

Biomarker Table - Summary of all biomarkers applied to Blue Mussel (author IRIS-Biomiljø, 25/05/2010)

Biomarker name	Category (level of biological organisation)	Type of biomarker	Method	Type of answer	Biological function/ meaning	Target tissue/cells	Response profile	Data format (unit)
Alkaline unwinding	Molecular	Exposure	32P-postlabelling (Reichert and French, 1994)	DNA damage	Breaks of the DNA elicits	digestive gland		
Addotti	Molecular	Exposure	32P-postlabelling (Reichert and French, 1994)	genotoxicity (DNA damage), indication of exposure to organic xenobiotics	Molecules attached to DNA	digestive gland/ gill	Increasing	number (nmol/mol normal nucleotides)
RNA/DNA ratio	Molecular	Effect	spectrofluorimetric	General stress	short term growth	whole organism, digestive gland	Bell shape	number (no unit, it is a ratio)
TOSC-OH	Molecular	Effect/Exposure	Reaction between OH and the substrate (KMBA) which is oxidase to ethylene (Winston et al 1998)	Oxidative stress	total oxiradical scavenging capacity	digestive gland	Bell shape	unit (TOSC unit/mg proteins)
TOSC-ROO	Molecular	Effect/Exposure	Reaction between ROO and the substrate (KMBA) which is oxidase to ethylene (Winston et al 1998)	Oxidative stress	total oxiradical scavenging capacity	digestive gland	Bell shape	unit (TOSC unit/mg proteins)
Malondialdehyde (MDA)	Biochemical	Effect	spectrophotometric	Oxidative stress, damage of the lipid membranes, contamination of PCBs, PAHs, metals	lipid peroxidation	digestive gland	Increasing	number (nmol/gr wet weight)
Acetylcholinesterase (AChE)	Biochemical	Exposure	spectrophotometric	Organophosphate, carbamate pesticides, Zn, Cu, Cd	Hydrolyse acetylcholine into choline and acetic acid, enzyme involved in synaptic transmission of nerve impulse	digestive gland/whole animal/foot	Bell shape	number (nmol/min/mg proteins)
Ethoxyresorufin-O-deethylase activity (EROD activity)	Biochemical	Exposure	spectrophotometric in cuvette or microplate	Planar chemicals (halogenated dioxins and biphenyls), PAHs, PCBs	Induction of CYP1A (response as biom. Strengthened if also high levels of CYP1A and/or CYP1A mRNA)	digestive gland	Increasing/Bell shape??	
Metallothionein	Biochemical	Exposure	Differential pulse polarography, radioimmunoassay, spectrophotometry (the most common), ELISA, gene expression (molecular analysis)	Heavy metals (especially Cd, Zn, Cu, Hg), oxidative stress	Binding metals to limit availability, but also other protective functions (oxyradical scavenging)	digestive gland/whole animal	Bell shape	Number (the unit depends on the used method)
Superoxide Dismutase (SOD)	Biochemical	Effect	spectrophotometric	Oxidative stress	catalyze the dismutation of superoxide anion into molecular oxygen and hydrogen peroxide, it is a metalloenzyme	digestive gland/gill	Bell shape	
Catalase (CAT)	Biochemical	Exposure/effect	spectrophotometric in cuvette or microplate	Oxidative stress	antioxidant enzyme for the breakdown of hydrogen peroxid	digestive gland	Bell-shaped	number (µmol/min/mg proteins)
Glutathione-S-transferase activity (GST activity)	Biochemical	Exposure	spectrophotometric in cuvette or microplate	Exposure to PAHs, PCBs, Oxidative stress in general	Phase II enzyme involved in detoxification of organic xenobiotics	digestive gland	Bell-shaped	number (nmol/min/mg proteins)
NAPDH-cyt c reductase	Biochemical	Effect		General stress		digestive gland	Bell-shaped	
Protein content	Biochemical	Effect		General stress		digestive gland/gill/haemocytes/whole animals	Bell-shaped	
Phagocytosis	Cellular	Effect/Exposure	spectrophotometric on microplate, cell counting	Immunocompetence	primary mechanism of immune defence	haemolymph	Increased or decreased	number (n of cells with zymosan/ mg proteins, of cells with zymosan/ ml haemolymph)
Comet assay	Cellular	Effect/Exposure	electrophoresis	genotoxicity	Breaks of the DNA elicits/fragmentation of DNA	haemolymph	Increasing	number (image analysis, unit=intensity of nucleus tail), mean % tail DNA
Micronuclei frequency (MN)	Cellular	Effect/Exposure	cells stain on slide	Index of cytogenetic damage caused by genotoxic compound	Increased frequency	haemocytes/ gills	Increasing	number (%)
Haemacrit value	Cellular	Effect	Burker camera of haematocritometer	General stress	Haemocytes are the first defence system	hemocytes	Bell-shaped	number (n of cells/ml of haemolymph)
Haemolymph cell type	Cellular	Effect	Dye cells on slide	general stress	Specific cells are involved in immunoreaction, number of cells increased under stress to react	haemocytes	Increasing	number (n of cells/ml of haemolymph)
Lysosomal membrane stability (LMS)	Cellular/Histological (depending on the used method)	Effect	Neutral Red Retention test, Histochemical assay	General toxicity of various classes of contaminants. General stress	Comprehensive information on progression of DG/haemocytes pathology and related disfunction	haemocytes/digestive gland	decreasing	Number, Unit = Minutes
Lipofuscin	Histological	Effect	Schmol reaction (Pearse, 1972)	Oxidative	Accumulation of lipofuscines reflect degradation of cell membrane caused by oxidative damage following exposure to toxicants	digestive gland	Increasing, Bell-shaped	number (mean absorbance)
Neutral lipid accumulation	Histological	Effect/Exposure	Oil Red O technique (Bancroft, 1967)	General stress, exposure to organic compounds	Accumulation of unsaturated neutral lipids, toxically induced disturbance of fat metabolism	digestive gland	Increasing, Bell-shaped	number (mean absorbance)
Structural changes in DG lysosomes	Histological	Effect	Image analysis on slide	General stress, exposure to organic compounds	lysosomal system respond to pollutants changing lysosomal size and content	digestive gland	Increasing	number
Lysosome/cytoplasm ratio	Histological	Effect		General stress		digestive gland	Increasing	
Reproductive state	Histological	Effect	staging the gonad	general stress, endocrine disruption effect	whole organism health condition, effect on reproduction/future generation	gonads	decreasing	number (stage)
Gonad development	Histological	Effect	staging the gonad, Maturation Index (Siah et al 2003)	general stress, endocrine disruption effect	whole organism health condition, effect on reproduction/future generation	gonads-eggs	decreasing	number (stage)
Survival in air or Stress on stress	Behavioural/Physiological	Effect	ability of mussels to survive aerial exposure (Eertman et al 1993)	General stress	integrated whole organism health	Organism	Decreasing	number (% of survivals)
Respiration rate	Physiological	Effect	measurement of oxygen consumption in respiration chamber	General stress	organism health	Organism	Decreasing	number (O2 consumption rate µmol/standard animal/h)
Filtration rate	Physiological	Effect	flowcytometer, number or algae filtrated per time	General stress	organism health	Organism	Decreasing	
Valve movement	Physiological	Effect	opening of valves per time	General stress	organism health	Organism	decreasing	
Heart rate	Physiological	Effect	heart rate is recorded with computer	General stress	physiological status	Organism	Bell shape	number (BPM, beats per minute)
Scope for growth	Physiological	Effect	Widdows et al 1995	General stress	integrated whole organism health	Organism	Decreasing	J/g per day, number
Condition index	Physiological	Effect	meat weight/shell weight, weight/length	General stress	integrated whole organism growth and health	Organism	decreasing	number
Byssal Thread Production	Physiological	Effect	BTP rate is determined by counting threads attached to a glass surface (Moles and Hale 2003)	General stress	physiological status	Organism	Decreasing	Number(threads/muscle/ 48 hours)
Early lifestage test	Behavioural/Physiological	Effect/Exposure				Organism		
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