroinvertebrates I→II→III→VI). We recorded only a slight change in the share and number of Bivalvia along the salinity gradient. The changes in the structure of complexes depending on the origin of species were in line with the change in salinity: the overwhelming value of freshwater fauna was typical for freshwater, while the share of Ponto-Caspian and sea species increased towards the sea.

Conclusions

As a whole, the area of interaction between the river and the sea is large-scale and very dynamic. A high structural diversity of macrofauna was caused by the high biotopes variety and the richness of a historically formed combination of species with various origins. The marine areas was the poorest in terms of species richness, which was explained by the severe hydrological conditions and the hydrochemical balance, the monotony of bottom sediments, the absence of vegetation and the constant substrata for the development of epifauna. A "disaster area" emerged there where only quite a limited number of species of macroinvertebrates could survive and exist. The extension of the Danube Delta into the sea lead to the formation of bays at the coast, where there was a stabilisation of abiotic indices and as a consequence a considerable increase in species richness and development of aquatic organism communities.

Acknowledgments: We would like to acknowledge the respected reviewer for the work towards abstract improving.

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