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Lipid Composition Modifications in the Blue Mussels (*Mytilus edulis* L.) from the White Sea

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Abstract

Studying biochemical indicators in response to various environmental factors allows revealing the metabolic adaptive strategy of the organism's tolerance and survival under a variety of environmental impacts. This review analyses both the authors' own data and the available literature on the problem of biochemical adaptations of the lipid composition in marine bivalves, particularly blue mussels, *Mytilus edulis* L., to various environmental impacts. Modifications in the composition of lipids and their fatty acids in blue mussels caused by short-term (under laboratory conditions) and chronic (field monitoring) exposure to natural and human factors indicate that homeostasis is maintained in cell membranes and the organism's energy requirements and facilitate the adaptation and tolerance of the mussels to environmental disturbances. The lipid and fatty acid composition indices in White Sea intertidal mussels which reflect their chronic exposure to a wide variety of environmental factors are discussed and compared to data on changes in the lipid composition of blue mussels exposed to some environmental factors (salinity, anoxia, metals) in aquarium experiments. The lipid profile plays an important role in the adaptation of blue mussels to new conditions in the habitat, and it can be used as a biochemical marker for indicating the organism's physiological state.

Keywords: lipids, fatty acids, biochemical adaptation, environmental factors, *Mytilus edulis*

1. Introduction

Biochemical processes underlie the development of cell metabolic responses to environmental impacts and allow an organism to adapt and survive in a changing environment [1]. Metabolic modifications up to the level of physiological and morphological disorders are reflected in the

changes of various biochemical indicators, which allow determining the adaptive strategy of an organism's tolerance and survival under both natural and human impacts. Lipid molecules, which are involved in all the essential physiological-biochemical processes [2], play a major role in the organism's adaptive responses to various factors in the environment [1]. The primary response to stress is modification of the physical state of cell membranes (mainly fluidity), which triggers a change of their lipid and fatty acid composition [3, 4]. The main lipid components of biological membranes are phospholipids and cholesterol. The ratio of phospholipids and cholesterol is considered as an indicator of membrane fluidity. Cholesterol is known to increase the order of the phospholipid fatty acid chains in membranes [5]. Membrane phospholipids in different molecular species and molecular shapes as well as their interaction with cholesterol and membrane proteins determine membrane fluidity and subsequently regulate the activity of membrane-bound enzymes and the functioning of ion channels, pumps and receptors [2, 6, 7]. Besides their effects on membrane fluidity, membrane phospholipids are also a source of bioactive compounds and messengers [8]. In particular, eicosapentaenoic acid (EPA, 20:5n-3) and arachidonic acid (AA, 20:4n-6) are released from phosphatidylcholine (PC), phosphatidylethanolamine (PE) and phosphatidylinositol (PI) by phospholipase A2 and serve as precursors of short-lived hormone-like substances called eicosanoids (prostaglandins, thromboxanes, leukotrienes, etc.). The bioactive molecules have a wide range of physiological actions, including immune response, inflammatory response, neural function, reproduction and enhancement of an organism's adaptation to environmental stress [2, 8]. PI is also a source of such messengers as diacylglycerols and inositol phosphates (namely, inositol trisphosphate and others). These messengers, as well as the phospholipid phosphatidylserine (PS), are involved in regulating the activity of protein kinase C, which controls many cell functions, such as differentiation, proliferation, metabolism and apoptosis [2, 8, 9]. Moreover, fatty acids are the most labile components of lipid molecules, quickly and accurately reflecting environmental impacts and activating an organism's adaptive abilities. For example, a well-known biochemical response of poikilothermic organisms to low temperature is increased fatty acid unsaturation of both membrane and storage lipids [7, 10, 11]. In addition to membrane lipids, an important role in the adaptive response of organisms to various environmental factors belongs to high-energy storage lipids, chiefly triacylglycerols and their fatty acids [12–15], which cover the energy costs needed for maintaining homeostasis under the new environmental conditions. Since long-chain polyunsaturated fatty acids, particularly such essential fatty acids as EPA and docosahexaenoic acid (DHA, 22:6n-3), cannot be de novo synthesized in marine mussels [16, 17], their incorporation and elimination in membrane and storage lipids are strongly regulated [18, 19]. Thus, lipid and fatty acid composition as a key component of various metabolic pathways that are linked to processes important for survival and tolerance reflects the adaptive response of an organism to environmental effects. It is assumed that lipid composition may be used as a biochemical marker for indicating the organism's physiological state in environmental assessments and biomonitoring.

The blue mussels, *Mytilus edulis* L., are used worldwide as marine sentinel organisms in biomonitoring programmes due to their longevity, sessile nature, global distribution and ability to bioaccumulate high concentrations of pollutants [20–22]. In the White Sea, *M. edulis* L. is the dominant species of coastal (intertidal) ecosystems. Numerous studies on White Sea mussels' response to various environmental effects have identified adaptive mechanisms on molecular, biochemical, cellular, physiological and behavioural levels of biological organization [23–38].

This paper summarizes the results of research on lipid composition effects in White Sea blue mussels, *M. edulis* L. (1758), in response to environmental factors such as temperature, salinity, short-term anoxia, change of nutrition source, metals and oil pollution. Phenotype-specific features of the lipid composition in White Sea blue mussels from different habitat conditions (intertidal zone and aquaculture), as well as compensatory modifications of the lipid composition in intertidal mussels under chronic stress in the natural habitat and under short-term exposure to stress in laboratory experiments, are discussed.

2. Environmental factors

2.1. Temperature

Being a major environmental factor, influences all aspects of life of an organism, especially poikilotherms [1]. The literature offers quite detailed descriptions of the contribution of the lipid composition to thermal adaptations in bivalves [11, 39–43]. Often, the response involving the lipid composition depends on the duration of exposure to ambient temperatures. Moreover, organ-specific distribution of lipids in Bivalvia causes differences in lipid composition response to temperature effects, depending on the studied organ. Thus, gills of bivalves, which are the location of primary contact with the environment, contain high concentrations of membrane lipids, chiefly cholesterol [42]. It is well-known cholesterol is necessary for membrane stabilizing and maintaining the permeability of membranes [2, 5]. It was demonstrated that when exposed to rapid (several hours) temperature fluctuations gills of bivalves experience modifications in cholesterol levels, whereas prolonged (several weeks) temperature impacts induce changes in the amount of phospholipids enriched in polyunsaturated fatty acids [41, 43]. Whereas the gill lipid composition response in White Sea mussels in the temperature experiment was the opposite: a significant rise of the cholesterol concentration in response to prolonged (14 days) impact of both low and high temperatures, while short-term temperature stress (1 day) influenced the content of phospholipids and their fatty acids [36]. Since the synthesis of polyunsaturated fatty acids in bivalves is limited as well as an involvement of essential fatty acids in/from membrane lipids is strictly regulated [18, 19], presumably, the mussels' adaptive strategy is to use a less energy-intensive mechanism for maintaining optimal membrane fluidity by redistributing polyunsaturated fatty acids among storage and membrane lipid fractions (in the absence of additional cholesterol synthesis) that bivalves employ to adapt to rapid temperature changes [35, 36]. The role of minor membrane phospholipids (namely, phosphatidylserine and sphingomyelin) in the acclimation of mussels to elevated ambient temperature was also demonstrated in gills. They are believed to facilitate adaptive modifications of the fluidity and permeability of cell membranes in response to elevation of the ambient temperature [35, 36]. Let us remark that a similar effect involving these phospholipids was observed in gills of mussels acclimating to variable seawater salinity [44]. Elevated ambient temperature is known to produce a destabilizing effect on cell membranes in poikilotherms [3]. Apparently, seawater salinity variations, primarily reduction of salinity, cause an analogous response of the membrane physicochemical properties which, in turn, initiates compensatory modifications of the composition of membrane

lipids and their fatty acids similar to those observed in response to elevated temperature. Digestive glands in bivalves contain higher concentrations of triacylglycerols (TAGs) required for energy metabolism during their acclimation to new environmental conditions as well as for reproductive processes. In particular, it was shown that bivalves from thermally different habitats differed in TAG metabolism in the digestive glands during overwintering. Blue mussels, *M. edulis*, adapted to harsh winters, accumulate TAGs enriched in 20:5n-3 fatty acids (EPA) in the digestive glands, while the oyster, *Crassostrea virginica*, which generally occurs in warmer habitats, on the contrary, did not reserve TAG before overwintering [42].

2.2. Salinity

Is one of the key abiotic factors in the marine environment. Marine and freshwater molluscs were shown to be alike in the content of total and neutral lipids, but the levels of individual fractions of phospholipids such as PC, PI, PS and PE, as well as PE plasmalogen form, were found to be dependent on the ambient salinity [45]. In gills of bivalves, salinity stress induces an increase in negatively charged phospholipids, chiefly PI and cardiolipin. This may supposedly be one of the intracellular mechanisms to bind excessive cations lest they degrade the cell's enzymatic systems [46]. Exposure of White Sea mussels to reduced seawater salinity (15 psu) in aquarium experiments (25 psu as a control) resulted in an increase in the concentration of phospholipids, mainly PC and PS, in gills [44], alongside a reduction in the levels of cholesterol and storage lipids (triacylglycerols and cholesterol esters) in gills and digestive glands [34, 47]. The reduced levels of cholesterol and storage lipids indicate an adverse effect of low salinity on the physiological state of the mussels and their metabolism. We know that when salinity is drawn down from 25 psu (normal values of salinity in the White Sea) to 14 psu, the functional activity of *M. edulis* is suppressed [23, 48], and the mussels' tolerance of low salinity is ensured by cellular volume regulation using organic and inorganic osmolytes [32, 49, 50]. Thus, the acclimation of molluscs to reduced salinity apparently implies that storage lipids are utilized not only as sources of metabolic energy but also as substrates for the synthesis of organic osmolytes [34]. Moreover, it was shown that the action of increased salinity (from 25 psu to 35 and 45 psu) leads to various responses of the lipid composition of White Sea mussels, *M. edulis*, depending on the studied organ. Although mantle edge and gills are sites for primary contact with external environment, the effect of increased seawater salinity on both intertidal and cultured mussels caused organ-specific reactions in the cholesterol level: the level rose in the mantle edge [51] but declined in gills [44]. Apparently, the different cholesterol content in gills and mantle edge of the mussels reflects differences in membrane fluidity and ion permeability in response to increased salinity effect. Some authors have pointed out the lack of distinctions between marine and freshwater bivalves in the fatty acid composition [45, 52, 53], although some papers have reported elevated concentrations of C20 and C22 unsaturated fatty acids, predominantly 20:5n-3, 22:5n-3 and 22:6n-3, in marine molluscs [54] as well as high level of monounsaturated fatty acids and arachidonic acid (20:4n-6) in freshwater molluscs [55]. Yet, the high variability of fatty acid content observed in both freshwater and marine mollusc species is primarily due to the factors of nutrition and ambient temperature [14, 15, 41–43, 45, 56–58]. Nonetheless, a lower level of n-6 polyunsaturated fatty acids was found in gills of marine bivalves acclimated to high salinity as compared to the individuals exposed to low salinity [46]. White Sea mussels acclimated to different seawater salinities also manifested considerable modifications of the lipid

fatty acid composition in gills and mantle edge. Thus, in gills of intertidal mussels, the level of n-6 polyunsaturated fatty acids (mainly owing to AA, 20:4n-6) increased in response to seawater salinity reduction (5 psu) and elevation (45 psu). At the same time, cultured mussels collected from aquaculture substrates responded with a decrease in n-3 polyunsaturated fatty acid (PUFA) content and an increase in saturated fatty acid level in gills both to a reduction (to 5 and 15 psu) and an elevation (to 35 and 45 psu) of seawater salinity. Remarkably, notwithstanding the considerably different lipid composition of gills in intertidal and aquaculture mussels, they both responded to critically low salinity (5 psu) with similar modifications of the lipid composition, indicative of non-specific defence reaction in bivalves—closure of shell valves, reduction of total metabolism and transition to anaerobic metabolic pathways [44]. Varied response of fatty acid composition to salinity effects was detected in the mantle edge of mussels from different tidal zones (intertidal and aquaculture) [51]. Thus, it was shown that the concentration of non-methylene-interrupted fatty acids (NMIFA) in mantle edge increased in the intertidal mussels exposed to 5, 35 and 45 psu (25 psu as a control), whereas in cultured mussels exposed to 5, 35 and 45 psu salinity, there was an increase in n-3 PUFA content. It is known that NMIFA can be synthesized in marine bivalve molluscs in the case of a lack of usual n-3 PUFA [53]. Probably, n-3 PUFA deficiency in intertidal mussels is the result of their utilization to generate energy required for mussel acclimation to different salinities, whereas additional synthesis of NMIFA is essential for maintaining the unsaturated state of membrane phospholipids as well as fluidity and permeability of membranes in mantle edge.

2.3. Short-term anoxia

Blue mussels, *M. edulis*, living in the marine coastal (intertidal) zone are facultative anaerobes tolerant of short-term anoxia during low tide [30, 59, 60]. The main sources of energy for bivalves in the anaerobic metabolism conditions are glycogen and proteins [1, 61], whereas lipids are utilized to provide for gametogenesis [61]. The role of storage lipids (chiefly triacylglycerols) in the adaptive reactions of mussels under anoxic conditions was demonstrated in our studies [62, 63]. In White Sea blue mussels, we observed a rise in the levels of cholesterol and PC within total lipids of soft tissues, which are known to have a stabilizing effect on membranes and thus reduce their permeability. It is known that anoxia may reduce the permeability of cell membranes, thus causing modifications in their lipid composition [64]. On the other hand, elevated concentrations of polyunsaturated fatty acids (in particular, arachidonic acid) and non-methylene-interrupted fatty acids within total lipids of soft tissues balance the stabilizing effect of membrane lipids and probably facilitate the functioning of membrane-bound proteins (enzymes, ion channels and receptors) [63]. Additional research is needed to determine organ-specific reaction of the lipid and fatty acid composition in blue mussels under short-term anoxia effect.

2.4. The nutrition factor

It is a known fact that lipid composition, especially the fatty acid profile of filter-feeding mussels, like in any consumers, is a trophic marker of the composition of their food and includes the biochemical markers of all seston components, namely, phytoplankton, zooplankton and bacteria (detritus) [14, 15, 56, 58, 65–68]. The study of modifications in the composition of lipids and their fatty acids in gills and digestive glands of White Sea mussels, *M. edulis*, induced by

their acclimation to laboratory conditions where they were fed with artificial feed ("Coraliquid", Sera) revealed organ-specific patterns in the assimilation and modification of lipids, primarily concerning their fatty acid profile [69]. It was shown that change of the food source caused alterations in the lipid and fatty acid composition, mainly in the digestive gland. Elevated content of high-energy lipids (triacylglycerols) enriched in saturated fatty acids (namely, myristic 14:0 acid), as well as vaccenic 18:1n-7 acid in the feed, promoted the storage of these lipids in mussel gills and digestive gland. At the same time, the fact that phospholipids in the feed lacked essential fatty acids, EPA and DHA, which are known to be derived from phytoplankton, told considerably on the fatty acid profile of triacylglycerols in the mussels [69].

Intertidal habitats are the most variable in terms of such abiotic environmental factors as temperature, salinity, aerial exposure and concentrations of suspended nutritive material [70]. Life under such heavily variable environmental conditions reflects both on the mussels' physiological (including growth rate) and metabolic processes and on the size and age structure of mussel beds (local populations), their abundance and biomass [27, 29, 30, 71]. Ecologo-biochemical monitoring during 2009–2014 years of two intertidal mussel beds located in different parts of the Gulf of Kandalaksha, White Sea, and differing in hydrological characteristics, including seawater salinity, revealed the features of the lipid composition in gills and digestive glands which reflect the chronic impact of salinity drops [38]. Frequent salinity drops in one of the investigated sites (Site 1) are due not only to discharge from streams but also to human activities (namely, unregulated freshwater discharges from hydropower plant). The effect of reduced seawater salinity (approximately 9.7–14.0 psu) on mussels from Site 1 appears not only in the level of some phospholipids (in particular, phosphatidylserine, phosphatidylethanolamine and phosphatidylcholine), and the ratio of n-3/n-6 polyunsaturated fatty acids in the molluscs' gills and digestive gland, but also in some ecological characteristics of the mussel beds, i.e. its size-age structure, abundance and biomass [38]. The elevated content of the named phospholipids and the prevalence of n-3 polyunsaturated fatty acids over n-6 polyenes apparently serve to keep membranes permeable to ions and maintain the functioning of membrane-bound enzymes involved in cellular volume regulation in response to low seawater salinity. These data agree with the results of previous aquarium experiments on the effect of low seawater salinity on the lipid composition of intertidal and cultured mussels [44], which suggest that the mussels' lipid and fatty acid composition is adapted to secure the survival of the molluscs under low seawater salinity. The elevated ratio of n-3/n-6 polyunsaturated fatty acids in the mussels chronically exposed to salinity drops may also be a result of high metabolic rate of n-6 polyunsaturated fatty acids (chiefly AA, 20:4n-6). Arachidonic acid is a precursor for the synthesis of physiologically active hormone-like molecules, eicosanoids (such as prostaglandins), which are known to build up bivalves' resistance to stress, including various seawater salinities [8, 72–75]. One must mention that intertidal mussels living in a habitat with relatively stable salinity conditions (away from freshwater discharges, Site 2 where seawater salinity is 20.1–22.5 psu) feature an elevated content of cholesterol and n-6 polyunsaturated acids within total lipids of both gills and digestive glands [38]. Our monitoring studies of the lipid and fatty acid composition in intertidal mussels from different habitats in the White Sea showed that the fatty acid composition of digestive glands, unlike their content in gills, reflects the adaptive features of the lipid metabolism in the mussels under chronic effect of a wide range of environmental factors [38].

There is a lot of research on the study of the differences in physiological (energetic, growth rate, clearance rate, ingestion rate, absorption rate, respiration rate) and biochemical indices between mussels collected in intertidal (rocky shore) and subtidal (aquaculture) environments [13–15, 76–78]. It is considered that these origin-related differences in physiological rates have to do with features of the energy distribution, namely, in intertidal mussels more energy is directed to the formation of a thicker shell, while in subtidal mussels the energy is spent on tissue growth [78]. Simultaneously, biochemical differences between these mussel groups are associated with various concentrations and quality of seston in the intertidal and subtidal zones [13, 14, 76]. In particular, frequent exposure to air (during low tide) has very high effect on the mussels' energy reserves including triacylglycerols, saturated fatty acids and some polyunsaturated fatty acids, similarly to the effect of starvation [13, 14]. We have also studied origin-related lipid composition differences in gills of littoral (intertidal) and cultured (sublittoral) mussels after 2 weeks of acclimation to laboratory conditions [44, 79]. It was demonstrated that gills of intertidal mussels differ from those kept under the fairly stable conditions of aquaculture (cultured mussels) in that the former have a higher level of lipids that stabilize membrane structure (cholesterol and saturated fatty acids), as well as n-6 polyunsaturated fatty acids (chiefly AA, 20:4n-6), which arguably contribute to the establishment of suitable membrane permeability and regulate the activity of membrane-bound enzymes, ion channels and receptors. High level of AA in the whole body as well as in gills of intertidal mussels appears to be due to selective retention of the fatty acid required for eicosanoid synthesis [14, 15]. In addition, unlike for mussels collected in August (where mussels were on reproductive stage IIIc or stage 0, resting), increased content of the fatty acid in the whole body of the mussels collected in June (where mussels were on reproductive stage IIIb, spawning) is needed for reproductive processes [79]. Although no differences were found in the sterol content in mussels originating from the two habitats (rocky shore and subtidal) [13], a significant excess in cholesterol level in the whole body and gills of intertidal mussels from the White Sea is probably due to the effect of severe fluctuations in temperatures (up to subzero temperatures). These features of the lipid composition are assumed to be one of the biochemical adaptation mechanisms providing for the phenotypic plasticity and survival of blue mussels in a frequently changing coastal environment. On the other hand, high level of triacylglycerols as well as elevated concentrations of n-3 polyunsaturated fatty acids, primarily of phytoplanktonic origin, EPA and DHA, in mussels collected from artificial substrates evidences high food availability (phytoplankton) and relatively stable environmental conditions in aquaculture [44, 79]. These origin-related differences of blue mussel lipid composition reflect the important role of lipids in adaptation to a changing environment.

3. Pollution effect

Natural habitats of marine aquatic organisms may also be negatively affected by human impact. Seawater is contaminated by organic and inorganic chemical substances (such as metals, petroleum hydrocarbons, pesticides) from municipal and industrial discharges. Since pollutants of various nature get either directly or indirectly involved in lipid peroxidation reactions [80–82], it is obvious that a characteristic sign of their impact on cell membranes is the disruption of lipid bilayer packing, which in its turn triggers modifications in the composition

of membrane lipid components (cholesterol, phospholipids and their fatty acids) [83]. Thus, mussels from contaminated sites had an elevated level of triacylglycerols and an increased triacylglycerol/phospholipid ratio, which implies a reduced rate of mobilization of triacylglycerols into the phospholipid pool with serious consequences for the structure and function of cell membranes. There was also a substantial decrease in phospholipids, apparently in connection with membrane destruction [84–86]. Some papers have reported the modifications in lipid and fatty acid composition of hydrobionts, including marine mussels, in response to organic and inorganic pollutants' effect [34, 37, 87–93]. Since the lipid metabolism plays an important role in living organism, it is believed that the lipid and fatty acid profile may be used to indicate the organism's health under stress conditions of pollutant effect. Exposure of blue mussels from the White Sea to various concentrations of oil products in an aquarium experiment led to an increase in the level of phospholipids and a reduction of cholesterol concentration in gills and mantle, i.e. the gateway organs for external impacts [25, 34]. These modifications in membrane lipids are believed to make cell membranes more permeable to oil products and create the conditions for their accumulation in these organs for further detoxification. A significant decrease in the level of membrane lipids—phospholipids (mainly at the expense of PC and PE) and cholesterol—simultaneously with an increase in triacylglycerols was observed in gills and digestive glands of mussels exposed to various concentrations of cadmium [37]. These modifications of the lipid profile reflect the destructive effect of cadmium on cell membranes realized through the activation of lipid peroxidation processes. It is worth noting that a significant decrease of the cholesterol concentration under the impact of oil products, mainly their high concentrations, was observed in all the studied organs (gills, mantle, mantle edge and foot) of *M. edulis* [25, 34], as well as under the impact of cobalt on *Mytilus galloprovincialis* [94]. One of the presumed examples of the toxic effect of oil products, as well as some heavy metals on bivalves, is the inhibition of cholesterol synthesis, leading to high membrane permeability. At the same time, the effect from exposure to copper as an essential metal was the opposite (significant increase of cholesterol concentration), probably meant to stabilize the membranes under the metal's oxidative action and to reduce their permeability. It was noted also that when exposed to cadmium and copper [37], as well as to relatively low concentrations of oil products [95], mussels demonstrated an elevated level of arachidonic acid. Apparently, AA involvement in the synthesis of eicosanoids ensures high resistance of the mussels to these xenobiotic impacts. On the other hand, when the concentrations of oil products were high, the level of this acid in the mussels decreased, probably due to inhibition of its biosynthesis, given the observed elevated concentrations of linoleic acid, its metabolic precursor [95]. The results of studies on the lipid composition of gills and digestive glands of intertidal blue mussels, *M. edulis*, collected from different sites in the Gulf of Kandalaksha, White Sea, prove that the composition of lipids and their fatty acids depends not only on the hydrological conditions in the habitat but also on the degree of human impact on it [38]. To wit, the fatty acid profile of the intertidal mussels living in habitats with high human impact is noted for the prevalence of oleic (18:1n-9) acid among total lipids of gills and digestive glands. A similar effect in the fatty acid composition of total lipids was observed in the mussels exposed to various doses of copper in an aquarium experiment [37]. Elevated content of non-essential oleic acid in bivalves may be associated with its additional synthesis under the toxic effect of pollutants and have the goal of binding and detoxifying xenobiotic substances. Unsaturated fatty acids are known

to be capable of forming complexes with metal ions and thus to contribute to the accumulation and detoxification of these xenobiotic substances in mussels [96].

4. Conclusions

The lipid profile of White Sea blue mussels, *M. edulis* L., is modified in response to various environmental factors in order to protect cell membranes, maintain or recover their homeostasis, replenish the cell's energy and metabolic resources and thus to secure the mussels' adaptation to the change in environmental conditions. Organ-specific distribution of lipids and fatty acids in White Sea blue mussels, as well as the dependence of the lipid and fatty acid composition response on the effect of various environmental factors on the studied organ, was detected. Modifications in the lipid composition predominantly in gills reflect the acute effect of environmental factors in aquarium experiment conditions, whereas changes in the lipid composition of digestive glands represent an adaptation of the lipid metabolism in response to chronic exposure to ambient factors (field monitoring). The composition of lipids and their fatty acids in intertidal mussels evidences their chronic exposure to abiotic environmental factors and human impact and is in agreement with data on the modifications of the lipid profile in White Sea blue mussels subjected to such environmental factors (namely, salinity, short-term anoxia, heavy metal and oil pollution) in aquarium experiments. The data discussed above prove that the lipid profile plays an important role in the adaptation of blue mussels, *M. edulis*, to new conditions in the habitat. Assessment of the lipid composition in intertidal and cultured mussels helps disclose the metabolic strategy to ensure resistance and adaptation of the organisms to environmental impacts of different nature and can be used as a biochemical marker for indicating the organism's physiological condition. This knowledge is necessary for environmental safety assessment under both natural and human impacts, as well as to predict an organism's and population's status in biomonitoring.

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