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Alien fishes in the Black Sea waters of Crimea (Ukraine)

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review article

key words

fishes, alien species, introduction, distribution, acclimatisation, mediterranisation, Ukraine, Crimea.

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abstract

The paper is devoted to alien fish species that have appeared in coastal waters of the Black Sea near Crimea for the past 50 years. The fish fauna of the Black Sea mainly comprises species that represent the Ponto-Caspian and Atlantic-Mediterranean faunal complexes. According to the generalised literature data, 158 fish species of 107 genera of 60 families have been recorded in the Black Sea since the publication of K. F. Kessler's work (Kessler 1877), all of them representing the Atlantic-Mediterranean complex. In waters of Crimea, 116 species of 86 genera of 51 families have been recorded for the same period. A full checklist of fishes of this complex is presented indicating 31 alien species that have appeared since the 1970s and which belong to 27 genera and 16 families. In waters of Crimea, alien fishes make up 26.5 % of all species, 31.0 % of all genera, and 31.4 % of all families of the Atlantic-Medirranean complex. According to the level of their occurrence in marine waters of Crimea, all recently introduced species are grouped into three categories: regular, sporadic, and casual. Their brief characterisics are given, including synonymy, representation in the fish collection of the NMNH NASU, brief description, distribution, and vector of introduction. It was found that benthic species predominate among introduced fishes that occur regularly in waters of Crimea (12 species, or 80.0 %), while bentho-pelagic and pelagic species are less represented (6.7 % and 13.3 %, respectively). Pelagic and bentho-pelagic species prevail (50.0 % and 37.5 %, respectively) among fishes that occur sporadically. Bentho-pelagic species predominate (57.1 %) among fishes that occur casually. It was discovered that among the 31 alien fishes recorded in the Black Sea waters of Crimea for the past 50 years predominate those that have appeared here due to the natural process of mediterranisation (22 species, 71.0 %). It was imposibble to determine the vector of introduction of 4 species (12.9 %). The appearance of 5 species, which represent 16.1 % of all alien species, is related to anthropogenic factors. It can be also concluded that benthic species predominate among the alien fishes (14 species, or 45.2 %), while bentho-pelagic (9 species) and pelagic (8 species) fishes make up 29.0 % and 25.8 %, respectively. Of the 31 introduced fishes, 10 (32.2 %) have naturalised and acclimatised in marine waters of Crimea and have founded independent breeding populations. Among them, representatives of the family Gobiidae notably prevail, followed by the taxonomically close family Oxudercidae, whereas one species belongs to the family Blenniidae. The so-iuy mullet, which is the only representative of the pelagic ecological group, was introduced intentionally.

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Alien fishes in the Black Sea waters of Crimea (Ukraine). — L. Manilo. — The paper is devoted to alien fish species that have appeared in coastal waters of the Black Sea near Crimea for the past 50 years. The fish fauna of the Black Sea mainly comprises species that represent the Ponto-Caspian and Atlantic-Mediterranean faunal complexes. According to the generalised literature data, 158 fish species of 107 genera of 60 families have been recorded in the Black Sea since the publication of K. F. Kessler's work (Kessler 1877), all of them representing the Atlantic-Mediterranean complex. In waters of Crimea, 116 species of 86 genera of 51 families have been recorded for the same period. A full checklist of fishes of this complex is presented indicating 31 alien species that have appeared since the 1970s and which belong to 27 genera and 16 families. In waters of Crimea, alien fishes make up 26.5 % of all species, 31.0 % of all genera, and 31.4 % of all families of the Atlantic-Medirranean complex. According to the level of their occurrence in marine waters of Crimea, all recently introduced species are grouped into three categories: regular, sporadic, and casual. Their brief characterisics are given, including synonymy, representation in the fish collection of the NMNH NASU, brief description, distribution, and vector of introduction. It was found that benthic species predominate among introduced fishes that occur regularly in waters of Crimea (12 species, or 80.0 %), while bentho-pelagic and pelagic species are less represented (6.7 % and 13.3 %, respectively). Pelagic and bentho-pelagic species prevail (50.0 % and 37.5 %, respectively) among fishes that occur sporadically. Bentho-pelagic species predominate (57.1 %) among fishes that occur casually. It was discovered that among the 31 alien fishes recorded in the Black Sea waters of Crimea for the past 50 years predominate those that have appeared here due to the natural process of mediterranisation (22 species, 71.0 %). It was imposibble to determine the vector of introduction of 4 species (12.9 %). The appearance of 5 species, which represent 16.1 % of all alien species, is related to anthropogenic factors. It can be also concluded that benthic species predominate among the alien fishes (14 species, or 45.2 %), while bentho-pelagic (9 species) and pelagic (8 species) fishes make up 29.0 % and 25.8 %, respectively. Of the 31 introduced fishes, 10 (32.2 %) have naturalised and acclimatised in marine waters of Crimea and have founded independent breeding populations. Among them, representatives of the family Gobiidae notably prevail, followed by the taxonomically close family Oxudercidae, whereas one species belongs to the family Blenniidae. The so-iuy mullet, which is the only representative of the pelagic ecological group, was introduced intentionally.

Key words: fishes, alien species, introduction, distribution, acclimatisation, mediterranisation, Ukraine, Crimea.

To the memory of my dear colleague A. R. Boltachev (21.07.1952–30.01.2019), the famous Ukrainian and Russian ichthyologist

Introduction

The fish fauna of the Black Sea is being constantly enriched with new representatives of the Atlantic-Mediterranean faunal complex, a process called "mediterranisation" (Puzanov 1967). This permanent process related to the specific history of formation of this water basin has lasted about 7000–8000 years since the latest connection of the Novoevksinske Lake-Sea with the Mediterranean Sea (Zaytsev 2006) opening a corridor for the spread of the Mediterranean fauna.

Coastal waters of the Crimean Peninsula are characterised by the highest diversity of the fish fauna compared to other regions of the Black Sea, which is related to the geographic location of the peninsula that extends southward to about the middle of the Black Sea, as well as to various abiotic and biocoenotic features. The species composition of fishes in this area, as well as in many other regions, has undergone notable changes due to natural and anthropogenic factors.

Records of alien species in the Black Sea has significantly increased in number over the past decade, including coastal waters of Crimea where a notable number of fishes that are new for the ichthyofauna of the Azov-Black Sea Basin and which belong to the Atlantic-Mediterranean and other faunal complexes has been recorded.

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It should be mentioned that in addition to such Atlantic-Mediterranean species as the salema porgy *Sarpa salpa* (Boltachev & Karpova 2014), sand steenbras *Lithognathus mormyrus* (Boltachev *et al.* 2013), zebra goby *Zebrus zebrus* (Manilo *et al.* 2013), and Bath's goby *Pomatoschistus bathi* (Boltachev & Karpova 2010), species of the Indo-West Pacific region are also recorded in the Black Sea. The latter has spread through the Suez Canal and eastern part of the Mediterranean Sea (Lessepsian migrants), some of them dispersed to the Aegean, Marmara, and Black Sea. Exapmles of these species are the red barracuda *Sphyraena pinguis* (Boltachev 2009) and the silver-cheeked toadfish *Lagocephalus sceleratus* (Boltachev & Karpova 2017). Some species have found favourable conditions in the Black Sea and are at different stages of acclimatisation or have already founded stable breeding populations.

Over the past decades, marine ecosystems of Ukraine have been under constant anthropogenic impact, including pollution and various forms of economic activity. Increased euthrophication of the sea, which has started in the 1970s, increased recreational activity on the coasts, development of fishery, increased shipping, and other factors have led to negative consequences that affected the fish fauna of the northern part of the Azov-Black Sea Basin. Due to anthropogenic impact and along with the general degradation of ecosystems in recent years, a change in species composition of fishes took place practically in all parts of this region (Manilo 2014). The increased spread of alien species, to some extent, is related to anthropogenic euthrophication of the sea.

The increase in the diversity of the fish fauna of the Black Sea due to economic activity is also related to attempts of intentional acclimatisation of valuable fish species (so-iuy mullet *Planiliza haematocheila*) and, possibly, to accidental introduction with mariculture (gilthead bream *Sparus aurata* and Korean rockfish *Sebastes schlegelii*).

Nonetheless, the current state of the fish fauna of the Black Sea within waters of Ukraine, as well as its changes due to the above processes, have been little studied. Issues related to assessment of the state and changes in diversity of marine fauna under the influence of natural and anthropogenic factors, including introduction of alien species, are extremely important (Aleksandrov *et al.* 2007, 2013).

A significant contribution to the study of fishes of Crimea were made by A. R. Boltachev and Ye. P. Karpova, researchers of A. O. Kovalevsky Institute of Biology of Southern Seas NAS of Ukraine, who have monitored the region's fish fauna for many years. The results of their studies are presented in numerous scientific articles and popular science issues (Boltachev *et al.* 1999, 2000, Boltachev & Karpova, 2012, 2017 and others).

In one of their works (Boltachev & Karpova 2014), these researchers carried out a faunal revision of all alien fish species of the Black Sea for the period 1998–2013. They indicate 25 species, among which 21 were found in the Black Sea waters of Crimea, although the ratio of species belonging to different ecological groups and having different vectors of introduction has remained unknown. In recent years, several other species have been found in this area.

The aim of the present work is to generalise data and analyse the materials on the description and further distribution of alien fish species in the Black Sea waters of the Crimean Peninsula for the past 50 years.

Material and Methods

Coastal waters of Crimea are analysed within boundaries of the Black Sea from the northern coast of the Tarkhankut Peninsula (Yarylhats'ka Bay) to the Sea of Azov, including the Kerch Strait.

The systemtics and nomenclature of fishes in this work are presented according to their validity by the current data of FishBase (Froese & Pauly 2020). More than 90 literature sources were used to compile the list of species and species descriptions.

Based on the level of the occurrence, all recently introduced species of marine waters of Crimea are grouped into three categories: regular, sporadic, and casual (Boltachev & Karpova 2014). These species represent three ecological groups: benthic, bentho-pelagic, and pelagic (a more detailed ecological classification, in our opinion, whould be impractical).

Most of recently introduces fishes in waters of Crimea — except for *Planiliza haematocheila* (Temminck et Schlegel, 1845), *Sebastes schlegelii* Hilgendorf, 1880, *Tridentiger trigonocephalus* Gill, 1859 and *Heniochus acuminatus* (Linnaeus, 1758), which appeared due to anthropogenic factors — represent the Antlantic-Mediterranean complex. The Indo-West Pacific *Sphyraena pinguis* Günther, 1874 and *Lagocephalus sceleratus* (Gmelin, 1789) have already became part of the fish fauna of the Mediterranean Sea and are considered as elements of this complex. Accordingly, in this publication, we consider data on invasive species in the light of the Atlantic-Mediterranean complex.

Two species — Kolombatovic's goby *Chromogobius zebratus* (Kolombatović, 1891) and Steinitz's goby *Gammogobius steinitzi* Bath, 1971 — are considered as recent invaders, although the time of their appearance in waters of the Black Sea (of Crimea) is unknown.

The full list of fishes also includes species the distribution of which is not restricted to the Atlantic Ocean and which have other type of geographic range, e.g. the circumglobal *Xiphias gladius* Linnaeus, 1758 (distributed in tropical, subtropical, and temperate waters of all oceans) and others.

Ecologically plastic freshwater species that disperse into estuaries (*Lepomis gibbosus* Linnaeus, 1758*, Gambusia holbrooki* Girard, 1859 and others) are not considered in this work, so neither are species of the Ponto-Caspian faunal complex.

The paper includes data on the presence of specimens of introduced species in the fish collection of NMNH NAS Ukraine (No.) and on their meristic characters (brief description), which were collected by the author and researchers of other institutions during expeditions to the Crimean coast.

The special terminology currently accepted by the Convention on Biological Diversity (Carlton 1996) is as follows:

- native area or donor area is the region from which the species spreads, recipient area is the area to which the species spreads;
- ways of dispersal of alien species called vectors can be natural or anthropogenic;
- pathways are ways through which alien species spread to new areas; such pathways are called invasive corridors if dispersal takes place systematically;
- a species that appeared in a recipient area and founded an independent breeding population is called a non-native, non-indigenous, alien, exotic, or introduced species.

Results and Discussion

The fish fauna of the Black Sea including freshwater species comprises not less than 263 species (Boltachev & Karpova 2017). These species belong to either the Ponto-Caspian or the Atlantic-Mediterranean faunal complex. Based on the generalised literature data, 158 fish species of the Atlantic-Mediterranean complex belonging to 107 genera and 60 families have been recorded in the Black Sea since K. F. Kessler's work was published (Kessler 1877). Earlier, many of them had been recorded beyond waters of Ukraine (41 species of 35 genera of 28 families). For instance, in waters of Turkey such species had been found as *Hexanchus griseus* (Bonnaterre, 1788); *Mustelus asterias* Cloquet, 1821; *Squalus blainville* (Risso, 1927); *Squatina squatina* (Linnaeus, 1758); *Gymnura altavela* (Linnaeus, 1758); *Merluccius merluccius* (Linnaeus, 1758); *Lophius budegassa* Spinola, 1807, *Chelidonichthys cuculus* (Linnaeus, 1758), *Lichia amia* (Linnaeus, 1758), *Mullus surmuletus* Linnaeus, 1758; *Symphodus bailloni* Valenciennes, 1839; *Parablennius gattorugine* (Linnaeus, 1758); *Auxis rochei* (Risso, 1810); *Arnoglossus laterna* (Walbaum, 1792) and others. In waters of Romania and Bulgaria, *Sphyrna zygaena* (Linnaeus, 1758); *Alopias vulpinus* (Bonnaterre, 1788); *Diplodus vulgaris* (Geoffroy St. Hilaire, 1817); *Centracanthus cirrus* Rafinesque, 1810; and *Scomber colias* Gmelin, 1789 were found. In the Black Sea waters of the Caucasus, *Argyrosomus regius* (Asso, 1810), *Pomatoschistus pictus* (Malm, 1865), and other species were recorded.

In waters of Crimea, 116 species belonging to 86 genera and 51 families were recorded for the same period; all of them represent the Atlantic-Mediterranean complex (Table 1).

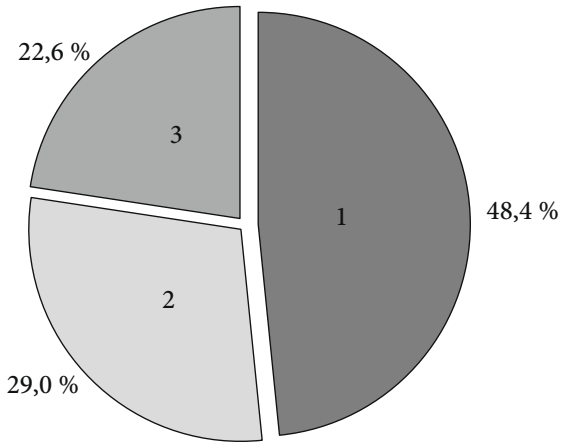

Fig. 1. The ratio of alien species that have been regularly (1), sporadically (2), and casually (3) found in waters of Crimea since the 1970s.

Рис. 1. Співвідношення видів-вселенців, що постійно (1), епізодично (2) і випадково (3) зустрічаються у водах Криму з 1970-х років.

Since the 1970s, 31 introduced species that belong to 27 genera and 16 families have been recorded in the Black Sea waters of Crimea, of which 15 occurred regularly (48.4 %), 9 sporadically (29.0 %), and 7 casually (22.6 %) (Fig. 1). Among all fishes of waters of Crimea, they make up 26.5 % of species, 31.0 % of genera, and 31.4 % of families that belong to the Atlantic-Mediterranean complex.

Table 1. **Species composition of the Atlantic-Mediterranean fish complex of Crimea and of alien fishes (since the 1970s) with their brief characteristics**

Таблиця 1. **Видовий склад атлантично-середземноморського комплексу риб Криму і риб-вселенців (з 70-х років XX століття) та їх коротка характеристика**

Family, species	Occurrence in waters of Crimea			Ecological group	Vector of introduction
	Reg	Spo	Cas		
I. Squalidae					
1. *Squalus acanthias* Linnaeus, 1758	+			BP	
II. Rajidae					
2. *Raja clavata* Linnaeus, 1758	+			B	
III. Dasyatidae					
3. *Dasyatis pastinaca* (Linnaeus, 1758)	+			B	
IV. Acipenseridae					
4. *Acipenser sturio* Linnaeus, 1758			+	BP	
V. Anguillidae					
5. *Anguilla anguilla* (Linnaeus, 1758)		+		BP	
VI. Congridae					
6. *Conger conger* (Linnaeus, 1758)			+	BP	
VII. Engraulidae					
7. *Engraulis encrasicolus* (Linnaeus, 1758)	+			P	
VIII. Clupeidae					
8. *Alosa fallax* (Lacepede, 1803)			+	P	
9. ***Sardina pilchardus* (Walbaum, 1792)**		+		P	M
10. ***Sardinella aurita* Valenciennes, 1847**		+		P	M
11. *Sprattus sprattus* (Linnaeus, 1758)	+			P	
IX. Phycidae					
12. *Gaidropsarus mediterraneus* (Linnaeus, 1758)	+			B	
X. Gadidae					
13. *Merlangius merlangus* (Linnaeus, 1758)	+			BP	
14. ***Micromesistius poutassou* (Risso, 1827)**			+	P	M
XI. Ophidiidae					
15. *Ophidion rochei* Müller, 1845	+			B	
XII. Lophiidae					
16. *Lophius piscatorius* Linnaeus, 1758			+	B	
XIII. Mugilidae					
17. *Chelon auratus* (Risso, 1810)	+			BP	
18. ***Chelon labrosus* (Risso, 1827)**		+		P	M
19. ***Chelon ramada* (Risso, 1827)**		+		P	M
20. *Chelon saliens* (Risso, 1810)		+		P	
21. *Mugil cephalus* Linnaeus, 1758		+		BP	

Family, species	Occurrence in waters of Crimea			Ecological group	Vector of introduction
	Reg	Spo	Cas		
22. ***Planiliza haematocheila* (Temminck et Schlegel, 1845)****	+			P	II
XIV. Atherinidae					
23. *Atherina boyeri* Risso, 1810	+			P	
24. *Atherina hepsetus* (Linnaeus, 1758)	+			P	
XV. Belonidae					
25. *Belone belone* (Linnaeus, 1758)	+			P	
XVI. Zeidae					
26. *Zeus faber* Linnaeus, 1758			+	P	
XVII. Gasterosteidae					
27. *Gasterosteus aculeatus* Linnaeus, 1758	+			BP	
XVIII. Syngnathidae					
28. *Hippocampus hippocampus* (Linnaeus, 1758)	+			BP	
29. *Nerophis ophidion* (Linnaeus, 1758)	+			BP	
30. *Syngnathus abaster* Risso, 1827	+			BP	
31. ***Syngnathus acus* Linnaeus, 1758**		+		BP	M/BW
32. *Syngnathus tenuirostris* Rathke, 1837	+			BP	
33. *Syngnathus typhle* Linnaeus, 1758	+			BP	
34. *Syngnathus variegatus* Pallas, 1814	+			BP	
XIX. Dactylopteridae					
35. ***Dactylopterus volitans* (Linnaeus, 1758)**			+	B	M/BW
XX. Scorpaenidae					
36. *Scorpaena porcus* Linnaeus, 1758	+			B	
37. ***Sebastes schlegelii* Hilgendorf, 1880**		+		BP	UI
XXI. Triglidae					
38. *Chelidonichthys lucerna* (Linnaeus, 1758)		+		B	
XXII. Moronidae					
39. *Dicentrarchus labrax* (Linnaeus, 1758)		+		P	
XXIII. Serranidae					
40. *Serranus scriba* (Linnaeus, 1758)	+			BP	
XXIV. Pomatomidae					
41. *Pomatomus saltatrix* (Linnaeus, 1766)	+			P	
XXV. Carangidae					
42. *Trachurus mediterraneus* (Steindachner, 1868)	+			P	
43. *Trachurus trachurus* (Linnaeus, 1758)		+		P	
XXVI. Sparidae					
44. ***Boops boops* (Linnaeus, 1758)**		+		BP	M
45. ***Dentex dentex* (Linnaeus, 1758)**			+	BP	M
46. *Diplodus annularis* (Linnaeus, 1758)	+			BP	
47. *Diplodus puntazzo* (Cetti, 1784)		+		BP	
48. *Diplodus sargus* (Linnaeus, 1758)			+	BP	
49. ***Lithognathus mormyrus* (Linnaeus, 1758)****		+		BP	M
50. *Pagellus erythrinus* (Linnaeus, 1758)			+	BP	
51. ***Sarpa salpa* (Linnaeus, 1758)**	+			P	M
52. ***Sparus aurata* Linnaeus, 1758**	+			BP	M/UI
XXVII. Centracanthidae					
53. *Spicara flexuosa* Rafinesque, 1810	+			P	
54. *Spicara maena* (Linnaeus, 1758)	+			P	
XXVIII. Sciaenidae					
55. *Sciaena umbra* Linnaeus, 1758	+			BP	
56. *Umbrina cirrosa* (Linnaeus, 1758)		+		BP	
XXIX. Mullidae					
57. *Mullus barbatus* Linnaeus, 1758	+			BP	
XXX. Chaetodontidae					
58. ***Heniochus acuminatus* (Linnaeus, 1758)**			+	BP	BW
XXXI. Pomacentridae					
59. *Chromis chromis* (Linnaeus, 1758)	+			BP	

Family, species	Occurrence in waters of Crimea			Ecological group	Vector of introduction
	Reg	Spo	Cas		
XXXII. Labridae					
60. *Ctenolabrus rupestris* (Linnaeus, 1758)		+		BP	
61. *Labrus viridis* Linnaeus, 1758		+		BP	
62. *Symphodus cinereus* (Bonnatterre, 1788)	+			BP	
63. *Symphodus ocellatus* (Linnaeus, 1758)	+			BP	
64. *Symphodus roissali* (Risso, 1810)	+			BP	
65. *Symphodus rostratus* (Bloch, 1791)		+		BP	
66. *Symphodus tinca* (Linnaeus, 1758)	+			BP	
XXXIII. Ammodytidae					
67. *Gymnammodytes cicerelus* (Rafinesque, 1810)	+			BP	
XXXIV. Trachinidae					
68. *Trachinus draco* Linnaeus, 1758	+			B	
XXXV. Uranoscopidae					
69. *Uranoscopus scaber* Linnaeus, 1758	+			B	
XXXVI. Tripterygiidae					
70. *Tripterygion tripteronotus* (Risso, 1810)		+		B	
XXXVII. Blenniidae					
71. *Aidablennius sphynx* (Valenciennes, 1836)	+			B	
72. *Blennius ocellaris* Linnaeus, 1758			+	B	
73. *Coryphoblennius galerita* (Linnaeus, 1758)	+			B	
74. *Microlipophrys adriaticus* (Steindachner et Kolombatovic, 1883)			+	B	
75. ***Parablennius incognitus* (Bath, 1968)****	+			B	M/BW
76. *Parablennius sanguinolentus* (Pallas, 1814)	+			B	
77. *Parablennius tentacularis* (Brünnich, 1768)	+			B	
78. *Parablennius zvonimiri* (Kolombatovič, 1892)	+			B	
79. *Salaria pavo* (Risso, 1810)		+		B	
XXXVIII. Gobiesocidae					
80. ***Apletodon dentatus* (Facciola, 1887)**	+			B	M
81. *Diplecogaster bimaculatus* (Bonnaterre, 1788)	+			B	
82. *Lepadogaster candolii* Risso, 1810	+			B	
83. *Lepadogaster lepadogaster* (Bonnaterre, 1788)	+			B	
XXXIX. Callionymidae					
84. *Callionymus pusillus* Delaroche, 1809	+			B	
85. *Callionymus risso* Lesueur, 1814	+			B	
XL. Gobiidae					
86. *Aphia minuta* (Risso, 1810)	+			P	
87. ***Chromogobius quadrivittatus* (Steindachner, 1863)****	+			B	M
88. ***Chromogobius zebratus* (Kolombatović, 1891)*****	+			B	M
89. ***Gammogobius steinitzi* Bath, 1971*****	+			B	M
90. *Gobius bucchichi* Steindachner, 1870	+			B	
91. *Gobius cobitis* Pallas, 1814	+			B	
92. ***Gobius couchi* Miller & El-Tawil, 1974****	+			B	M
93. ***Gobius cruentatus* Gmelin, 1789****	+			B	M
94. *Gobius niger* Linnaeus, 1758	+			B	
95. *Gobius paganellus* Linnaeus, 1758	+			B	
96. ***Gobius xanthocephalus* Heymer et Zander, 1992****	+			B	M
97. ***Millerigobius macrocephalus* (Kolombatovič, 1891)****	+			B	BW
98. ***Pomatoschistus bathi* Miller, 1982****	+			B	M
99. *Pomatoschistus marmoratus* (Risso, 1810)	+			B	
100. *Pomatoschistus minutus* (Pallas, 1770)	+			B	
101. ***Zebrus zebrus* (Risso, 1826)****	+			B	M
102. *Zosterisessor ophiocephalus* (Pallas, 1814)	+			B	
XLI. Oxudercidae					
103. ***Tridentiger trigonocephalus* Gill, 1859****	+			B	EC

Family, species	Occurrence in waters of Crimea			Ecological group	Vector of introduction
	Reg	Spo	Cas		
XLII. Acanthuridae					
104. ***Acanthurus monroviae* Steindachner, 1876**			+	BP	M
XLIII. Sphyraenidae					
105. ***Sphyraena pinguis* Günther, 1874**			+	P	M
106. *Sphyraena sphyraena* (Linnaeus, 1758)		+		P	
XLIV. Scombridae					
107. *Sarda sarda* (Bloch, 1793)		+		P	
108. *Scomber scombrus* Linnaeus, 1758		+		P	
109. *Thunnus thynnus* (Linnaeus, 1758)			+	P	
XLV. Xiphiidae					
110. *Xiphias gladius* Linnaeus, 1758			+	P	
XLVI. Bothidae					
111. *Arnoglossus kessleri* Schmidt, 1915		+		B	
XLVII. Pleuronectidae					
112. *Platichthys flesus* Linnaeus, 1758	+			B	
XLVIII. Scophthalmidae					
113. ***Scophthalmus rhombus* (Linnaeus, 1758)**		+		B	M
XLIX. Soleidae					
114. *Pegusa nasuta* (Pallas 1814)	+			B	
L. Balistidae					
115. *Balistes capriscus* Gmelin, 1789			+	BP	
LI. Tetraodontidae					
116. ***Lagocephalus sceleratus* (Gmelin, 1789)**			+	BP	M

Note. Introduced species that have appeared since the 1970s are given in bold. Occurrence of species in waters of Crimea: Reg — regular, Spo — sporadic, Cas — casual. Ecological groups of fishes: P — pelagic, BP — bentho-pelagic, B — benthic. Vector of introduction: M — natural expansion (mediterranisation); BW — by ballast waters; M/BW — unknown, either mediterranisation or by ballast waters; M/UI — unknown, either mediterranisation or unintentional introduction; UI — unintentional introduction; II — intentional introduction; EC — escape from captivity; ** — species that have acclimatised in waters of Crimea; *** — unknown time of introduction.

Brief information is given below on introduced species that have occured regularly, sporadically, or casually in the Black Sea waters of Crimea since the 1970s.

Species that occur regularly in waters of Crimea

Order Mugiliformes

***Family Mugilidae* Bonaparte, 1831**

***Genus Planiliza* Whitley, 1945**

1. *Planiliza haematocheila* (Temminck et Schlegel, 1845) — Redlip mullet

Synonyms: *Mugil haematocheilus* Temminck & Schlegel, 1845; *Mugil soiuy* Basilewsky, 1855; *Liza menada* Tanaka, 1916.

Material (in the fish collection of NMNH NASU): Sea of Azov — No. 3292, 5711, 5786, 6285, 6483, 6489, 6502, 6610, 6625, 6642, 8074, 8075, 8076, 9605, 10223; Danube Delta — No. 8429).

Brief description. D_1 IV, D_2 I 8–9, *A* III 8–10, *P* 14–17, *Squ* 36–46 (our data).

Distribution. The species' native range covers coastal waters of the Sea of Japan and the Yellow Sea. It has acclimatised in the Azov-Black Sea Basin and widespread in seas of the Mediterranean Basin (Streftaris & Zenetos 2006). Currently occurs along the entire seacoast of Ukraine, including Crimea.

Vector of introduction. Intentional introduction to the Azov-Black Sea Basin since the 1970s with a formation of a breeding population. The species has completely acclimatised and become commercially important.

[1] Accidental escape to natural water bodies from isolated cultivating facilities.

Order Perciformes

Family Sparidae Bonaparte, 1832

Genus Sarpa Bonaparte, 1831

2. *Sarpa salpa* (Linnaeus, 1758) — Salema porgy

Synonyms: *Sparus salpa* Linnaeus, 1758; *Box salpa* (Linnaeus, 1758).

Material (in the fish collection of NMNH NASU): No. 6526, 8168.

Brief description. *D* XI–XII 14–17; *A* III 13–15; *P* I 15; *V* I 5; *l.l.* 71–80; *sp.br.* 6–7 on the upper and 12–14 on the lower parts of the firt gill arch (our data).

Distribution. The species' range covers the continental shelf of the eastern Atlantic Ocean from the North Sea to South Africa, as well as the Mediterranean Sea (Svetovidov 1964). Single records were known in the Black Sea off the shore of Turkey, Georgia (Batumi), Bulgaria (Varna Bay), and Romania (Constanţa) (Vasileva 2007). In waters of Ukraine, it was first recorded near Crimea in Balaklava Bay (September 1999) and it has reached a relatively high abundance near southwest Crimea; several specimens were caught off the southern coast of the peninsula near Cape Martyan and Cape Ayu-Dag (Boltachev & Yurachno 2002; Boltachev & Karpova 2012). Since 1995, the species has been recorded annually in Tendra Bay, Yahorlyk Bay, and in the coastal marine zone of Kinburn Spit and Tendra Island (Tkachenko 2012).

Vector of introduction. Natural spread through the Bosphorus from seas of the Mediterranean Basin (mediterranisation) with further dispersal along the coast of the Black Sea. In coastal waters and in coves of Sevastopol Bay, the species occurs regularly in flocks of 100 and more specimens. It is caught by commercial industrial seines and gill nets (Boltachev & Karpova 2014).

Genus Sparus Linnaeus, 1758

3. *Sparus aurata* Linnaeus, 1758 — Gilthead seabream

Synonyms: *Aurata aurata* (Linnaeus, 1758); *Chrysophrys aurata* (Linnaeus, 1758); *Pagrus auratus* (Linnaeus, 1758); *Chrysophrys aurathus* (Linnaeus, 1758); *Sparus auratus* Linnaeus, 1758.

Material (in the fish collection of NMNH NASU): No. 8740, 8741, 10345.

Brief description. *D* XI 12–14, *A* III 11–12, *P* 15, *V* I 5, *l.l.* 73–85, *sp.br.* 4–6 on the upper and 7–8 on the lower parts of the first gill arch (our data).

Distribution. The species is distributed in the eastern Atlantic Ocean from Britain to Cap-Vert, common in most seas of the Mediterranean Basin (Fishes of... 1986*a*; Marine Species… 2000). In the Black Sea, records were reported from coastal waters of Turkey, Bulgaria, Romania, and Georgia (Vasileva 2007). In waters of Ukraine, the species was first found near the entrance of Balaklava Bay in August 1999 and it was regularly recorded in the coastal zone of Sevastopol (Boltachev & Yurachno 2002; Boltachev *et al.* 2009). Since 2004, 10 and more specimens have been regularly recorded near the Danube Delta, Kinburn Spit, as well as in Tendra and Yahorlyk Bays and in the Dnipro-Bug Estuary (Tkachenko 2012; Manilo & Redinov 2019). The species was also found in the southern part of the Sea of Azov (Milovanov & Dubovik 2013).

Vector of introduction. Natural spread through the Bosphorus from seas of the Mediterranean Basin (mediterranisation). The appearance of marine farms in Turkey that specialise on the cultivation of this species allows to consider possible escapes of the species from these facilities to the Black Sea.

Family Blenniidae Rafinesque, 1810

Genus Parablennius Ribeiro, 1915

4. *Parablennius incognitus* (Bath, 1968) — Mystery blenny

Synonyms: *Blennius incognitus* Bath, 1968; *Blennius ponticus incognitus* Bath, 1968.

Material (in the fish collection of NMNH NASU): No. 7259.

Brief description. *D* XII 17; *A* II 18–19; *P* 13–14; *V* I 2–3 (our data).

Distribution. The species' range covers the eastern Atlantic Ocean from the Azores and Canary Islands to the shores of Cameroon, as well the Iberian Peninsula and most seas of the Mediterranean

Basin (Fishes of... 1986*b*). The first record of the species in the Black Sea was reported off the shores of Abkhazia in 2001 (Bogorodskii 2006) and, about at the same time, near Turkey and in the Kerch Strait (Vasileva 2007; Keskin 2010). It is possible that *P. incognitus* had appeared in the Black Sea notably earlier. In waters of Ukraine, the species was first recorded near Sevastopol in the summer of 2002, wheares in 2003 it was often found in open rocky areas of the shore from Sevastopol Bay to Cape Fiolent (Boltachev *et al.* 2009). According to data from 2013 (Boltachev & Karpova 2017), the species has spread along the entire southern coast of Crimea to Cape Opuk having an abundance as high as native blenny species.

Vector of introduction. Introduction of the species to the Black Sea could take place naturally from the Marmara Sea (mediterranisation), although almost simultaneous catches in several remote locations might indicate human-mediated appearance with ballast waters or on the bottoms of ships.

Family Gobiesocidae Bleeker, 1859

Genus Apletodon Briggs, 1955

5. *Apletodon dentatus* (Facciola, 1887) — Small-headed clingfish

Synonyms: *Lepadogaster bacesqui* Murgoci, 1940; *Apletodon dentatus dentatus* (Facciola, 1887).

Material (in the fish collection of NMNH NASU): absent.

Brief description. *D* 5–6; *A* 5–7; *P* 21–24 (Vasileva 2007, Black Sea). *D* 7–8; *A* 6–8; *P* 19 (Karpova *et al.* 2017, Black Sea, Crimea).

Distribution. The species' range covers waters of the eastern Atlantic Ocean from the southwest coast of the Scandinavian Peninsula to Spain; it is common in the Mediterranean Basin. In the Black Sea, a small number of records of the species are known from a narrow coastal zone of Romania; one specimen was caught in waters of Turkey near Cape Sinop in May 2000 (Fishes of… 1986*b*; Mediterranee... 1987; Bat *et al.* 2006). In waters of Ukraine, the species was recorded only near Sevastopol (in coves and along the open coast) and near the Tarkhankut Peninsula. Records of the small-headed clingfish in the Black Sea are related to habitats with outcrops of porous limestones (Karpova *et al.* 2017).

Vector of introduction. Natural spread through the Bosphorus from seas of the Mediterranean Basin (mediterranisation).

Order Gobiiformes

Family Gobiidae Fleming, 1822

Genus Chromogobius de Buen, 1930

6. *Chromogobius quadrivittatus* (Steindachner, 1863) — Chestnut goby

Synonyms: *Gobius depressus quadrivittata* Steindachner, 1863; *Relictogobius kryzhanovskii* Ptchelina, 1939; *Chromogobius kryzanowskii* (Ptchelina, 1939).

Material (in the fish collection of NMNH NASU): No. 2771, 6185.

Brief description. D_1 VI, D_2 I 10, *A* I 9, *P* 17 (Kovtun 2013, Black Sea, underwater caves of the Tarkhankut Peninsula). D_1 VI, D_2 I 10, *A* I 9–10, *P* 17 (our data, Black Sea coast of the Caucasus).

Distribution. The species' range covers coastal waters of the northern and eastern parts of the Mediterranean Sea (Adib 2005), as well as the Marmara, Aegean (Bilecenoglu *et al.* 2014), and Black Seas. A rare and non-abundant species in all localities. In had been known earlier in the Black Sea near the shore of the Caucasus (Pchelina 1939; Pinchuk 1987), where it has entirely disappeared (Pashkov *et al.* 2013), and in Varna Bay (Georgiev 1961). A single specimen found during fish kill near Odessa was reported by A. K. Vinogradov and S. A. Khutornoy (2013), but the specimen was lost and only a photo was published. In waters of Ukraine, the species was first recorded in underwater karst caves of Cape Tarkhankut (Kovtun 2013). Several specimens, including juveniles, were found in Martynova Cove (Sevastopol) in 2015 (Boltachev & Karpova 2016) and in Kozacha Cove in 2016 (Boltachev & Karpova 2017), which, in our opinion, can be considered as current further dispersal

and acclimatisation of the species in waters of Crimea. According to the latest data (O. A. Kovtun's personal report), this species was found in underwater caves of Bulgaria north of Varna Bay, close to the border with Romania.

Vector of introduction. Natural spread through the Bosphorus from seas of the Mediterranean Basin (mediterranisation).

7. *Chromogobius zebratus* Kolombatovic, 1891 — Kolombatovic's goby

Synonyms: *Gobius depressus* var. *zebratus* Kolombatovic, 1891; *Chromogobius zebratus zebratus* (Kolombatovic, 1891); *Gobius depressus zebratus* Kolombatovic, 1891.

Material (in the fish collection of NMNH NASU): absent.

Brief description. D_1 VI, D_2 I 11, *A* I 10, *P* 14, *Squ* 46. (Kovtun & Karpova 2014, Black Sea, underwater caves of the Tarkhankut Peninsula).

Distribution. The species' range covers the northwest and eastern parts of the Mediterranean Sea from the Strait of Gibraltar to Israel. Near the shores of Turkey, *Ch. zebratus* was first found in the Aegean Sea only in 2008 (Engin & Dalgic 2008). The species' abundance is low. It is a cryptobenthic and quite rare species. In waters of Ukraine, it was first recorded in underwster karst caves of Cape Tarkhankut (Kovtun & Karpova 2014).

Vector of introduction. Natural spread through the Bosphorus from seas of the Mediterranean Basin (mediterranisation). The time of its appearance in the Black Sea is unknown.

***Genus Gammogobius* Bath, 1971**

8. *Gammogobius steinitzi* Bath, 1971 — Steinitz's goby

Synonyms: absent.

Material (in the fish collection of NMNH NASU): No. 9261.

Brief description. D_1 VI, D_2 I 8–9, *A* I 7–9, *P* 15–17, *V* I 5, *Squ* 31–32 (Crimea, underwater caves of Cape Tarkhankut; our data).

Distribution. The species is known from several localities of the northern part of the Mediterranean Sea: near the coast of France (Dufour *et al.* 2007), Ibiza, (Scsepka & Ahnelt 1999), in the north of the Tyrrhenian Sea near Giglio Island, Italy (Ahnelt *et al.* 1998), in the north of the Adriatic Sea near Krk Island (Kovačić 1999), and near Cretea (Kovačić *et al.* 2011). In the Black Sea, the species in known only in waters of Ukraine from underwater karst caves of the Tarkhankur Peninsula (Malyi Atlesh tract) (Kovtun 2012; Kovtun & Manilo, 2013).

Vector of introduction. Natural spread through the Bosphorus from seas of the Mediterranean Basin (mediterranisation). The time of its appearance in the Black Sea is unknown.

***Genus Gobius* Linnaeus, 1758**

9. *Gobius couchi* Miller et El-Tawil, 1974 — Couch's goby

Synonyms: absent.

Material (in the fish collection of NMNH NASU): absent.

Brief description. D_1 (V) VI (VII), D_2 I (11) 12–13, *A* I (10) 11–12, *P* 16–17, *Squ* 36–44 (Karpova & Boltachev 2018).

Distribution. A quite rare Atlantic-Mediterranean species. It was recorded near the shores of Great Britain and Ireland, as well as in the northern part of the Mediterranean Sea and in the Aegean Sea (Miller & El-Tawin 1974; Minchin 1988; Costello 1992; Kovačić *et al.* 2013). The species did not occur in the Black Sea until recently, when it was found in Kozacha and Karantinna Coves of Sevastopol Bay (Karpova & Boltachev 2018). According to these researchers, the species has fully adapted to conditions of the southwest coast of Crimea.

Vector of introduction. Natural spread through the Bosphorus from seas of the Mediterranean Basin (mediterranisation).

10. *Gobius cruentatus* Gmelin, 1789 — Red-mouthed goby
Synonyms: *Gobius rubens* Rafinesque, 1810; *Gobius strictus* Fage, 1907.

Material (in the fish collection of NMNH NASU): No. 7253.

Brief description. D_1 VI, D_2 I 14, *A* I 13, *P* 20, *Squ* 53 (our data).

Distribution. The native range of the species includes waters of the eastern Atlantic Ocean from the southwest of Ireland to Senegal, as well as the western and northern parts of the Mediterranean Sea (Miller 1986; Kovačić 2005; Golani *et al.* 2006). In the Black Sea, it was found off the coast of Turkey (Engin *et al.* 2007). Near the shores of Ukraine, the species is known in Crimea from coastal waters near Sevastopol (Boltachev *et al.* 2009). Since 2009, the species has occurred regularly in the coastal zone and in some coves of Sevastopol Bay.

Vector of introduction. Natural spread through the Bosphorus from seas of the Mediterranean Basin (mediterranisation) with further acclimatisation off the coast of southwest Crimea.

11. *Gobius xanthocephalus* Heimer et Zander, 1992 — Yellow-headed goby
Synonyms: absent.

Material (in the fish collection of NMNH NASU): No. 7254.

Brief description. D_1 VI, D_2 I 14–16, *A* I 13–14, *V* 12, *Squ* 44–45 (our data).

Distribution. The species' range covers the eastern Atlantic Ocean along the shores of Portugal (Almeida & Arruda 1998) and the Canary Islands (Wirtz & Herrera 1995). It is a common species in the Mediterranean Sea off the coast of France (Heimer & Zander 1992). In the Black Sea, the species is rare and its records are known from near the shores of Abkhazia (Vasileva & Bogorodskii 2004) and from Crimea near Sevastopol (Boltachev *et al.* 2009) and Cape Tarkhankut (Karpova & Saksahanskyy 2011). The yellow-headed goby is currently quite common but non-abundant in the coastal zone of southwest Crimea from Cape Tovstyi to Cape Fiolent and near Cape Tarkhankut.

Vector of introduction. Natural spread through the Bosphorus from seas of the Mediterranean Basin (mediterranisation) with further acclimatisation off the coast of southwest Crimea and Abkhazia.

***Genus Millerigobius* Bath, 1973**

12. *Millerigobius macrocephalus* (Kolombatovic, 1891) — Large-headed goby
Synonyms: *Gobius macrocephalus* Kolombatovič, 1891.

Material (in the fish collection of NMNH NASU): No. 8894.

Brief description. D_1 VI, D_2 I 11, *A* I 10, *P* 14–16, *Squ* 29–31 (our data).

Distribution. The species was known as an endemic of the Aegean and Adriatic Seas (Miller 1986; Golani *et al.* 2006; Kovačić 2008) and in the western part of the Mediterranean Sea near Ibiza Island (Fischer *et al.* 2007). It had not been recorded in the Black Sea earlier. In waters of Ukraine, the species' population comprising specimens of different age was first recorded in 2009 in the lower part of Sevastopol Bay (Boltachev *et al.* 2010). An independent population has formed here.

Vector of introduction. The species could have appeared in the Black Sea with ballast waters. The vector of its individual spread currently needs further studies (Boltachev *et al.* 2010).

***Genus Pomatoschistus* Gill, 1863**

13. *Pomatoschistus bathi* Miller, 1982 — Bath's goby
Synonyms: absent.

Material (in the fish collection of NMNH NASU): No. 7913.

Brief description. D_1 VI, D_2 I 7–9, *A* I 8–9, *P* 15–17, *Squ* 34–35 (Kozacha Cove, Black Sea; our data).

Distribution. The species' native range covers the Mediterranean Basin. In the Black Sea, the species occurs near the shores of the Caucasus (Vasileva & Bogorodskii 2004; Vasileva 2007) and Bulgaria (Vassilev *et al.* 2012). In marine waters of Ukraine, the species has been recorded since the early 2000s in Sevastopol Bay and along the southern shore of Crimea from Cape Sarych to Cape Tovstyi

(Boltachev & Karpova 2010*a*). Bath's goby is currently an abundant species in Sevastopol Bay, Lake Donuzlav, near Cape Tarkhankut (Eremeev *et al.* 2012), in Karkinit Bay (Prishchepa *et al.* 2018), and in waters of Kara-Dag Nature Reserve. Based on the relatively frequent occurences of groups of various sizes, the species has formed an independent breeding population in the coastal zone of Crimea. The species increases its abundance and distribution range along the Black Sea coast.

Vector of introduction. Natural spread through the Bosphorus from seas of the Mediterranean Basin (mediterranisation) with further naturalisation off the shore of Crimea, the Caucasus, and Bulgaria. The spread of Bath's goby to the Black Sea is a typical example of mediterranisation with subsequent complete and successful naturalisation.

***Genus Zebrus* Gill, 1859**

14. *Zebrus zebrus* (Risso, 1827) — Zebra goby

Synonyms: *Gobius zebrus* Risso, 1827.

Material (in the fish collection of NMNH NASU): absent.

Brief description. D_1 VI (V–VI), D_2 I 10–11, *A* I 9 (7–10), *P* 17 (16–18), *Squ* 29–38, *Vert.* 26–27 (Miller 1986).

Distribution. The species is distributed in the Mediterranean Sea except for the offshore waters of northern Africa. In the eastern Atlantic Ocean, the zebra goby occurs off the shore of Spain in the south of the Iberian Peninsula. In 2007, a mature specimen was caught in the Black Sea off the shore of Turkey near Cape Jason (Kovačić & Engín 2009). In 2009, it was recorded in Sevastopol Bay on mussel collectors (Boltachev *et al.* 2010) together with *Millerigobius macrocephalus.* In the following years, the species was found in Striletska and Martynova Coves of Sevastopol Bay, which allows concluding on the species' acclimatisation in Crimea (Manilo *et al.* 2013).

Vector of introduction. Natural spread through the Bosphorus from seas of the Mediterranean Basin (mediterranisation) with further naturalisation near the shores of Turkey and southwest Crimea.

Family Oxudercidae Günther, 1861

***Genus Tridentiger* Gill, 1859**

15. *Tridentiger trigonocephalus* Gill, 1859 — Chameleon goby

Synonyms: *Triaenophorus trigonocephalus* Gill, 1858; *Triaenophorichthys trigonocephalus* Gill, 1859; *Tridentiger bifasciatus* Steindachner, 1881.

Material (in the fish collection of NMNH NASU): No. 2464, 7255.

Brief description. D_1 VI, D_2 I 11, *A* I 11, *P* 19, *V* 10, *Squ* 51 (Sevastopol, mouth of the Chorna river, our data).

Distribution. The species' native range covers coastal and estuary waters of the Sea of Japan, the Yellow Sea, and the South China Sea (Lindberg & Krasyukova 1975), wherefrom it spread with ballast waters of commercial vessels, as well as due to the large-scale export of the Pacific oyster from cultivation farms of Japan with goby eggs attached to the shells. The species appeared in waters of California (USA) and Australia, where it completely naturalised (Global Invasive…2007). In the Mediterranean Basin, the species is known by a single specimen recorded near the coast of Israel in the harbour of the port of Ashdod (Goren *et al.* 2009). In waters of Ukraine, it was first recorded in Sevastopol Bay in 2006 (Boltachev *et al.* 2007). It was concluded in 2009 that the species have completely acclimatised in waters of Sevastopol Bay (Boltachev & Karpova 2010*b*).

Vector of introduction. The most probable vector of introduction of the species is escape from captivity. In early 1980, several dozens of specimens were brought from Posyet Bay (Far East) to the Sevastopol Aquarium for decorative keeping, but their colouration was not spectacular enough for demonstration and they were released into Sevastopol Bay, where they probably formed a local population (Boltachev & Karpova 2010).

Species that occur sporadically in waters of Crimea

Order Clupeiformes

Family Clupeidae Cuvier, 1816

Genus Sardina Antipa, 1904

16. *Sardina pilchardus* (Walbaum, 1792) — Pilchard sardine

Synonyms: *Clupea harengus pilchardus* Walbaum, 1792; *Alosa pilchardus* (Walbaum, 1792); *Clupea pilchardus* Walbaum, 1792; *Clupea pilchardus* Bloch, 1795; *Sardina dobrogica* Antipa, 1904.

Material (in the fish collection of NMNH NASU): No. 7641, 9267, 9269.

Brief description. *D* 13–21; *A* 12–23; *sp.br.* 78–90 (our data).

Distribution. The species' range covers the eastern Atlantic Ocean from the North Sea and Iceland to Senegal, as well as the Mediterranean and Black Seas. In the latter, the species occurs along the coasts, but mostly in the Bosphorus area. In small numbers, it is also caught by seines in the coastal zone and coves of Sevastopol, in the Kerch Strait during spring and autumn migrations of pelagic fishes, while in winter it occurs off the shore and observed in catches of trawlers along the southers coast of Crimea. Since the 2000s, the species has been sporadically recorded in cathes of trawlers on the southern continental shelf of Crimea in autumn and early winter. It is rare in the coastal zone (Boltachev *et al.* 2014).

Vector of introduction. Episodic migrations to the Black Sea from seas of the Mediterranean Basin through the Bosphorus (mediterranisation).

Genus Sardinella Valenciennes, 1847

17. *Sardinella aurita* (Valenciennes, 1847) — Round sardinella

Synonyms: *Clupea allecia* Rafinesque, 1810; *Alosa senegalensis* Bennett, 1831; *Sardinella anchovia* Valenciennes, 1847; *Sardinia pseudohispanica* Poey, 1860; *Sardinella euxina* Antipa, 1906.

Material (in the fish collection of NMNH NASU): absent.

Brief description. *D* III–IV 14–16; *A* 13–15; *P* I 12; *V* I 8; *sp.br.* 201–208, 31–36 abdominal spikes (Movchan 2011).

Distribution. Warm waters of the western and eastern Atlantic Ocean, the Mediterranean, Aegean, and Marmara Seas (Fishes of...1986*a*; Vasileva 2007). Rarely occurs near the shores of Crimea and in the Black Sea in general, where records were reported from near Burgas, Constanța, and Batumi (Svetovidov 1964). Single specimens were recorded off the coast of Crimea near Kara-Dag in 1981 and 1988 (Salekhova & Kostenko 1989) and in coves of Sevastopol Bay: in Balaklava in October 1998 (Boltachev *et al*. 2000) and in Striletska in July 2008 (Boltachev *et al*. 2010).

Vector of introduction. Episodic migrations during warm periods to the Black Sea from the Mediterranean Basin through the Bosphorus (mediterranisation).

Order Mugiliformes

Family Mugilidae Bonaparte, 1831

Genus Chelon Röse, 1793

18. *Chelon labrosus* (Risso, 1827) — Thicklip grey mullet

Synonyms: *Mugil labrosus*Risso, 1827; *Crenimugil labrosus*(Risso, 1827); *Mugil chelo* Cuvier, 1829; *Mugil chelon* Cuvier, 1829; *Mugil curtus* Yarrell, 1836; *Mugil buosega* Nardo, 1847.

Material (in the fish collection of NMNH NASU): absent.

Brief description. D_1 III–IV, D_2 I 8 (9), *A* III 3 (8) 9, *P* 16 (17), *sp.br.* 35–76, *Squ* 41–47 (Movchan 2011).

Distribution. The species' range covers coastal waters of the eastern Atlantic Ocean from the south of Norway to the islands of Cap-Vert and of the northern Atlantic Ocean from Europe to the south of Iceland. The species is abundant in seas of the Mediterranean Basin (Froese & Pauly 2020). It was first recorded in Balaklava Cove in October 1999 and it occurred regularly in the following ten

years near the southwest coast of Crimea from Cape Khersones to Cape Aya (Boltachev & Yurachno 2002; Boltachev *et al*. 2009). Since the early 2010s, the species has been rarely recorded, which could be related to either the complexity of its catching or the cyclic appearance of the species near the coast of Crimea. The species occurs in mixed groups with native mullet species (Boltachev *et al*. 2009).

Vector of introduction. Natural spread from seas of the Mediterranean Basin through the Bosphorus (mediterranisation). Annual feeding migrations to the shores of Crimea from the seas of the Mediterranean Basin.

19. *Chelon ramada* (Risso, 1827) — Thinlip mullet

Synonyms: *Mugil ramada* Risso, 1827; *Liza ramada* (Risso, 1827); *Mugil capito* Cuvier, 1829; *Mugil caustelus* Nardo, 1847; *Mugil petherici* Günther, 1861; *Liza alosoides* Fowler, 1903.

Material (in the fish collection of NMNH NASU): absent.

Brief description. D_1 IV, D_2 I 8–9, *A* III (8) 9, *P* 16, *Squ* 44–46 (Movchan 2011).

Distribution. The species inhabits seas of the Mediterranean Basin and the eastern Atlantic Ocean from Scandinavia and the southern part of the Baltic Sea to Senegal and the islands of Cap-Vert. It is rare in the Black Sea and most of its records are known from the coastal zone of Turkey, Romania, and Bulgaria (Harrison 2003). The first record of this species off the coast of Crimea was reported from near Sevastopol in 1930, but it was found again only in October 2006. In October 2012, the species was found for the third time in catches near Balaklava (Boltachev *et al*. 2009).

Vector of introduction. Natural spread through the Bosphorus from seas of the Mediterranean Basin (mediterranisation). Annual feeding migrations to the Black Sea.

Order Gasterosteiformes

Family Syngnathidae Bonaparte, 1831

Genus Syngnathus Linnaeus, 1758

20. *Syngnathus acus* Linnaeus, 1758 — Greater pipefish

Synonyms: *Syngnathus acus* (Linnaeus, 1758); *Typhle heptagonus* Rafinesque, 1810; *Syngnathus rubescens* Risso, 1810; *Syngnathus brachyrhynchus* Kaup, 1856; *Syngnathus delaland* Kaup, 1856.

Material (in the fish collection of NMNH NASU): No. 4861, 4862, 7258.

Brief description. *D* 31–34, *A* 3–4, *P* 13, 16–18 trunk vertebrae, 36–43 caudal rings, 8–9 subdorsal rings (our data).

Distribution. The species' native range covers the eastern Atlantic Ocean from the coasts of Norway, Faroes, and the British Isles to Western Sahara, including the Mediterranean and Aegean Seas, as well as the area from Namibia to the southeast coast of the Republic of South Africa (Froese & Pauly 2020). In the Black Sea, it was first mentioned by K. F. Kessler (1877), although later the species was re-identified as *S. variegatus* Pallas, 1814 and excluded from the list of Black Sea fishes (Svetovidov 1964). Relatively recently, the species has been found off the coast of Turkey (Vasileva 2007). In November 2006, male and female specimens were caught in the upper part of Sevastopol Bay at the mouth of the Chorna River, and another female a year after at the same place (Boltachev *et al*. 2009). Despite regular ichthyological studies, the species has not been recorded since. Due to the finds of mature male and female specimens in Sevastopol Bay, it is assumed that the species has started to naturalise in the studied area (Boltachev *et al*. 2010), although this issue needs further studies.

Vector of introduction. Unknown, either mediterranisation or spread by ballast waters.

Order Scorpaeniformes

Family Scorpaenidae Swainson, 1839

Genus Sebastes Cuvier, 1829

21. *Sebastes schlegelii* Hilgendorf, 1880 — Korean rockfish

Synonyms: *Sebastichthys schlegelii* (Hilgendorf, 1880).

Material (in the fish collection of NMNH NASU): absent.

Brief description. *D* XII–XIV 11–13; *A* III 5–8; *P* 17–19 (Froese & Pauly 2020).

Distribution. The species' native range covers the northwest part of the Pacific Ocean: waters of Korea, Japan, and Primorye region of Russia, also occurs in waters of Sakhalin, Iturup, and Kunashir Islands (Froese & Pauly 2020). In April 2008, a specimen of this species was caught in waters of Denmark, where its appearance was explained by transportation with ballast waters (Kai & Soes 2009). In Ukraine, a specimen of the Korean rockfish was first recorded on 26 April 2013, when it was caught by an industrial bottom trap exposed 40 m deep in the coastal zone near Cape Aya (44°28'8 N, 33°37'4 E) and erroneously identified as *E. caninus* Valenciennes, 1834 of the family Serranidae (Boltachev *et al.* 2013). For some time, the specimen had been kept in the Sevastopol Aquarium. Later, the species has been sporadicaly recorded in waters of Crimea (near Balaklava, Kacha, Cape Meganom, and Cape Ayu-Dag), as well as near the Black Sea coast of the Caucasus (Cape Utrish). It was suggested that the species has naturalised in the Black Sea (Karpova *et al.* 2019); this view currently cannot be supported.

Vector of introduction. Unintentional introduction of juveniles and larvae to the Black Sea from the basin of the Pacific Ocean due to the cultivation of the Pacific oyster *Crassostrea gigas* (Ye. P. Karpova's personal report).

Order Perciformes

Family Sparidae Bonaparte, 1832

Genus Boops Cuvier, 1914

22. *Boops boops* (Linnaeus, 1758) — Striped bigeye

Synonyms: *Sparus boops* Linnaeus, 1758; *Box boops* (Linnaeus, 1758); *Box vulgaris* Valenciennes, 1830; *Boops canariensis* Valenciennes, 1839; *Box canariensis* (Valenciennes, 1839).

Material (in the fish collection of NMNH NASU): absent.

Brief description. *D* XIII–XIV (13) 14–16 (17); *A* III (14) 15–17; *P* I 16–17; *l.l.* 74–82 (Movchan 2011).

Distribution. The species inhabits the eastern Atlantic Ocean from Norway to Angola and seas of the Mediterranean Basin. In the Black Sea, the species occurs quite rarely near all rocky shores, except for the northwest part. Until recently, it was known in Crimea only by single records, although in recent years the species has occurred episodically in coves and in the coastal zone of Sevastopol (Boltachev & Karpova 2017).

Vector of introduction. Individual rare spread through the Bosphorus from the Mediterranean Sea (mediterranisation).

Genus Lithognathus Swainson, 1839

23. *Lithognathus mormyrus* (Linnaeus, 1758) — Sand steenbras

Synonyms: *Sparus mormyrus* Linnaeus, 1758; *Pagellus mormyrus* (Linnaeus, 1758); *Pagellus goreensis* Valenciennes, 1830.

Material (in the fish collection of NMNH NASU): absent.

Brief description. *D* XI 12–13; *A* III 10–11; *P* 15; *l.l.* 62–64 (Boltachev *et al.* 2013; Guchmanidze & Boltachev, 2017).

Distribution. The species is distributed in seas of the Mediterranean Basin, in the eastern Atlantic Ocean from the Bay of Biscay to Cape of Good Hope, as well as in the Indian Ocean south of Mozambique (Froese & Pauly 2020). In the Black Sea, until recently it had been known by single records near the shores of Bulgaria in Varna Bay (Vasileva 2007) and Romania (Yankova *et al.* 2013). A specimen was first caught in the coastal zone of Crimea by industrial bottom trap near Cape Aya in June 2013 (Boltachev *et al.* 2013). Later, the number of findings increased off the coast of Turkey (Engin *et al.* 2015), Georgia (Guchmanidze & Boltachev 2017), the Northern Caucasus (Guskov *et al.* 2017), and southwest Crimea (Yalta and Kozacha Cove, Sevastopol). Based on the observation of a flock of juveniles of more than 50 specimens in Kozacha Cove, it was concluded that the species has naturalised in waters of Crimea (Karpova 2020).

Vector of introduction. A bentho-pelagic species that have spread to the coast of Crimea individually through the Bosphorus from the Marmara Sea (mediterranisation).

Order Pleuronectiformes

Family Scophthalmidae Jordan, 1923

Genus Scophthalmus Rafinesque, 1810

24. *Scophthalmus rhombus* (Linnaeus, 1758) — Brill

Synonyms: *Pleuronectes rhombus* Linnaeus, 1758; *Pleuronectes laevis* Turton, 1802; *Rhombus laevis* (Turton, 1802).

Material (in the fish collection of NMNH NASU): absent.

Brief description. *D* 83, *A* 61, *P* 11–12, *V* 6, *C* 17, *sp.br.* 18 (Giragosov *et al*. 2012).

Distribution. The species is distributed in the eastern part of the Atlantic Ocean from Norway and Great Britain to the north of Africa, also occurs in the Baltic, Mediterranean, Aegean, and Marmara Seas and in the Bosphorus (Mengi 1971; Nielsen 1986). In the northern part of the Black Sea, only 3 specimens have been recorded for the entire history of ichthyological research: 1 near Feodosia in the 19th century (Kessler 1877) and 2 near Kara-Dag in 1946 (Vinogradov 1949). A female specimen was found off the shore of Bulgaria in May 1954 (Georgiev *et al*. 1960). In 2010, 3 specimens were caught by seine in Striletska Cove in Sevastopol (Giragosov *et al*. 2012).

Vector of introduction. A typical benthic species with no long-term migrations, although it clearly apparead near Crimea naturally through the Bosphorus from the Marmara Sea (mediterranisation).

Species that occur casually (single records) in waters of Crimea

Order Gadiformes

Family Gadidae Rafinesque, 1815

Genus Micromesistius Gill, 1863

25. *Micromesistius poutassou* (Risso, 1827) — Blue whiting

Synonyms: *Merlangus poutassou* Risso, 1827; *Boreogadus poutassou* (Risso, 1827); *Gadus poutassou* (Risso, 1827); *Merlangus vernalis* Risso, 1827; *Merlangus pertusus* Cocco, 1829.

Material (in the fish collection of NMNH NASU): absent.

Brief description. D_1 13 (12–14), D_2 14 (12–14), D_3 23 (23–26), A_1 35 (33–39), A_2 26 (24–27), *P* 22, *sp. br.* 27–33 (Movchan 2011).

Distribution. An Atlantic-Boreal species distributed from Spitsbergen along the coast of Europe to the Canary Islands, northwest Africa to Cape Bojador, as well as to west from the Barents Sea to Iceland, Greenland, and northeast coast of the USA. The species inhabits most seas of the Mediterranean Basin, although it is more common in the western part of the Mediterranean Sea (Svetovidov 1964; Marine Species… 2000). The only specimen known in the Black Sea was caught by hook in January 1999 near Cape Aya (southwest coast of Crimea) at a depth of 60 m (Boltachev *et al*. 1999, 2010).

Vector of introduction. Accidental natural spread from seas of the Mediterranean Basin through the Bosphorus (mediterranisation).

Order Scorpaeniformes

Family Dactylopteridae Gill, 1885

Genus Dactylopterus Lacepede, 1801

26. *Dactylopterus volitans* (Linnaeus, 1758) — Mediterranean flying gurnard

Synonyms: *Trigla volitans* Linnaeus, 1758; *Dactylopterus vulgaris* Steindachner, 1867; *Cephalacanthus volitans* (Linnaeus, 1758); *Dactylopterus blochii* Swainson, 1839.

Material (in the fish collection of NMNH NASU): No. 4970.

Brief description. D_1 VII; D_2 VIII; *A* 6 (our data).

Distribution. The species is distributed in the eastern and western Atlantic Ocean south of the English Channel to Angola and from Massachusetts (USA) to Argentina, as well as near Madeira,

the Azores, and in seas of the Mediterranean Basin (Mediterranee... 1987; Froese & Pauly 2000). In the Black Sea, 2 records of the species were reported from Odessa Bay in September 1979. (Movchan 2011) and an immature 40 mm long specimen from near Sevastopol (Liubymivka village) (Boltachev & Karpova 2014).

Vector of introduction. It is hard to determine the species' vector of appearance; it could be passive spread by either currents or ballast waters.

Order Perciformes

Family Sparidae Bonaparte, 1832

Genus Dentex Cuvier, 1814

27. *Dentex dentex* (Linnaeus, 1758) — Common dentex

Synonyms: *Sparus dentex* Linnaeus, 1758; *Dentex vulgaris* Valenciennes, 1830.

Material (in the fish collection of NMNH NASU): absent.

Brief description. *D* X–XII 11; *A* III 8; *P* I 14; *V* I 5; *l.l.* 60–65 (Movchan 2011).

Distribution. The species is distributed in the eastern Atlantic Ocean from the Bay of Biscay and southern part of the British Isles to Senegal, near Madeira and the Canary Islands, as well as in the Mediterranean, Aegean, and Marmara Seas. Rare records of the species are known from the Black Sea off the coast of Turkey, Bulgaria, and Romania. In waters of Ukraine, only a single specimen was caught in June 2014 in the coastal zone of Cape Fiolent at a depth of 9 m (Boltachev & Karpova 2017).

Vector of introduction. Independent accicental spread from seas of the Mediterranean Basin through the Bosphorus (mediterranisation).

Family Chaetodontidae Rafinesque, 1815

Genus Heniochus Cuvier, 1816

28. *Heniochus acuminatus* Linnaeus, 1758 — Pennant coralfish

Synonyms: *Chaetodon acuminatus* Linnaeus, 1758; *Chaetodon macrolepidotus* Linnaeus, 1758; *Heniochus macrolepidotus* (Linnaeus, 1758); *Taurichthys macrolepidotus*.

Material (in the fish collection of NMNH NASU): No. 8099, 10695.

Brief description. *D* XI–XII 22–27, *A* III 17–19, *P* I 16, *V* I 5, *l.l.* 51 (our data).

Distribution. Tropical waters of the Indian and Pacific Oceans from South Africa to Japan and Papua New Guinea. The only finding of the species in the Black Sea was reported in October 2003 from Balaklava Bay (Boltachev & Astakhov 2004).

Vector of introduction. An Indo-West Pacific species, possibly spread by ballast waters.

Family Acanthuridae Bonaparte, 1835

Genus Acanthurus Forsskal, 1775

29. *Acanthurus monroviae* Steindachner, 1876 — Monrovia doctorfish

Synonyms: *Teuthis munroviae* Steindachner, 1876; *Acanthurus monrovie* Steindachner, 1876; *Acanthurus phlebotomus* (non Valenciennes, 1835).

Material (in the fish collection of NMNH NASU): absent.

Brief description. *D* IX 24–26, *A* VI 24–26 (Froese & Pauly 2020).

Distribution. The native range of the species covers the eastern Atlantic Ocean from the coast of Morocco to Angola, the Canary Isalnds, and the islands of Cap-Vert. A significant increase in the number of records of *A. monroviae* and in the expansion of its range has been observed since the 2000s in the Mediterranean Sea: specimens have been found off the coast of southern Spain, Malta, Tunisia, Algeria, Israel, and Greece. The only specimen with *TL* 235 mm known from waters of Ukraine was caught on 19 September 2015 by fishing net near the entrance of Balaklava Bay in the southwest part of the Crimean Peninsula (Boltachev & Karpova 2020).

Vector of introduction. A bentho-pelagic species that appeared in coastal waters of Crimea from eastern seas of the Mediterranean Basin through the Bosphorus (mediterranisation).

Family Sphyraenidae Rafinesque, 1815

Genus Sphyraena Röse, 1793

30. *Sphyraena pinguis* Günther, 1874 — Red barracuda

Synonyms: absent.

Material (in the fish collection of NMNH NASU): No. 6525.

Brief description. D_1 V, D_2 I 9, *A* II 9, *P* 11–13, *V* I 5, *l.l.* 80–92 (our data).

Distribution. A pelagic species migrating in flocks. It is widely distributed in the Indo-West Pacific region along the continental shelf of East Africa from the Red Sea to Mozambique and the Republic of South Africa, as well as along the shores of Asia from the Arabian Peninsula to Indonesia. The species also occurs in the Pacific Ocean from the southern Primorye and Hokkaido to Papua New Guinea and southern Australia (Doiuchi & Nakabo 2005). Through the Suez Canal, the species spread to the eastern part of the Mediterranean Sea (Lessepsian migrant) and it was recorded off the coast of Palestina in 1931 (Golani *et al.* 2002). In following years, the red barracuda has spread along the coast of Egypt, Israel, Lebanon, and Turkey, including the Aegean Sea. The species also occurs near Malta and it has completely naturalised in the eastern part of the Mediterranean Sea (Golani *et al.* 2002). Two specimens were caught in Balaklava Bay in August 1999, which were initially identified as *S. obtusata* Cuvier, 1829, but later re-identified as *S. pinguis* (Boltachev 2009).

Vector of introduction. The species' vector of introduction near the coast of Crimea is migration from the Marmara Sea through the Bosphorus (mediterranisation).

Order Tetraodontiformes

Family Tetraodontidae Rafinesque, 1815

Genus Lagocephalus Swainson, 1839

31. *Lagocephalus sceleratus* Gmelin, 1789 — Silver-cheeked toadfish

Synonyms: *Fugu sceleratus* (Gmelin, 1789); *Gastrophysus sceleratus* (Gmelin, 1789); *Tetraodon sceleratus* Gmelin, 1789; *Tetraodon bicolor* Brevoort, 1856; *Tetraodon blochii* Castelnau, 1861.

Material (in the fish collection of NMNH NASU): No. 4005, 4961, 3117, 4196.

Brief description. Only soft radials in the fins, 10–13 in the dorsal and 8–12 in the anal fin (our data).

Distribution. The species is distributed in coastal waters of the tropical zone of the Indian and Pacific Oceans. It has spread to the Mediterranean Basin through the Suez Canal (Lessepsian migrant), where it was first recorded in 2003 in the Aegean Sea. Currently, the species has widely dispersed in the eastern and central parts of the Mediterranean Sea near the coast of Israel, Turkey, and Greece, as well as in the Aegean Sea to the Dardanelles. A living specimen was caught by net in Staropivnichna Cove (Sevastopol Bay) in November 2014 (Boltachev & Karpova 2017).

Vector of introduction. The species' vector of introduction near the coast of Crimea is migration from the Marmara Sea through the Bosphorus (mediterranisation).

Among the introduced species that occur regularly in waters of Crimea, benthic species predominate (12 species, or 80.0 %), while bentho-pelagic and pelagic species make up an insignificant part—6.7 % and 13.3 %, respectively. Among species that occur sporadically, pelagic (50.0 %) and bentho-pelagic species prevail (37.5 %). Bentho-pelagic species predominate among fishes that occur casually (57.1 %) (Fig. 2).

Among the 31 introduced species recorded in the Black Sea waters of Crimea for the past 50 years, species that appeared due to the natural process of mediterranisation prevail (22 species, or 71.0 %). The vector of introduction could not be identified for 4 species (*Syngnathus acus, Dactylopterus volitans, Sparus aurata,* and *Parablennius incognitus*), the ratio of which is 13.3 %. The appeareance of the remaining 5 species (*Planiliza haematocheila, Sebastes schlegelii, Heniochus acuminatus, Millerigobius macrocephalus,* and *Tridentiger trigonocephalus*), which make up 16.1 %, is due to anthropogenic factors (Fig. 3).

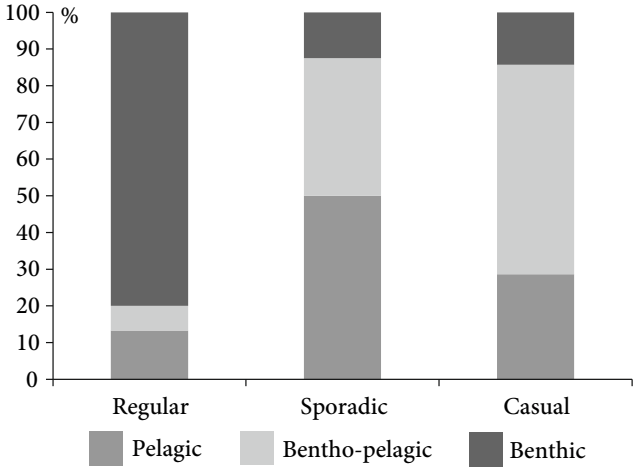

Fig. 2. The ratio of species of different ecological groups (benthic, bentho-pelagic, pelagic) among alien fishes in the Black Sea waters of Crimea.

Рис. 2. Співвідношення видів різних екологічних груп (бентичної, бентопелагічної, пелагічної) серед риб-вселенців в чорноморських водах Криму.

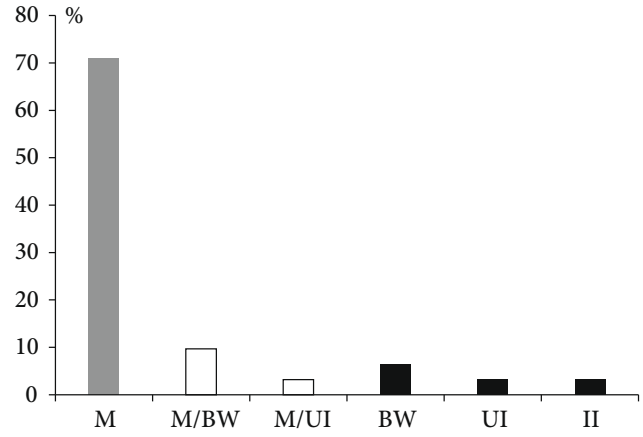

Fig. 3. The ratio of alien fishes in the Black Sea waters of Crimea with different vectors of introduction.

Рис. 3. Співвідношення видів-вселенців в чорноморських водах Криму з різними векторами вселення.

Note. For vectors of introduction, see Table. 1 (grey — introduction related to mediterranisation, white — unknown vector of introduction, black — introduction due to anthropogenic factors).

Примітка. Позначення векторів вселення див. у табл. 1 (сірий — поява пов'язана з процесом медітерранізації, білий — невідомий вектор вселення, чорний — поява через антропогенні фактори).

In general, benthic species predominate among the introduced fishes (14 species, or 45.2 %), whereas bentho-pelagic (9) and pelagic (8) species make up only 29.0 % and 25.8 %, respectively.

Of the 31 introduced species in marine waters of Crimea, 10 have naturalised and acclimatised (32.2 %), forming independent breeding population. Among them, species of the family Gobiidae (*Ch. quadrivittatus, G. couchi, G. cruentatus, G. xanthocephalus, M. xanthocephalus, P. bathi,* and *Z. zebrus*) and the taxonomically close family Oxudercidae (*T. trigonocephalus*) significantly prevail, whereas one species *P. incognitus* represents the family Blenniidae. The only representative of the pelagic ecological group of fishes from the family Mugilidae — the redlip mullet *P. haematocheila* — was intentionally introduced in the 1970s and it has completely acclimatised in the Azov-Black Sea Basin, including coastal waters of Crimea, and has become an important commercial object.

Conclusions

The main vector of introduction of new species of fish in the Black Sea is natural migration, as well as the spread of juveniles through the Bosphorus by currents (mediterranisation) and the Black Sea plays the role of recipient area. Further dispersal of species to coastal waters of Crimea is related to the geographic location of the peninsula, currents, habitat diversity, and biological features of species.

The appearance of alien fish species in coastal waters of Crimea is currently considered as an increasing invasion process. For the past 50 years, 31 species have been recorded in this region, 48.4 % of which occur regularly, 29.0 % sporadically, and 22.6 % casually. Of the 10 species that have naturalised and acclimatised, only one was introuduced intentionally.

Benthic and bentho-pelagic species predominate among the introduced fishes.

The increase of species diversity of fishes in the Azov-Black Sea region (including Crimea) due to alien species is also related to human activity such as intentional or accidental introduction, spread by ballast waters and underwater constructs of vessels, etc.

Four of the introduced fish species with unindentified vector of appearance (mediterranisation or spread by ballast waters) belong to the benthic ecological group that lay their eggs and have their offspring at the bottom. The spread of such species with ballast waters is almost impossible since ballast tanks are filled above a considerable depth to avoid clogging. In such case, these species with a high probability can be included into the group of fishes that have spread naturally (mediterranisation).

Noteworthy that the increase in the number of introduced fish species in waters of Crimea in the past 50 years is also a result of detailed monitoring of the regional ichthyofauna, which has been carried out by researchers of A. O. Kovalevsky Institute of Biology of Southern Seas NAS of Ukraine using modern trapping tools.

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