Morska ekotoksikologija

Marine Ecotoxicology

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Študijsko leto: 2026/2027

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Academic Year: 2026/2027

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Obveznosti pri predmetu

Course Requirements

Prisotnost na vajah
Attendance at practical sessions

Izpolnjen in oddan laboratorijski dnevnik
Completed and submitted laboratory notebook

Seminarska naloga (rok za oddajo?)
Seminar assignment (submission deadline: TBD)

2

Zemljevid/Roadmap

Teoretične osnove/Theoretical Foundations

pomembne definicije/key definitions
morfologija klapavice/mussel morphology
priprava in shranjevanje tkiv (sekcija in zamrzovanje)/tissue preparation and storage (dissection and freezing)
encimski testi/enzymatic assays
oksidativni stres/oxidative stress

Analiza in komentar rezultatov/Data Analysis

diskusija o pridobljenih rezultatih/discussion of the results obtained in the laboratory

Laboratorijski del na MBP/Laboratory Work at the MBP

sekcija školjke/mussel dissection
homogenizacija tkiva/tissue homogenisation
encimski testi (CAT, GST)/enzymatic assays
ogled tekočega poskusa s školjkami/overwiev of the ongoing mussel exposure experiment

TERENSKE VAJE: Četrtek, 12.11.2026, od 10:00 do 13:00 na MBP (Fornače 41, Piran)

Seminar Presentations/Seminar Presentations

datum in navodila tbd/date and instructions: TBD

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Seminarska naloga

- Dolžina: 2–3 A4 strani (ne vključuje seznama virov)
  - Pisava: Times New Roman, velikost 12
  - Razmik med vrsticami: 1,15
  - Robovi: 2,5 cm na vseh straneh
- Naslovna stran: Naslov seminarske naloge, ime in priimek avtorja, študijsko leto vpisa predmeta, predmet: Morska ekotoksikologija (izbirni), datum oddaje.
  - Uvod: kratka predstavitev izbranega vira onesnaženja, pojasnilo, zakaj je izbrani vir onesnaženja primeren za obravnavo v kontekstu ekotoksikologije, namen seminarske naloge in kratka predstavitev vsebine
  - Jedro: opis vira onesnaževanja (izvor in značilnosti izbranega onesnažila, kako in v kakšni meri vstopa v (morski) ekosistem), posledice za okolje (opis vplivov onesnažila na ekosistem, npr. na izbrane organizme, spremembe v bioloških procesih, kumulativni učinki in morebitni specifični toksični učinki, npr. bioakumlacija, biomagnifikacija, motnje v reprodukciji, smrtnost, motnje v prehranskih spletih,...), posledice za družbo (vpliv na zdravje ljudi,gospodarske dejavnosti, ekonomijo), intervencije (izvedeni ukrepi za zmanjšanje onesnaženja, učinkovitost ukrepov in njihovo vrednotenje)
  - Diskusija: diskusija o drugih možnih rešitvah in pristopih za obravnavo izbranega onesnažila, ki še niso bili izvedeni ali bi jih bilo mogoče izboljšati, predlogi za izboljšanje trenutnih ukrepov
  - Zaključek: povzetek glavnih ugotovitev, predlogi za prihodnje raziskave ali izboljšave v obravnavi problema
  - Seznam virov: Vsi uporabljeni viri morajo biti ustrezno navedeni v skladu z navodili za pisne izdelke fakultete.
- Drugo:
  - Poskrbite, da bo besedilo tekoče in dobro strukturirano, prehodi med poglavji pa jasni.
  - Pri pisanju uporabljajte strokovno izrazje in natančne podatke.
  - Citirajte vse uporabljene vire in se izogibajte kopiranju vsebin brez ustrezne navedbe avtorstva.
  - Pred oddajo naloge jo preglejte za slovnične in slogovne napake.

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Seminar Paper Guidelines

- Length: 2–3 A4 pages (excluding references).
  - Font: Times New Roman, size 12.
  - Line Spacing: 1.15.
  - Margins: 2.5 cm on all sides.
- Title Page: Title of the seminar paper, author's full name, academic year, course title ("Marine Ecotoxicology" (elective)), submission date.
- Structure
  - Introduction: Briefly present the selected source of pollution, explain why it's relevant in the context of ecotoxicology, state the purpose of the seminar paper, and provide a short overview of the content.
  - Main Body:
    - Source of Pollution: Describe the origin and characteristics of the chosen pollutant, how and to what extent it enters the (marine) ecosystem.
    - Environmental Consequences: Describe the pollutant's impact on the ecosystem, e.g., effects on selected organisms, changes in biological processes, cumulative impacts, and any specific toxic effects (e.g., bioaccumulation, biomagnification, reproductive disruption, mortality, disruptions in food webs, etc.).
    - Societal Impact: Discuss the impact on human health, economic activities, and the economy.
    - Interventions: Review measures taken to reduce pollution, their effectiveness, and an evaluation of these measures.
  - Discussion: Consider other possible solutions and approaches for addressing the selected pollutant that have not been implemented or could be improved; propose improvements to current measures.
  - Conclusion: Summarize the main findings and suggest future research directions or improvements in addressing the issue.
  - References: All sources used must be properly cited following the university's guidelines for written work.
- Additional Guidelines:
  - Ensure the text is coherent and well-structured, with clear transitions between sections.
  - Use professional language and accurate data.
  - Cite all sources and avoid copying content without appropriate attribution.
  - Proofread for grammatical and stylistic errors before submission.

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Teme / Seminar Topics

Naslov	Ime in priimek	Ime in priimek
Endokrini motilci in njihovi učinki na morske organizme / Endocrine disruptors and their effects on marine organisms	Tiara Kaligaro	Tjaša Klavžer
Metil živo srebro (MeHg) in učinki na morsko bioto / Methylmercury (MeHg) and its effects on marine biota	Pia Juričić	Milica Pantelič
Mikroplastika v morju in vplivi na morske organizme / Microplastics in the marine environment and their effects on marine organisms	Jernej Grubar	Noemi Ljudvik
Razlitja surove nafte in posledice za morsko okolje / Crude oil spills and their impacts on the marine environment	Sara Verhovnik	Manca Trdan
PFAS v morskem okolju in njihove ekološke posledice / PFAS in the marine environment and their ecological consequences		
Farmacevtske učinkovine v morskem okolju / Pharmaceuticals in the marine environment	Daša Jovanivić	
Tributilkositer (TBT) in toksični učinki na morske organizme / Tributyltin (TBT) and its toxic effects on marine organisms		
Transport in kemijske spremembe onesnaževal v morskem okolju / Transport and chemical transformations of pollutants in the marine environment	Elma Bajrić	Laura Bajs

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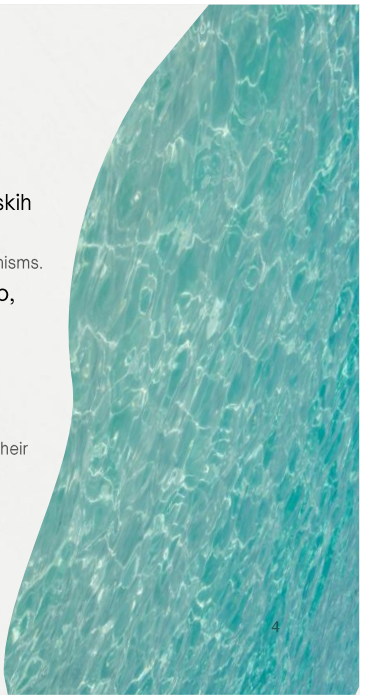
Za uvod/Getting Started

Morja pokrivajo približno 2/3 Zemljine površine in so dom izjemni raznolikosti morskih organizmov
Oceans cover approximately 2/3 of Earth's surface and are home to an immense diversity of marine organisms.

Morski ekosistemi zagotavljajo številne ekosistemske storitve, vključno s hrano, zaposlitvijo, prometom.
Marine ecosystems provide numerous ecosystem services, including food, employment, transportation.

Onesnaževanje, prekomerni ribolov in vse večji vpliv človekovih dejavnosti pomembno ogrožajo morske ekosisteme in njihove organizme
Pollution, overfishing, and increasing human activities pose significant threats to marine ecosystems and their organisms.

Varovanje zdravja in biotske raznovrstnosti morij je zato ključnega pomena za prihodnost našega planeta
Protecting the health and biodiversity of our oceans is therefore essential for the future of our planet.



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Kazalniki stanja morskih ekosistemov/Indicators of marine ecosystem condition

5 kategorij: pritiski, fizikalne značilnosti, biološka struktura, funkcionalna struktura in ekološki modeli.
5 indicator categories: pressures, physical characteristics, biological structure, functional structure, and ecological models.

Pritiski: invazivne vrste, pomorski promet, pridneni ribolov in onesnaževanje s kopnega.
Pressures: invasive species, commercial shipping, demersal trawling, and land-based pollution.

Fizikalni in kemijski parametri: temperatura, slanost ter značilnosti morske vode in sedimenta.
Physical and chemical parameters: temperature, salinity, and characteristics of seawater and sediment.

Biološki kazalniki: zaznavajo kompleksne spremembe; biotski indeksi združujejo več kazalnikov v poenostavljeno oceno.
Biological indicators: detect complex changes; biotic indices combine multiple indicators into a simplified assessment.

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Struktura in delovanje ekosistema/Ecosystem structure and functioning

Funkcije ekosistema: fizikalni, kemijski in biološki procesi, ki omogočajo pretok energije in snovi.
Ecosystem functions: physical, chemical, and biological processes driving energy and material flows.
Funkcionalna raznolikost: raznolikost bioloških procesov, funkcij in lastnosti organizmov.
Functional diversity: the variety of biological processes, functions, and organismal traits.
Ekološki parametri: velikost združbe vpliva na ekološke mreže ter pretok energije in snovi.
Ecological parameters: community size influences ecological networks and energy and material flows.
Posredni kazalniki merijo posamezne sestavine, npr. pritiske ali fizikalne značilnosti; **neposredni kazalniki** temeljijo na strukturi in delovanju ekosistema.
Indirect indicators measure individual ecosystem components, such as pressures or physical characteristics; **direct indicators** assess ecosystem structure and functioning.
Ocena stanja temelji na primerjavi z referenčnim stanjem; bolj neposredne ocene zahtevajo več podatkov in intenzivnejše spremljanje.
Ecosystem condition is assessed relative to a reference condition; more direct assessments require more data and intensive monitoring.

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Spremljanje in obnova morskih ekosistemov/Monitoring and restoration of marine ecosystems

Človeški vplivi na obalne ekosisteme se povečujejo in spreminjajo.
Human impacts on coastal ecosystems are increasing and changing.
Učinkovito upravljanje in obnova zahtevata:
Effective management and restoration require:

- merljive ekološke cilje,
  - measurable ecological targets,
- redno spremljanje in vrednotenje,
  - regular monitoring and assessment,
- kazalnike za spremljanje napredka glede na cilje,
  - indicators to track progress toward targets,
- referenčno stanje za načrtovanje in ocenjevanje obnove.
  - reference conditions for planning and evaluating restoration.

Naravna nihanja in človekove dejavnosti lahko prispevajo k degradaciji obalnih ekosistemov.
Natural fluctuations and human activities can contribute to coastal ecosystem degradation.
Celostni programi spremljanja podpirajo načrtovanje ukrepov za zmanjšanje vplivov, varstvo in obnovo ekosistemov.
Integrated monitoring programmes support mitigation, ecosystem protection, and restoration.

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Onesnaževanje morja/Marine Pollution

Definicija (UNCLOS, 1982): vnos snovi ali energije v morsko okolje s strani človeka, kar povzroča škodo morskim organizmom, ekosistemom ter industrijam, kot sta ribištvo in turizem.
Definition (UNCLOS, 1982): The introduction of substances or energy into the marine environment by humans, causing harm to marine organisms, ecosystems, and industries such as fishing and tourism.

Viri onesnaženja: Več kot 80% onesnaževanja v morju izvira iz dejavnosti na kopnem, kot so (ne)namerna izlitja, namerno odlaganje odpadkov, neočiščene odplake in odtekanje iz rek ter kanalizacije (WWF).
Sources of Pollution: More than 80% of marine pollution originates from land-based activities, including accidental and intentional spills, deliberate waste disposal, untreated sewage, and runoff from rivers and drainage systems (WWF).

Poročilo UN IPBES (2019): več kot 300–400 milijonov ton industrijskih odpadkov, ki se letno odvržejo v oceane, ter 80% neprečiščenih odpadnih voda, ki se iztekajo v okolje.
UN IPBES Report (2019): Over 300–400 million tons of industrial waste are dumped into the oceans annually, and 80% of wastewateris discharged untreated into the environment.

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Glavne oblike onesnaženja/Main Types of Pollution

Onesnaženje s hranili: N in P iz kmetijskih površin ter mestnih odplak (evtrofikacija obalnih območij).
Nutrient Pollution: Nitrogen (N) and Phosphorus (P) from agricultural lands and urban wastewater contribute to the eutrophication of coastal areas.

Uporaba gnojil se je povečala od sredine 20. stoletja povečala za desetkrat. Izpusti N v oceane so se med letoma 1970 in 2000 povečali za 43% (Breitburg et al., 2018).
Fertilizer use has increased tenfold since the mid-20th century. Nitrogen discharges into oceans rose by 43% between 1970 and 2000 (Breitburg et al., 2018).
Presežek hranil povzroča cvetenje morja, kar vodi do nizke koncentracije kisika in ustvarja "mrtve cone", v Mehiškem zalivu, je taka mrtva cona v letu 2017 pokrivala 22.730 kvadratnih kilometrov (NOAA, 2019).
Excess nutrients cause algal blooms, which lead to low oxygen levels and create "dead zones." In the Gulf of Mexico, such a dead zone covered 22,730 square kilometers in 2017 (NOAA, 2019).

Kemično onesnaženje: industrijski izpusti, izlitja nafte, pesticidi, sredstva proti obraščanju, farmacevtski in osebni negovalni izdelki
Chemical Pollution: Includes industrial discharges, oil spills, pesticides, antifouling agents, pharmaceuticals, and personal care products.

Onesnaženje s plastiko: odpadki, mikroplastika in zavržena ribiška oprema. Največ prispevajo nepravilno ravnanje z odpadki, zavržena ribiška oprema in mikroplastika iz gospodinjstev. Veliko pacifiško smetišče je znano območje kopičenja plastike (Lebreton et al., 2018), eno izmed petih točk kopičenja plastike.
Plastic Pollution: Consists of waste, microplastics, and discarded fishing gear. Major contributors are improper waste management, abandoned fishing equipment, and microplastics from households. The Great Pacific Garbage Patch is a well-known area of plastic accumulation, one of five major plastic accumulation zones (Lebreton et al., 2018).



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Uvodne definicije/Ecotoxicology Concepts

Morska ekotoksikologija: preučuje učinke strupenih snovi na morske ekosisteme, vključno s tem, kako onesnažila vplivajo na morsko življenje na vseh trofičnih ravneh. Vključuje tudi razumevanje virov onesnaženja in vplivov onesnaženja na okolje.
Marine Ecotoxicology: Study of toxic effects of pollutants on marine ecosystems, including impact on marine life across trophic levels.

Strupena snov: vsaka kemikalija ali zmes, ki lahko povzroči škodo okolju, živim bitjem. V kontekstu morskih ekosistemov to vključuje širok nabor onesnažil, kot na primer so težke kovine, pesticidi in plastika.
Toxic Substance: Any chemical or mixture causing harm to the environment or living organisms.

Akutna toksičnost/strupenost: škodljivi učinki snovi, ki so posledica kratkotrajne izpostavljenosti (običajno ocenjujemo s testi LD50).
Acute Toxicity: Harmful effects from short-term exposure.

Kronična toksičnost/strupenost: dolgoročni učinki izpostavljenosti organizmov strupeni snovi, pogosto ocenjeni z dolgotrajnimi študijami o razmnoževanju, rasti in obnašanju organizmov.
Chronic Toxicity: Long-term effects on reproduction, growth, and behavior.

Porajajoča se onesnažila: nova ali prej neprepoznana onesnažila, kot so farmacevtski izdelki in mikroplastika, ki predstavljajo vse večje izzive za morske ekosisteme.
Emerging Pollutants: Newly recognized pollutants, like pharmaceuticals and microplastics, challenging to address in marine ecosystems.

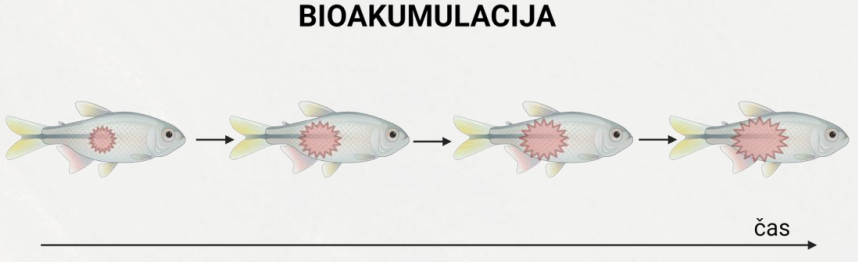
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Bioakumulacija/Bioaccumulation

Biološko kopičenje: proces, pri katerem kemikalije vstopajo v vodne organizme skozi škrge ali epitelno tkivo neposredno iz okoliškega medija in se koncentrirajo v organizmu bolj kot v okoliškem mediju (voda, prst,...)
Bioconcentration: The process by which chemicals enter aquatic organisms through gills or epithelial tissue directly from the surrounding environment and concentrate within the organism at higher levels than in the surrounding medium (water, soil, etc.).

Bioakumulacija: zajema vnos snovi iz vseh okoljskih virov, npr. voda, hrana in usedline in je povezana z za organizem značilnimi stopnjami privzema, presnove in izločanja ter se pojavi, ko se snov v organizem absorbira hitreje, kot se izloča.
Bioaccumulation: Involves the uptake of substances from all environmental sources, such as water, food, and sediments, and is related to organism-specific rates of uptake, metabolism, and excretion. Bioaccumulation occurs when a substance is absorbed by the organism faster than it is excreted.



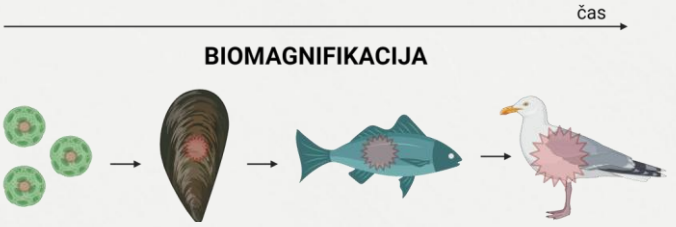
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Biomagnifikacija/Biomagnification

Biomagnifikacija: proces, pri katerem se koncentracije bioakumulirane snovi v tkivih povečujejo z zaporednimi višjimi trofičnimi nivoji v prehranskem spletu (vsaj dve trofični ravni). Ta pojav je redek, obstajajo pa onesnažila, za katere je znano, da se biomagnificirajo, npr.:

- klorirani ogljikovodiki;
- insekticidi (npr. DDT);
- neinsekticidi (npr. PCB-ji);
- nekatere organokovinske spojine (npr. metil živo srebro, tributilkositer [TBT]).
  - Za ta onesnažila je značilna visoka topnost v lipidih => kopičenje v biološkem tkivu z visoko vsebnostjo maščob (maščobno tkivo, belo mišičje, nekateri organi). V organizmu so stabilni, kopičenje pa lahko vodi do bolezni in smrtnosti organizmov na višjih trofičnih nivojih.



Biomagnification: The process by which concentrations of bioaccumulated substances in tissues increase across successive, higher trophic levels in a food web (at least two trophic levels). This phenomenon is rare, but certain pollutants are known to biomagnify, such as:

- Chlorinated hydrocarbons,
- Insecticides (e.g., DDT),
- Non-insecticide pollutants (e.g., PCBs),
- Certain organometallic compounds (e.g., methylmercury, tributyltin [TBT]).
  - These pollutants are characterized by high lipid solubility, leading to accumulation in biological tissues with high fat content (adipose tissue, white muscle, certain organs). They are stable within organisms, and their accumulation can lead to diseases and mortality in organisms at higher trophic levels.

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Biološka dostopnost/Bioavailability

Biološka dostopnost se nanaša na delež elementa (ali spojine), ki je na voljo za prevzem organizmu. Nanjo vpliva tudi način vstopa snovi v organizem (npr. preko vode, usedlin, hrane itd.). Problematične so snovi, ki so šibko vezane na delce usedlin (močno vezane snovi niso toliko problematične, saj gredo večinoma skozi organizem z delcem).

Bioavailability refers to the proportion of an element (or compound) that is available for uptake by an organism. It is also influenced by the entry pathway of the substance into the organism (e.g., through water, sediments, food, etc.). Problematic substances are those weakly bound to sediment particles (strongly bound substances are less problematic, as they mostly pass through the organism with the particle).

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Vzorčenje organizmov/Sampling and Analysis

Interakcije organizmov z okoljem so odvisne od poti izpostavitve in vnosa / Interactions of organisms with the environment depend on the exposure pathway and intake.

- Vnos je odvisen od fizikalno-kemijskih dejavnikov (vrsta snovi, razpad snovi,...) / Intake is influenced by physicochemical factors (type of substance, degradation of the substance, etc.).

Pri absorbciji igrajo pomembno vlogo tudi **biološke spremenljivke in dejavniki okolja** / Biological variables and environmental factors also play a significant role in absorption, such as:

- Vrsta, habitat, fiziologija, prehranjevalne navade, starost organizma,... / Species, habitat, physiology, feeding habits, age of the organism, etc.
- Sezona => vpliv na porazdelitev in razpoložljivost / Season => impacts distribution and availability.
- Razumevanje bioloških in ekoloških značilnosti organizma je ključno za razumevanje obremenitve z onesnažili v tem organizmu. / Understanding the biological and ecological characteristics of an organism is essential for understanding its pollutant burden.

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Vzorčenje tkiv/Tissue Sampling

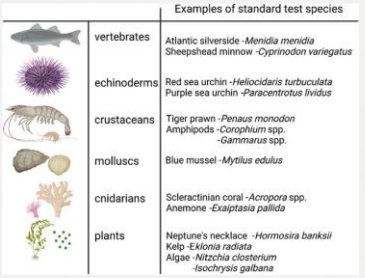
- Vzorčenje organizmov za določanje obremenitve z onesnažili vključuje identifikacijo in zbiranje reprezentativnih vrst, ki jih najdemo na izbranih lokacijah v okviru vzorčevalnega programa. / Sampling organisms for determining pollutant burden involves identifying and collecting representative species found at selected locations as part of the sampling program.
- Različna tkiva se odvzamejo za ločene analize, običajno so to: jetra, škrge in gonade (glede na raziskovalno vprašanje in izbrane analize). / Different tissues are taken for separate analyses, usually including the liver, gills, and gonads (depending on the research question and chosen analyses).
- Med postopkom pazimo, da ne pride do kontaminacije vzorcev tkiv (izrez tkiv pred zamrzovanjem). / During the process, care is taken to avoid contamination of tissue samples (e.g., tissue excision before freezing).

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Vzorčenje tkiv/Tissue Sampling

- Vrsta organizma je odvisna od raziskovalnega vprašanja. Organizem mora biti pogost, družbeno/ekološko pomemben, reprezentativen, jasna biologija/taksonomija. / The type of organism depends on the research question. The organism must be common, socially/ecologically important, representative, with clear biology/taxonomy.
- Koncentracije onesnažil so različne v različnih tkivih in organih. / Pollutant concentrations vary in different tissues and organs.
  - Živ vzorec – biopsija, mrtev vzorec – nekropsija / Live sample – biopsy, dead sample – necropsy.
  - Pred vzorčenjem je potrebno pridobiti potrebna dovoljenja in etične odobritve / Before sampling, necessary permits and ethical approvals must be obtained.
- Pri sekciji uporabljamo filtrirano morsko vodo za spiranje tkiv pred zamrzovanjem, na terenu vzorce shranimo na ledu, če so analize načrtovane več kot 24 h po odvzemu vzorcev, se vzorce zamrzne v tekočem dušiku in shrani na -80 °C (pomembno je, da vzorcev ne odtaljujemo in zamrzujemo!). / In dissection, filtered seawater is used to rinse tissues before freezing; on-site, samples are stored on ice. If analyses are planned more than 24 hours after sample collection, the samples are frozen in liquid nitrogen and stored at -80 °C (it is important not to thaw and refreeze samples!).
- Majhne organizme pogosto uporabljamo za testiranje toksičnosti (biomonitoring in situ – školjke) / Small organisms are often used for toxicity testing (biomonitoring in situ – mussels).

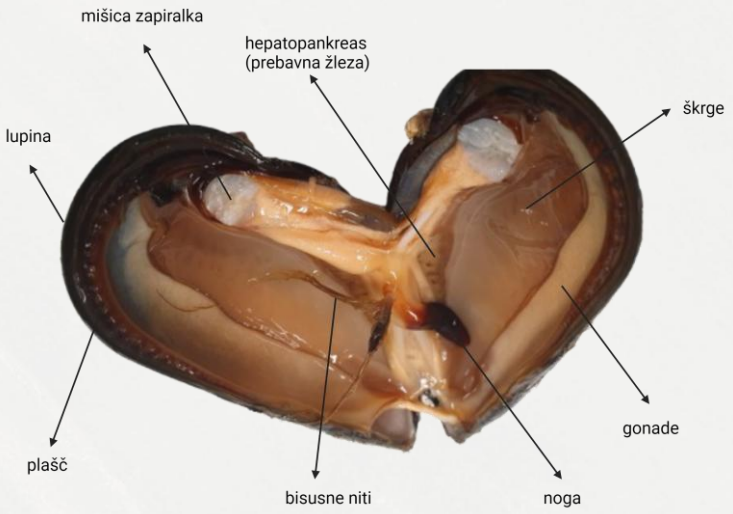


Vir slike: https://doi.org/10.1007/978-3-031-10127-4

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Užitna klapavica (*Mytilus galloprovincialis*) - morfologija/Morphology

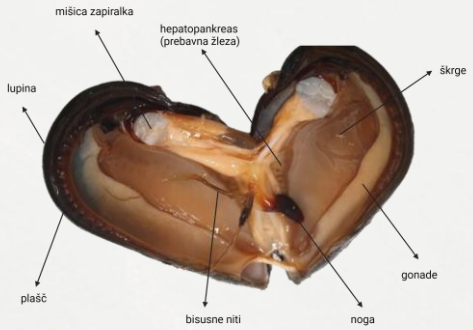




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Užitna klapavica (*Mytilus galloprovincialis*) - morfologija/Morphology



- Plašč: Vloga pri bioakumulaciji kovin in organskih onesnažil (tudi škrge, ledvice, prebavne žleze) / Mantle: Role in the bioaccumulation of metals and organic pollutants (also gills, kidneys, digestive glands)
  - Organska onesnažila → presnova in izločanje skozi ledvice / Organic pollutants → metabolism and excretion through the kidneys
  - Težke kovine → metalotioneini v tkivu škrg, plašča, prebavnih žlez (lizosomi) / Heavy metals → metallothioneins in the gill tissue, mantle, and digestive glands (lysosomes)

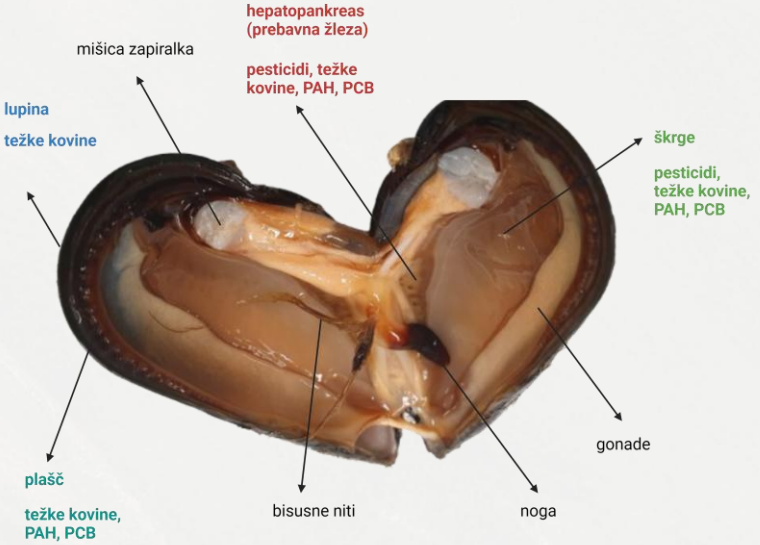
- Metalotioneini = specializirani proteini, ki vežejo težke kovine, in lovilci prostih radikalov, kot sta glutation in vitamin C, so zelo razširjeni škrgah in prebavnih žlezah / Metallothioneins = specialized proteins that bind heavy metals, and scavengers of free radicals, such as glutathione and vitamin C, are highly abundant in the gills and digestive glands.



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Užitna klapavica (*Mytilus galloprovincialis*) - morfologija/Morphology

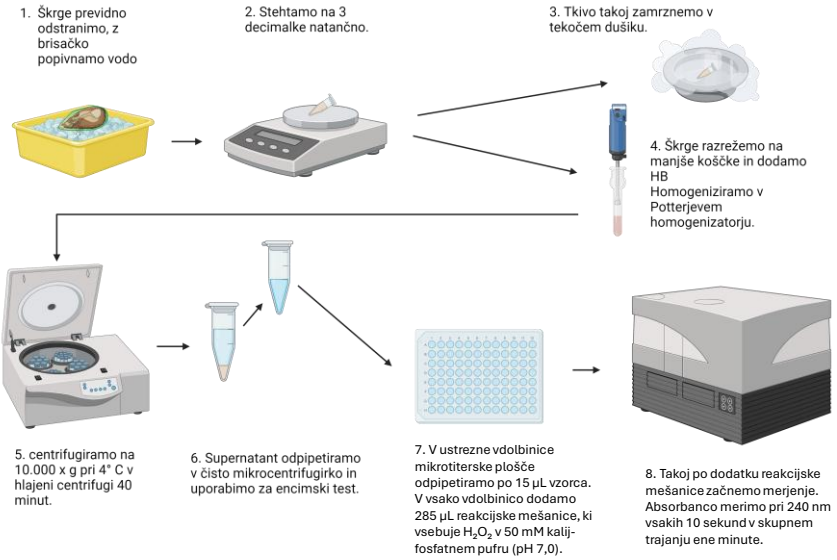




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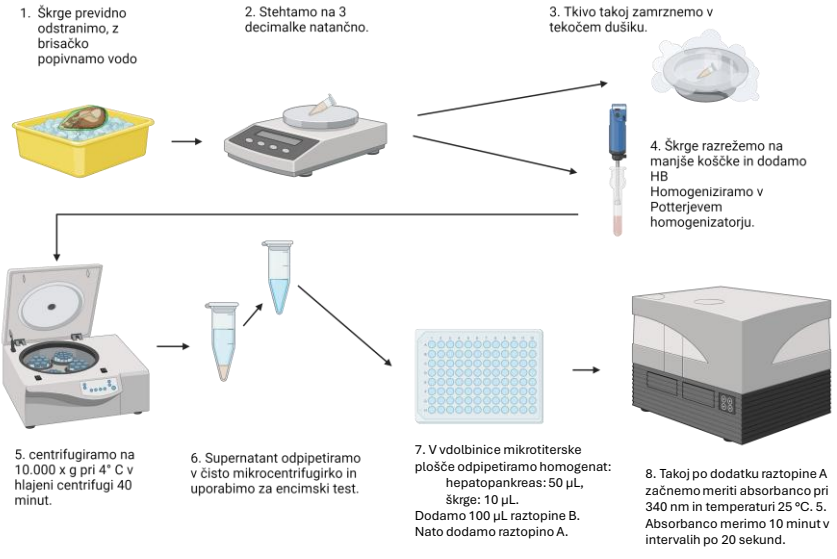
Specifična aktivnost katalaze/CAT specific activity



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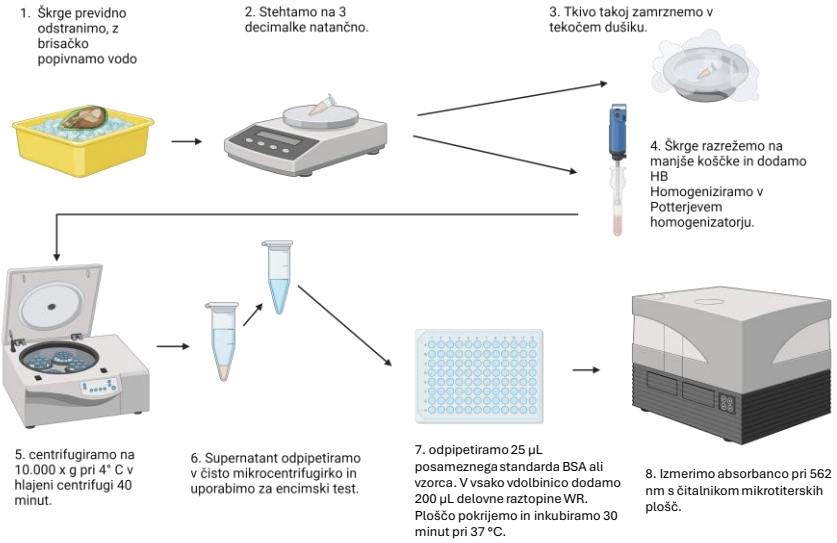
Specifična aktivnost glutation-S-transferaze/GST specific activity



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Koncentracija proteinov/Protein concentration



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