

Research Vessel *Deneb*: 10 Years of Marine Scientific Research

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Study of natural and anthropogenic processes in the southern seas of Russia is a priority task of the Southern scientific center of Russian Academy of Sciences. Annually for 15 years, the Southern scientific center of RAS carried out sea expeditions in the south of Russia. The year of 2017 was marked as a 10-year anniversary of the first expedition of the R/V *Deneb* in the Azov and Black seas. During a five-year period from 2012 to 2016, 36 complex expeditions in the Azov and Black seas were carried out by R/V *Deneb*; the oceanographic database was enriched with the data of 3500 oceanological stations, more than 11,000 samplings were done at more than 900 complex hydrobiological stations. The expeditionary materials enlarged the oceanographic database of the Southern scientific center: the field and archival data permitted to assess long-term dynamics of organic matter and carbon, the Azov Sea transparency and salinity and to calculate the characteristics of small-scale variability of temperature, salinity, internal waves and level fluctuations in the Azov and Black seas. The research in the Black Sea provided extensive synchronous data which characterize current state of the most vulnerable psammophilic benthic communities at the depths of 2–20 m. The estuaries of small rivers at their junction with the sea were studied in details. The new data on distribution and quantitative characteristics of jelly-like-, phyto- and pico-plankton over the whole shelf area of the Russian sector of the Black Sea is obtained. The Black Sea population of newcomers – Holland crabs (*Rhitropanopaeus harrisi tridentate*) – living exclusively in the sea canyons with unstable salinity was studied. The metagenomic approaches applied to study the plankton communities in the Azov and Black seas, were used to obtain new data on diversity and structure of marine bacterial communities. The oceanological observation data on the environment conditions in the Azov and Black seas are annually directed to the Hydrographic department of the Black Sea Navy of Russian Federation where it is used in the field service.

Keywords: R/V *Deneb*, marine research, hydrology, hydrochemistry, hydrobiology, biological invasions, metagenomics, the Azov Sea, the Black Sea.

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Study of modern natural and anthropogenic processes in the southern seas of Russia is one of the priorities of the Southern Scientific Center of the Russian Academy of Sciences (SSC RAS). The SSC RAS has been annually carrying out marine expeditions in the south of Russia for 15 years, [1–17]. In 2017 the 10th

anniversary of the first expedition of the research vessel *Deneb* (see Figure) to the Azov and the Black Sea was celebrated. Previously, the results of marine research were published, which R/V *Deneb* took part at [3–7]. The present article gives the main results of marine scientific research for a 5-year period of 2012–2016.

Since 2014 marine research at R/V *Deneb* has been carried out under the targeted support of the Ministry of Science and Higher Education of the Russian Federation (formerly, the Federal Agency of Scientific Organizations of Russia) as part of scientific programs approved by the Council on the Earth's Hydrosphere.

Within the period from 2012 to 2016 R/V *Deneb* carried out 36 complex expeditions to the Azov and Black Seas. The oceanographic database [16] was replenished with 3,500 oceanological stations. Over more than 11,000 samples were taken at more than 900 integrated hydrobiological stations.



Research vessel *Deneb*

Expedition surveys were carried out according to the schemes, being a combination of standard “secular” meridional and latitudinal sections, individual stations and polygons. Oceanological, hydrochemical and hydrobiological observations were carried out according to the standard methods using modern expeditionary equipment. Comprehensive studies included meteorological observations, the study of the hydrological and hydrochemical regime, the features of the spatial distribution of plankton and benthos and the implementation of shipborne observations for birds and marine mammals. The studies were carried out in accordance with generally accepted methods and guidelines for oceanographic work using modern oceanological equipment.

Marine expeditions in the summer of 2012 were carried out immediately after the infamous “Krymsk flood”, when the city of Krymsk, Krasnodar Krai suffered as a result of heavy rains. Significant damage was noted in the coastal zone in the area from Anapa to Tuapse. A joint expedition with the Institute of Oceanology of the Russian Academy of Sciences [7] revealed features of the distribution of benthic and plankton communities to depths of 40–50 m. A detailed geo-ecological survey of coastal areas affected by flooding was carried out. Simultaneously with the sea expedition, the coastal group worked with the participation of specialists from two organizations and professional divers (E. V. Verbitsky and R. E. Verbitsky). The research in the Black Sea [7] provided extensive synchronous data to characterize the current state of the most vulnerable psammophilic benthic communities dominated by the *Donax trunculus*, *Lucinella divaricata*, *Spisula triangulara*, *Chamelea gallina* species at depths of 2–20 m, as well as pelophilic communities at depths up to 200 m [18]. The mouth areas of small rivers at the junction of the river – the sea were studied in detail. New data on the distribution and quantitative characteristics of yellow plankton, phytoplankton and picoplankton on the scale of the entire shelf area of the Russian sector of the Black Sea were obtained. The Black Sea population of the invader, the Dutch crab (*Rhitropanopeus harrisi tridentata*), living exclusively in marine canyons with unstable salinity, was first studied. The expedition carried out a detailed (with a 5-meter increment in depth) sampling of soil and benthos in areas exposed to the strongest coastal discharge in July 2012. It made possible to assess the effects of catastrophic flooding on coastal marine ecosystems [18].

A specific feature of marine expeditions in 2013 was the use of the latest oceanographic equipment obtained on the initiative and with the support of Corresponding Member of the RAS D. G. Matishov. This is a carousel-type sub-bottom sampling complex consisting of 12 bathometers and a *SBE19plus* V2 hydrological probe (produced in USA), a narrow-beam acoustic profiler *SES 2000 light* (made in Germany), a gravitational soil tube with a piston mechanism (made in Denmark), a flow analyzer for biogenic elements *San⁺⁺* (produced in Netherlands). In the autumn expedition of 2013, testing of a multichannel measuring-technological platform was carried out. The platform was developed under the guidance of Academician G. V. Smirnov [10]. Vertical profiles of hydrophysical parameters were obtained, as well as video recording of suspended particles at depths of up to 300 m, which made it possible to obtain statistical data on the size-quantitative composition of suspended particles in depth. Simultaneously with the testing of new equipment, vertical probing of the water column was carried out by *SEACAT SBE 19 plus* Profiler CTD. It was revealed that in October 2013, the upper mixed layer in the area of the Anapa bank dump had a thickness of up to 40 m, which was caused by the activation of thermal convection processes and wind-wave activity. The cold intermediate layer is fixed at depths of 60–120 m, the core of the layer is marked between 90 and 100 m with a temperature value of 7.8 °C. The density jump layer is in the range of 35–50 m [10]. Seismoacoustic studies conducted in conjunction with the selection of columns of bottom sediments showed that the Holocene sediment of the Azov Sea was formed under conditions of unstable sea level [14]. In the process of joint use of the side-scanning sonar and hydroacoustic

profiler, new data on the structure of the bottom relief and thickness of bottom sediments in different parts of the water area of the eastern part of the Taganrog Bay were obtained. High resolution seismic data showed high performance of *SES 2000 light Profiler* in the shallow waters of the Azov Sea, especially with detailed seismic facies analysis and identification of anomalous gas saturation areas in bottom sediments. On the profile in the area of the Sazalnitskaya Spit in the studied thickness of the bottom sediments, three acoustic boundaries were distinguished, with the upper boundary of the layer located 15 cm from the bottom surface [14].

In 2014 the important political events related to the return of the Republic of Crimea to the Russian Federation took place. This made possible to attract specialists from the Institute of Biology of the Southern Seas (IBSS, Sevastopol) and the Southern Research Institute of Marine Fisheries and Oceanography (YugNIRO, Kerch) to participate in a joint expedition to the R/V *Deneb* in the Azov Sea [16]. During the June cruise the Khamsa spawning with maximum quantitative indicators near the Kerch Strait was observed: the average number of roe was 277.5 sp./10 m³, which is three times higher than in July 2010. The abundance of forage zooplankton (23.82–113.7 thousand sp./m³) and high proportion of the crustacean in zooplankton especially the younger stages of development – copepods, being the basis of the Khamsa larvae ration, the presence of food residues, including crustaceans, in the intestines of the khamsa larvae, as well as the low number of yellow forms and the absence of the ctenophore *Mnemiopsis*, should have a positive effect on the spawning results. However, a high percentage of dead roe in the early stages of development (48–79 %) and a low number of larvae in the sea indicate a low spawning performance, which is possibly due to adverse weather conditions in the period preceding the observations [16]. In 2014 during the marine expeditions, the brilliant idea on the use of metagenomics in the studies of the seas of Russia, introduced by Corresponding Member of RAS D. G. Matishov, was implemented [19]. So far, this is the first and only work like this, carried out in our country. Using metagenomic approaches to the study of plankton communities of the Azov and Black Seas, D.G. Matishov and his colleagues obtained unique results that allow to take a fresh look at the diversity, structure and functioning of marine bacterial communities.

In 2015 the SSC RAS carried out 6 sea expeditions with a duration of 35 vessel days. The marine expeditions covered the waters of the Azov and Black Seas within the territorial sea and economic zone of the Russian Federation, as well as the southeastern Black Sea. An assessment of the species diversity of marine biota of various groups (microalgae, planktonic and benthic invertebrates, marine, migratory and semi-migratory fish, aquatic and near-water birds and marine mammals) was carried out. Special attention was focused on the role of invasive (alien) organisms in pelagic and benthic ecosystems of the Azov and Black Seas. The dynamics of climate change and anthropogenic pollution of the main biotic components of marine systems (plankton and benthos) was studied. Studies of levels of water pollution and bottom sediments with heavy metals and oil products were continued. The conditions and factors that form the Don Estuary area in the Late Holocene were studied. The environmental conditions were reconstructed to assess the char-

acteristics of the economic activities of the population of the Azov and Don area over 2–3 thousand years.

In 2016 8 marine expeditions on R/V *Deneb* were carried out with a total duration of 90 vessel days. In March, a large-scale “bloom” of seawater covering almost the entire Azov Sea area was monitored. For the Azov Sea, this factor is one of those determining the reservoir productivity throughout the year. An unusually early appearance of the ctenophore *Beroe ovata* Bruguière, 1789 (a predator consuming the crested invader *Mnemiopsis leidyi* A. Agassiz, 1865) previously unnoted in the waters of the Azov Sea, was found. Comprehensive ichthyological studies were carried out in the southeastern Black Sea in places of mass wintering of the Black Sea sprat.

During the May cruise, comprehensive studies of the eastern Taganrog Bay were carried out. It was established that the salinity of this part of the bay was higher than the mean multiyear values characteristic for the given year period. The main reason is the protracted low water flow of the Don River, which has been observed since 2011. An important result of the marine expedition was the confirmation of the assumption that the *Marenzelleria neglecta* Mesnil, 1896, a new inhabitant of the Taganrog Bay, brought here with the ballast waters of the Atlantic ships [20], was widely spread.

In July, with the R/V *Deneb* and the coastal group participation, comprehensive studies in the area of the Crimean Peninsula were carried out. Three oceanological sections were made in the areas of Katsiveli and Feodosiya. The features of the distribution of planktonic and benthic communities in upwelling areas were studied. Special attention was paid to studying the optical properties of seawater. A verification of the fluorometer developed at the SSC RAS [21] with new unique capabilities for measuring the optical seawater properties was also carried out. Seismic acoustic profiling was carried out in the eastern part of the Taganrog Bay aimed to study Holocene sediments and paleogeographic reconstruction of the Don Delta evolution.

In September comprehensive studies were conducted in the waters of the Black and Azov Seas, including in the western part of the Azov Sea and the water area adjacent to Ukraine [7]. The main attention was paid to the study of the “bloom” of seawater and the conduct of sub-satellite observations of the chlorophyll *a* distribution in the Azov Sea. A significant increase in the salinity of the Azov Sea waters (its maximum values reached 14.5) was found. An intensive inflow of water from the Black Sea and the distribution of lenses of the Black Sea water over considerable distances were also found.

In November – December 2016, studies of the ecological, oceanographic, hydrometeorological and hydrobiological conditions of the shallow water areas of the Black and Azov Seas were carried out. Ichthyological studies were carried out in the southeastern Black Sea. An atypical location of pycnocline in the Black Sea was revealed. It indicated anomalous conditions of the upcoming winter period. In March and June 2016 methods for the operative remote monitoring of the Taganrog Bay and Don estuary aquatic environment state were tested, based on analyzing the shape of the spectra of the spectral brightness of the radiation ascending from the water [22].

Expeditionary materials significantly replenished the oceanographic database of the Southern Scientific Center of the Russian Academy of Sciences [23]: based on field and archival data, the long-term dynamics of organic matter and carbon, transparency and salinity of the Azov Sea [24–26] were estimated. The characteristics of small-scale variability of temperature, salinity, internal waves and fluctuations in the level of the Black Sea were calculated [27–29].

Each year, materials from oceanographic observations of the Azov and Black Sea aquatic environment state are carried over to the Hydrographic Service of the Black Sea Fleet of the Russian Federation (Sevastopol), where they are used by naval sailors in operational and combat work.

It should be noted that young specialists – students, masters and graduates of the Department of Oceanology of the St. Petersburg State, Moscow State and Southern Federal Universities, the Department of Aquaculture Facilities of Don State Technical University took part in practically all the cruises.

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