CONTENTS

9 770506 425003

VARSTVO NARAVE 2009

22

VARSTVO NARAVE 22

ISSN 0506 4252

VARSTV NAR LETNIK/VOL. 22 STR. 1–192 LJUBLJANA 2009

Izdajatelj/Published by:

**Zavod Republike Slovenije
za varstvo narave**

Naslov uredništva/Address of the Editorial Office:
Zavod Republike Slovenije za varstvo narave
Dunajska 22, SI-1000 Ljubljana

Urednik/Editor:
mag. Robert Turk

Recenzenti te številke/Reviewers of this Issue:
Janez Forte, mag. Martina Kačičnik Jančar, dr. Lovrenc Lipej, dr. Cecilia Lopez y Royo, prof. dr. Alenka Malej, prof. Giuseppe Notarbartolo di Sciara, prof. Gerard Pergent, prof. Giulio Relini, mag. Robert Turk, doc. dr. Ksenja Vodeb

Prevajalec in lektor/ Translator and Language Editor:
Henrik Ciglič

Tehnični uredniki/ Tehnical Editors:
Damjan Vrček, Mateja Živkart, Mateja Nose Marolt

Fotografije na naslovnici/Photos on Front Page:
Tihomir Makovec; Leščur (*Pinna nobilis*)

Tisk/Print:
Birografika Bori d.o.o.

Naklada: 500 izvodov
Printed in 500 copies

Izdajo 22 tematske številke revije Varstvo narave je finančno podprla
Kneževina Monako

NAVODILA AVTORJEM ZA PISANJE PRISPEVKOV ZA REVIJO VARSTVO NARAVE

V reviji Varstvo narave objavljamo znanstvene, strokovne in kratke prispevke, ki obravnavajo teorijo in prakso varstva narave. Prispevki pokrivajo vse vidike ohranjanja narave: naravoslovni, družboslovni in upravljavski vidik. Temeljnih del z drugih znanstvenih področij, ki nimajo jasnih varstvenih implikacij, v Varstvu narave ne objavljamo.

Znanstveni in strokovni prispevki naj ne bodo daljši od 30 tisoč znakov, kratki prispevki pa od 7 tisoč znakov. Znanstvene in strokovne prispevke recenziramo; kratke prispevke pregleda uredniški odbor.

Prispevki so v slovenskem ali angleškem jeziku. Za prevajanje lahko poskrbimo v uredništvu; avtorji naj zagotovijo prevod pomembnejših strokovnih terminov. Stroške prevajanja ter slovenskega in angleškega lektoriranja nosi uredništvo.

Prispevek naj bo opremljen z imeni in priimki avtorjev, točnim naslovom ustanove, v kateri so zaposleni oziroma naslovom bivališča, če niso zaposleni, naslovom elektronske pošte in telefonsko številko.

Besedilo mora biti napisano z računalnikom (Word), leva poravnava, velikost znakov 12. Znanstveni in strokovni članki naj imajo UMRDP-zgradbo (uvod, metode, rezultati, diskusija, povzetek); če to ni mogoče, pa obvezno uvod in povzetek. Vsi, tudi kratki prispevki naj bodo opremljeni z izvlečkom (do 250 znakov) in ključnimi besedami. Poglavja naj bodo oštevilčena z arabskimi številkami dekadnega sistema (npr. 2.3.1). Opombe med besedilom je potrebno označiti zaporedno in jih dodati na dnu strani. Latinska imena morajo biti izpisana ležeče (*Leontopodium alpinum* Cass.).

Viri naj bodo med besedilom navedeni po sledečih vzorcih:

– kot pravi Priimek (1999) je to in to
– (Priimek 1999, 23)
– (Priimek 1999a, 1999b)
– (Priimek in Priimek 1999); v angl. prispevku (Priimek et Priimek 1999)
– (Priimek in sod. 1999); v angl. prispevku (Priimek et al. 1999)
– (Priimek 1999, 23, Priimek 1999, 23)
– Zakon (Kratica glasila št./99)

Med besedilom citirane vire navedite na koncu prispevka v poglavju ‘Literatura’, in sicer po abecednem redu priimkov prvih avtorjev oziroma po abecednem redu naslova dela, če avtor ni naveden. Upoštevajte naslednje vzorce:

– Priimek, I., I. Priimek (1999): Naslov članka. Naslov revije 99(5): 777–888
– Zakon. Kratica glasila št./99
– Naslov. http://
– Priimek, I., I. Priimek (1999): Naslov članka. V: Priimek I., Priimek I. (ur.): Naslov krovnega dela. Naslov revije 99(5): 777–888
– Priimek, I., I. Priimek (1999): Naslov dela. Založba. Kraj. 136 str.
– Priimek, I., I. Priimek (1999): Naslov dela. Založba. Kraj. Str. 4–15
– Organizacija (1998): Naslov dela. Srečanje. Kraj.

Tabele, grafi, slike in fotografije morajo biti opremljeni z zaporednimi oznakami. Naslovi tabel morajo biti zgoraj, pri ostalem gradivu spodaj. Tabele naj bodo čim manj oblikovane. Grafi naj bodo praviloma dvodimenzionalni in šrafirani. Slike naj imajo kakovostno resolucijo.

VARSTVO NARAVE

REVIJA ZA TEORIJO IN PRAKSO
OHRANJANJA NARAVE

22

NATURE CONSERVATION

A PERIODICAL FOR RESEARCH AND PRACTISE
OF NATURE CONSERVATION

LJUBLJANA
2009

VSEBINA/CONTENTS

AVANT-PROPOS

Our handling of the sea and its coast stipulates a great deal of how and to what extent the sea and its natural resources will be able to be exploited by our descendants. It also determines, however, whether they will be still able to admire the sea turtles, dolphins, underwater meadows, pen shells and date mussels in this extreme part of the Mediterranean. The Northern Adriatic is a relatively shallow ecosystem, considering that its depth does not exceed 50 m. It is earmarked by the stratification of its water column, great fluvial input, and high productivity. But above all, is a very sensitive ecosystem, for apart from the stated characteristics it is known for its intensive fisheries, tourism, industry and maritime transport. Years ago we blamed our insufficient knowledge, lack of data and similar deficiencies for our grossly unsuitable interventions into the sea and its coast. Today, however, this can no longer be an excuse. The years when Lord Byron wrote that human impact ends on the coast are long past, and it is high time that we have a look under the surface of the sea and see, with our own eyes, the destruction we have caused in it.

This year, precisely two decades have passed since the formal debate on proclaiming individual protected areas on the Slovenian coast began to unroll in our country. On the basis of the Law on natural and cultural heritage, which was in force at that time, the Littoral municipalities of Slovenia protected the sea in front of Piran, the Bay of Strunjan, 200 metres wide belt of the sea along the northern part of Strunjan peninsula, as well as the extreme part of Debeli rtič and the sea in front of it. By doing so, the Littoral municipalities considerably contributed to the efforts towards preserving biodiversity and integrity of the ecosystem of the Gulf of Trieste as well as of the entire Northern Adriatic.

The period of twenty years is fairly long, but at the same time it is an opportunity to assess how reasonable and successful were the measures and arrangements made at that time. We are able to find part of the answers to this issue in the everyday events at both the local and global levels. During the increasing pressures exerted on the sea and its coast, the role of protected areas has even gained in its significance. An important part of the activities carried out within the framework of the Convention on biodiversity has been devoted to the founding of marine protected areas in territorial waters as well as in open seas and on deepsea floor. The cognition about the urgency of preserving the marine ecosystem's integrity, biodiversity and ecological processes is a significant background for the functioning of the majority of international government and non-government organisations, including those dealing with exploitation of natural resources, from fishing to the exploitation of minerals on the sea floor and under it. The international community has set two important objectives: to stop the decline of biodiversity by 2010 and to establish a representative network of marine protected areas by 2012 at the regional and global levels.

An important contribution to the this international effort in achieving a more sustainable use of the marine biodiversity was the "Expert Meeting on the Impacts of Human Activities at Sea, on the Coast and its Hinterland on the Northern Adriatic's Biodiversity", organized by the Institute of the Republic of Slovenia for Nature Conservation and held on 7th and 8th October 2008 in Piran. The objective of the meeting is to contribute to an integral treatment of the Northern Adriatic, both from the aspect of the state of marine and coastal habitat types and from the aspect of human activities and impacts, their separate and above all cumulative effects on marine and coastal ecosystems. At the end of the workshop the participants from Croatia, Italy, France and Slovenia agreed on a set of conclusions that were sent to the regional and national authorities and to the competent bodies of the European Union. Common position was expressed about the need of a common, integrated approach to the management of the Northern Adriatic and of the whole Adriatic basin. You can find some of the findings, thoughts and discussions concerning the Northern Adriatic in the present number of our nature conservation magazine *Varstvo narave*, in which some of the presentations and conclusions from the Piran Expert Meeting are gathered.

Robert Turk, MSc

PREDGOVOR

Naše ravnanje z morjem in morskim obrežjem v veliki meri odloča, kako in koliko bodo morje in njegove naravne vire lahko koristili naši zanamci. Odloča tudi o tem, ali bodo v tem skrajnem delu Sredozemlja še občudovali morske želve, delfine, podvodne travnike, leščurje, morske datlje. Severni Jadran je razmeroma plitev ekosistem, saj je globina manjša od 50 m. Opredeljujejo ga stratifikacija vodnega stolpca, veliki rečni vnosi in visoka produktivnost, predvsem pa je to zelo občutljiv ekosistem, kajti navedenim značilnostim je treba dodati še izdaten ribolov, turizem, industrijo in pomorski promet. Svojčas smo se za neustrezno poseganje v morje in morsko obrežje izgovarjali na nepoznavanje, pomanjkanje podatkov in podobno. Danes to ne more in ne sme biti več izgovor. Leta, ko je lord Byron zapisal, da se človekov vpliv konča na morskem obrežju, so davno mimo in skrajni čas je, da pogledamo pod morsko gladino in se na lastne oči prepričamo o razdejanju, ki ga povzročamo.

Letos mineva natanko dvajset let od začetka formalne razprave o razglasitvi posameznih zavarovanih območij na slovenski obali. Na osnovi takratnega Zakona o naravni in kulturni dediščini so obalne občine zavarovale morje pred Piranom, Strunjanski zaliv in 200-metrski pas morja ob severnem delu Strunjanskega polotoka ter skrajni del Debelega rtiča in morje pred njim. Obalne občine so s tem pomembno prispevale k naporom za ohranjanje biotske raznovrstnosti in celostnosti ekosistema Tržaškega zaliva ter celotnega severnega Jadrana.

Dvajset let je dolga doba in obenem tudi priložnost za oceno oz. vprašanje o smiselnosti in uspešnosti takratnega ukrepa. Del odgovora lahko prepoznamo v vsakdanjem dogajanju, na lokalnem in na globalnem nivoju. Ob vse večjih pritiskih na morje in morsko obrežje je postala vloga zavarovanih območij še pomembnejša. Pomemben del aktivnosti v okviru Konvencije o biotski raznovrstnosti je namenjen ustanavljanju morskih zavarovanih območij v teritorialnih vodah ter na odprtih morjih in globokomorskem dnu. Spoznanje o nujnosti ohranjanja celostnosti morskega ekosistema, njegove raznolikosti in ekoloških procesov je pomembna osnova delovanja večine mednarodnih vladnih in nevladnih organizacij, tudi tistih, ki se ukvarjajo z izkoriščanjem naravnih virov, od ribolova do izkoriščanja rudnin na morskem dnu in pod njim. Mednarodna skupnost si je zastavila dva pomembna cilja: da bo do leta 2010 ustavila upadanje biotske raznovrstnosti in da bo do leta 2012 na regionalnem in globalnem nivoju vzpostavljena reprezentativna mreža morskih zavarovanih območij.

Pomemben prispevek k iskanju odgovorov je bilo tudi Mednarodno strokovno srečanje »Vpliv človekovih dejavnosti na morju, morskem obrežju in zaledju na biotsko raznovrstnost Severnega Jadrana«, ki ga je Zavod RS za varstvo narave organiziral 7. in 8. oktobra 2008 v Piranu. Cilj posveta je bil prispevati k celostni obravnavi severnega Jadrana, tako z vidika stanja morskih in obrežnih habitatnih tipov kot z vidika nabora človekovih dejavnosti in vplivov, njihovega posamičnega in predvsem kumulativnega učinka na morske in obrežne ekosisteme. Udeleženci posveta iz Hrvaške, Italije, Francije in Slovenije so na koncu dvodnevne razprave oblikovali zaključke, ki so bili posredovani pristojnim organom odločanja na regionalni in državni ravni Slovenije, Italije in Hrvaške ter ustreznim organom in delovnim telesom na ravni EU. Udeleženci posveta smo si bili tudi edini, da je treba s skupno in celostno obravnavo ne le severnega Jadrana, pač pa celotnega Jadranskega morja nadaljevati tudi v prihodnje. Nekaj misli, ugotovitev in razmišljanj o severnem Jadranu ponuja tokratna številka revije Varstva narave, v kateri so zbrani posameznimi prispevki in zaključki srečanja v Piranu.

mag. Robert Turk

For the attention of DG Research, DG Environment, DG Fisheries, and the Environment Commission of the European Parliament, European Science Foundation (marine board), Committee of the Regions, Presidency of the EuroAdriatic Region, Committee of trilateral agreement Croatia-Italy-Slovenia, Ministers of Research and Environment of all Adriatic States, Committee INTERREG offices

RECOMMENDATIONS FROM THE INTERNATIONAL WORKSHOP "THE IMPACTS OF HUMAN ACTIVITIES AT SEA, ON THE COAST AND ITS HINTERLAND ON THE NORTHERN ADRIATIC'S BIODIVERSITY"

held in Piran, Slovenia, 7th and 8th October 2008

We, marine biologists and ecologists from many different European institutions, met in Piran to discuss the ecological significance and conservation status of the Northern Adriatic basin and its potential influence on the health of the Mediterranean Sea ecosystem.

As scientists, we outline the importance of goods and services supplied for free by the Northern Adriatic ecosystems to human societies, and the relevance of the Northern Adriatic basin as a reservoir of endangered biodiversity, being the coldest Mediterranean Sea area in the period of major climate change, as well as one of the water circulation engines in the Mediterranean Sea.

On the other hand, we have to emphasize a weakness in the governance of processes affecting the health of the Northern Adriatic Sea ecosystem, due to both the excessive fragmentations of administrative responsibility and scientific competencies and to the lack of an ecological perspective (Eco-Governance).

The point of view arisen from the Piran meeting discussion is summarized in the following recommendations to EU, transnational and national institutional bodies.

An ecological governance of socio-economical and political processes is required to achieve the control of health of the Northern Adriatic Sea. Furthermore, some actions to deepen our knowledge on what we need to protect, to improve our ecological defence from human impacts and increase the effectiveness of research and higher education efforts are needed.

1. We need an inventory and assessment of the Northern Adriatic Sea biodiversity, in order to in fact know what we have to protect and preserve as unique natural heritage of this cold water spot in the Mediterranean Sea.

2. In order to develop suitable strategies for the mitigation of human impacts, we need international programmes to monitor the ecological status of coastal wetlands, which act as biological filters for the dampening of various pressures exerted by urban and agro-industrial centres.

3. We need to invest more effort in the protection of this environment, both through marine protected areas and a better governance system outside MPAs.

4. We need to resolutely reduce the existing fragmentation of the Adriatic scientific and academic community, to address the ecological problems of the Northern Adriatic basin at the suitable EcoRegional Adriatic level.

Scientists and conservationists outline the priority to develop a transnational research and academic institution for coastal and marine biology and ecology, built as a virtual centre representing the institutional framework for multi-national professorships and studentships in the Adriatic area for the study of biology and ecology of the Adriatic Sea.

We kindly ask these topics to be also dealt with at the ensuing meeting by transnational institutions when debating on the environment governance in the Northern Adriatic Sea basin, and that these issues are passed on to the appropriate European and national governmental institutions.

Piran, October 8th, 2008

V vednost: evropskemu Generalnemu direktoratu (GD) za raziskovanje, GD za okolje, GD za ribištvo, Okoljski komisiji Evropskega parlamenta, Evropski fundaciji za znanost (odbor za pomorstvo), Komiteju regij, Predsedništvu Evrojadranske regije, Komiteju za trilateralni sporazum med Hrvaško, Italijo in Slovenijo, Ministrstvom za raziskave in okolje v vseh jadranskih državah, uradom programa INTERREG

PRIPOROČILA MEDNARODNEGA SREČANJA "VPLIV ČLOVEKOVIH DEJAVNOSTI NA MORJU, MORSKEM OBREŽJU IN ZALEDJU NA BIOTSKO RAZNOVRSTNOST SEVERNEGA JADRANA", ki je potekalo 7. in 8. oktobra 2008 v Piranu

Morski biologi in ekologi iz različnih evropskih inštitucij smo se v Piranu srečali z namenom, da se temeljito pogovorimo o ekološki pomembnosti in naravovarstvenem statusu severnega Jadrana ter njegovem potencialnem vplivu na vitalnost ekosistema Sredozemskega morja.

Kot znanstveniki bi radi poudarili pomen dobrin in storitev, ki jih severnojadranski ekosistemi brezplačno dostavljajo in opravljajo za človeško skupnost, kot tudi pomen severnega Jadrana kot rezervoarja biotske raznovrstnosti - najhladnejšega območja v Sredozemskem morju v času podnebnih sprememb, hkrati pa kot enega izmed pogonskih motorjev za kroženje vode v Sredozemskem morju.

Po drugi strani pa moramo poudariti šibkost upravljanja s procesi, ki vplivajo na vitalnost ekosistema severnojadranskega morja, tako zaradi prerazdrobljene administrativne odgovornosti in znanstvene pristojnosti kot zaradi pomanjkanja ekološke perspektive in upravljanja (Eco-Governance).

Naše stališče, ki izhaja iz diskusij na piranskem srečanju, je povzeto v naslednjih priporočilih Evropski uniji, mednarodnim in nacionalnim organom s področja varovanja okolja, raziskav in ribištva.

Da bi pridobili nadzor nad zdravstvenim stanjem severnega Jadrana, je treba zagotoviti ustrezno upravljanje (eco-governance) socio-ekonomskih in političnih procesov, hkrati pa moramo narediti vse, da bi poglobili svoje znanje o tem, kaj je treba zaščititi, da bi izboljšali ekološko obrambo pred človekovim vplivom in nenazadnje povečali učinkovitost naših naporov na področju raziskav in znanja (vedenja) o območju.

1. Če želimo vedeti, kaj moramo zaščititi in ohraniti kot enkratno naravno dediščino tega najhladnejšega območja v Sredozemskem morju, potrebujemo popis elementov biotske raznovrstnosti severnega Jadrana in oceno stanja.

2. Da bi lahko razvili ustrezne strategije za ublažitev človekovih vplivov, potrebujemo meddržavne programe za spremljanja ekološkega stanja obalnih mokrišč, ki so nekakšni biološki filtri za blaženje pritiskov, ki prihajajo iz urbanih, kmetijskih in idustrijskih središč.

3. Nujno si moramo v večji meri prizadevati za varovanje in ohranjanje, tako z vzpostavitvijo morskih zavarovanih območij kot tudi z boljšim upravljanjem morskega ekosistema zunaj zavarovanih območij.

4. Da bi o problemih severnega Jadrana lahko razpravljali na ustreznem nivoju, tj. na nivoju ekoregije, moramo odločno zmanjšati razdrobljenost jadranske znanstvene in akademske skupnosti.

Ena izmed prioritet, ki jo znanstveniki in naravovarstveniki želimo posebej poudariti, je razvoj mednarodne raziskovalne in znanstvene inštitucije za morsko in obalno biologijo in ekologijo, ki naj bi delovala kot virtualno središče in institucionalni okvir za mednarodno skupino raziskovalcev, profesorjev in študentov za študije in raziskave s področja biologije in ekologije Jadranskega morja.

Prosimo, da se o teh temah razpravlja tudi na naslednjih srečanjih meddržavnih in medregijskih ustanov, ko bo govor o okoljskem nadzoru v severnem Jadranu, ter da se s tem seznanijo tudi ustrezne evropske in nacionalne vladne inštitucije.

V Piranu, dne 8. oktobra 2008

THREATS AND CHALLENGES TO THE MARINE ENVIRONMENT IN THE MEDITERRANEAN SEA

OGROŽENOST IN IZZIVI MORSKEGA OKOLJA V SREDOZEMSKEM MORJU

Ferdinando BOERO

Key words: Mediterranean Sea, climate change, habitats, Marine Protected Areas, macrodescriptors
Ključne besede: Sredozemsko morje, podnebne spremembe, habitati, morska zavarovana območja, makrodeskriptorji

ABSTRACT

Marine environments are exposed to many threats, mostly deriving from direct human impact through manifold activities. Environmental protection should be accomplished by identifying the source of disturbance and by removing it. This is particularly possible when disturbance is direct and limited in space and time. The Habitat Directive of the European Union aims at identifying relevant habitat types that merit protection (even though the list does not reflect the diversity of Mediterranean habitat types), and a network of Marine Protected Areas has been instituted just to protect particular environments from direct threats. However, there are many forms of disturbance (one for all: global warming) that are acting at very large scale, if not global, and cannot be eliminated by local measures. The stopping of deep water formation in the Northern Adriatic led already to an altered situation (the Eastern Mediterranean Transient) that should be a source of the greatest concern in the light of the impact of global warming on the state of the Mediterranean Sea. The role of the scientific community, within this framework, is not only to evaluate the state of the environment and to propose measures of restoration, but also to enhance public awareness about a proper relationship between our species and the rest of nature.

IZVLEČEK

Morska okolja so izpostavljena neštetim grožnjam, večinoma zaradi neposrednih antropogenih vplivov, ki so posledica različnih človekovih posegov v ta prostor. Varovanje okolja bi se morali lotiti z ugotavljanjem vira motenj in njihovim odpravljanjem. To je še posebej mogoče, kadar je motnja neposredna in omejena v prostoru in času. Namen Direktive o habitatih Evropske unije je opredeliti pomembne habitatne tipe, ki so potrebni ustrezne zaščite (čeprav njihov seznam ne odseva pestrosti sredozemskih habitatnih tipov), medtem ko je bilo omrežje morskih zavarovanih območij osnovano le za zaščito določenih okolij pred neposrednimi grožnjami. Toda dejstvo je, da se moramo spopadati z mnogimi oblikami motenj (predvsem kot posledico globalnega segrevanja), ki delujejo v zelo velikem obsegu (če že ne v globalnem) in jih ni mogoče odpraviti z lokalnimi ukrepi. Že zastoj v formiranju (pridnenih) hladnih vodnih mas v severnem Jadranskem morju vodi v precej spremenjene razmere (vzhodni sredozemski klimatski odziv), ki bi jim morali zaradi učinkov globalnega segrevanja na stanje Sredozemskega morja posvetiti vso pozornost in skrb. Vloga znanstvene skupnosti v tem okviru ni le oceniti stanje okolja in predlagati ukrepe za vzpostavitev nekdanjega stanja, marveč tudi okrepiti ozaveščenost javnosti o pravem odnosu med našimi vrstami in preostalo naravo.

1. INTRODUCTION

The Mediterranean Sea has a paramount role in both natural and human domains. In fact, it is both a hot spot of biodiversity and the cradle of western civilization, being a crossroad of three continents, having more than 380 million people living in the countries that form the basin, 146 million living directly on its shores. Its nature, climate and culture have greatly contributed to the fact that the Mediterranean area has become the most visited part of the entire world, with a tourist flux that is the first source of income for the area, leading to the doubling of the population living along the shore, due to tourist fluxes.

Human pressure is a threat to this beauty, and to the ecological systems that allow for it. The main threats are the usual ones, affecting the whole world: industrial pollution, urban pollution, coastal development (often triggered by tourist presence), industrial fisheries, poaching, human-promoted arrival of alien species. It is in the interest of the Mediterranean people that the reasons for visiting the area remain valid, and that the goods and services provided by the sea remain available for future generation. It is imperative, therefore, to protect the Mediterranean Sea. Marine Protected Areas are one of the tools to achieve this goal.

2. THE MEDITERRANEAN: A BEAUTIFUL PLACE

In recent times, many Marine Protected Areas throughout the Mediterranean area have been instituted for a very precise reason: to defend beauty. It seems a very naive reason, but let us not forget that terrestrial National Parks have been designed for the very same reason as well. Beauty can be a landscape, like a rocky shore with many caves, continuing underwater with steep cliffs that dive into the blue water. Or it can be a single or a group of flagship species, like the monk seal, or cetaceans in general. There are places in which Nature is particularly generous, and we can feel it, even with no aid from science. These places are sacred to all humans, and it is not by chance that sometimes the word “sanctuary” is used for them.

Mediterranean MPAs are essentially sanctuaries. They protect unique places that have no counterpart anywhere else. These locations, and the species that inhabit them, are irreplaceable because they occur only at THAT place, and THAT place is to be preserved. It is not by chance that almost all Mediterranean MPAs are situated on rocky shores, and it is not by chance that many are islands.

So, the aim is clear: beautiful places must continue to be beautiful.

The very beauty of a given place is source of the main threat. Beautiful places are usually not exploited by humans. They are beautiful because they are as pristine as possible and pristine means with no sign of human activities. The threats to the beauty of these places start when somebody discovers it, and few illuminated people go and take advantage of it for some time, to enjoy it. Then other people realize the potential of the place, and they work to “develop” it. They build facilities that will allow more and more people enjoying the direct contact with a beautiful place. The place becomes rich, hotels are built, and marinas, maybe even airports. The best places, the most beautiful ones, become parks of villas of very rich people. After this treatment, the beauty of the place is gone. The features that made that place beautiful were linked to the absence of human signs. After "development", human signs become very evident, and beauty is spoiled. This treatment has been inflicted to too many parts of the Mediterranean coast, and it is our duty to defend the few places that are still untouched. Is this enough to "save the sea" from all threats? The answer is simple: no, it is not.

3. SAVING THE MEDITERRANEAN

The most important habitat of the Mediterranean is not a habitat, it is the result of the presence of a habitat-forming species: *Posidonia oceanica*, the seagrass that forms extensive meadows along the greater part of the Mediterranean coast, changing the primary habitat that hosts it (from sand to rock) into a secondary habitat with vital functions for the rest of the Mediterranean biota. *Posidonia* meadows are threatened by coastal development and illegal fisheries throughout the basin; their protection is urgent and badly needed. Can we save them with Marine Protected Areas? There are too many people on the coast, and we cannot propose a MPA for every spot where *Posidonia* occurs, i.e. a great part of the coast of the whole basin. There have to be other tools. Luckily, for *Posidonia* there is one: the Habitat Directive of the EU. The other side of the coin is that the Directive is valid only in the EU, but the Mediterranean is much more than the EU. A shared legislation is needed to prevent all countries from depleting their natural capital, in this case: the capital represented by *Posidonia* meadows.

The presence of *Posidonia* meadows, thus, is a reason for stopping coastal development, so that meadows remain untouched by direct impact, like the construction of harbours, the passage of pipelines, the discharge of materials. A more general legislation than that ruling Marine Protected Areas is aimed at protecting an ecologically valuable habitat of the Mediterranean.

Seagrass meadows, however, are just one of the important habitats of the Mediterranean. And we are very far from having explored the basin. How can we dream of protecting something if we do not know our capital?

The other marine habitats covered by the Habitat Directive are:

11. Open sea and tidal areas

1110 Sandbanks, which are slightly covered by seawater all the time

1120 * *Posidonia* beds (*Posidonion oceanicae*)

1130 Estuaries

1140 Mudflats and sand flats not covered by seawater at low tide

1150 * Coastal lagoons

1160 Large shallow inlets and bays

1170 Reefs

1180 Submarine structures made by leaking gases

The list of marine habitat types comprises also:

8330 Submerged or partially submerged sea caves

It is very evident that the Habitat Directive did not consider the diversity of habitat types that characterizes the Mediterranean Sea. Coralligenous formations are not covered and, furthermore, the spectacular diversity of Mediterranean biota found on capes and promontories is ignored, with the enhancement of mudflats and shallow inlets and bays! These habitats might fall under the Reefs category which, in fact, is too generic, comprising too many different habitat types.

Habitats have to be listed and mapped, in order to identify the most valuable ones, and their distribution. At present, there are far too many lists of Mediterranean habitats, and it is urgent to merge them under a robust rationale. Then we must try to identify the main threats on each of them, wherever they do occur. The exploratory phase, which is very far from being accomplished, might lead to the discovery of valuable sites that are still unknown, especially on the southern shore of the Mediterranean, not to speak about the deep sea.

Of course, we cannot wait for the complete exploration of the basin and we must act now, but the ultimate objective should be the proper knowledge of the Mediterranean biota. Whenever an area is sufficiently explored, and we know the features of its biota, for some places, we might say: at this place there is something really unique, and beautiful. This will be a Marine Protected Area. Probably, all countries have already identified all these places in their own territories. Some are MPAs already; some will be, sooner or later.

There are other places, however, that might be extremely important not for the way they look, but for what they do, just as *Posidonia* meadows.

Such places might be important for the functioning of ecosystems, like marine canyons, leading to the formation of upwelling currents, the currents that bring nutrients from the deep sea to the shallow waters of the shore. If marine canyons become the recipients of dumping, their ecological role might become impaired. The Pelagos Sanctuary for Mediterranean Marine Mammals, for instance, hosts a huge number of whales owing to the presence of large populations of the euphausiacean *Meganychtiphanes norvegica.* These are concentrated in accordance with the upwelling currents that are generated by the large system of marine canyons that characterizes the deep bottoms of the sanctuary. Whales are there simply because the canyons "pump" their food and concentrate it. Protection of whales passes through the protection of marine canyons!

There are places that are important for the reproduction of species. Some are used by the reproductive adults (spawning areas), others are important for the initial growth of larvae and juveniles (nursery areas). The existence of widespread species throughout the basin might be linked to a few places where the representatives of that species concentrate during some part of their existence. If that or those places are degraded, the species is in peril. Maybe there is nothing so special there, in our eyes, and we just need to say that the integrity is to be preserved by prohibiting the most destructive activities, usually fisheries.

Once we have made the list of the places that are beautiful and of the places that are important for ecosystem functioning, we have an inventory of the most valuable natural items. Once we know that these valuable places exist, we must identify their vulnerabilities.

4. STATING OBJECTIVES

Protection implies the presence of a threat. If a place is protected, one should ask: protected from what? And what are the expected results of protection? It is too easy to make a generic list of threats and of possible improvements, and then to apply it to all Protected Areas. This would make it too difficult to evaluate the efficacy of the measures of protection: if we list every positive goal for each MPA, then some results will be surely obtained. But are they relevant for the objectives of that particular MPA? Or, if beauty is not involved, for the area that we wanted to defend due to its ecological importance?

So, stating the threats and the ways to avoid them is a prerequisite for the good management for any place, and this is even truer for Marine Protected Areas.

The test of efficacy, however, is rather difficult. To decide whether management has been effective, in fact, one should compare the managed area with a series of similar areas (the controls, and they have to be more than one) that have not been managed. Because the obtained results might not be the fruit of good management but of chance. So, management is effective when the managed area has more positive features in a series of indicators (decided in function of the identified threats) than similar but not managed areas in its vicinities. The procedure is very simple, in theory, but it is often impossible in practice. Unicity, in fact, is one of the main reasons for the institution of Marine Protected Areas, and if a place is unique then there will be no other places like it, and this makes the finding of adequate controls impossible.

A different way of evaluation might be trend analysis. Once the feature to protect has been identified and the possible threats to it have been removed by protection, one might monitor the descriptors of that feature in order to evaluate if any improvements have been made. The presence of improvements, without proper controls, might not be unambiguously ascribed to management, but this might become irrelevant. As long as the situation improves, or at least does not undergo further degradation, management might be considered as effective. If the trend is showing a decrease in the indicators of quality, then we are most likely that we have a case of mismanagement on our hands.

5. WHAT MPAS CANNOT DO

A Marine Protected Area, however, cannot stop an alien species (like *Caulerpa racemosa*) and one cannot blame the manager if the bottoms of its area are invaded. Equally, protection cannot stop an oil wave deriving from of an oil tanker wreck. Direct threats like these, in fact, do not depend on the local conditions of the MPA, those that can be controlled by management, but do have their origin outside the MPA and, within this framework, they might be called indirect threats. Such threats therefore cannot be avoided by localized protection, as that of MPAs, but need basin-scale management, like that protecting *Posidonia* meadows. Protection can avoid direct and localized threats, such as overfishing, sewage discharges, and untenable tourist pressure.

Promising impossible results, thus, invariably leads to failure.

6. THE GREATEST THREAT TO MEDITERRANEAN BIOTAS

There are three areas in the entire Mediterranean basin that are of paramount importance for the well being of its biota. One is Gibraltar, from where a shallow Atlantic current enters the basin and a deep Mediterranean current flows out. This water exchange is vital for Mediterranean biota. The other two places are the northern portions of the Western and the Eastern basins, namely the Gulf of Lyon (maybe the Ligurian Sea) and the Northern Adriatic, plus some parts of the North Aegean. At these places, the northerly cold winds reduce temperatures in surface waters to a much greater extent than in any other part of the basin. Cold water is heavier than warmer water, and tends to sink. At these places, therefore, a shallow formation of potentially deep water occurs. The cold water, in fact, tends to sink towards the deeper portions of the Mediterranean. The Gulf of Lyon is the point of origin of deep waters in the Western Mediterranean, whereas the Northern Adriatic and the Northern Aegean are the points of origin of deep waters in the Eastern Mediterranean. The new deep water displaces the old water and generates a turn-over that is vital for the mixing of the basin. If vertical mixing stops, for any reason, we can have a situation like that of the Black Sea, where the surface is vital but the deeper parts are anoxic and host much simplified biota. Now the situation becomes clear. If there is a tendency towards global warming, what are the portions of the Mediterranean that will be most affected by it? The answer is simple: the coldest portions. The threat is twofold. There is a direct threat to the northern biotas, since they cannot tolerate too warm waters and run the risk of extinction. In the Northern Adriatic, for instance, there is a boreal biota having the brown alga *Fucus virsoides* as its flagship species. It is the only *Fucus* of the whole eastern basin and, together with it, there are other species that are endemic to that portion of the Mediterranean. These species cannot migrate northwards and they cannot go deeper, since the Northern Adriatic is a shallow *cul-de-sac*. If there are species running a serious risk of extinction due to global warming, then they are certainly in the Northern Adriatic. The other threat is indirect for the whole basin. If deep water is not formed anymore, since the climate is not conducive for its formation, there will be a weaker renewal of deep waters, with a tendency of stagnation. The catastrophic scenarios for this event are happening already. In 2007, along the Apulian coast, from the Gargano Peninsula to the Gulf of Taranto, mucilage events occurred during January and April, impairing coastal fisheries in a dramatic way. This had never happened before. Jellyfish blooms are becoming more and more frequent, with impacts on tourism and on fisheries.

The formation of the Eastern Mediterranean Transient, at the end of the 1990s, stemmed from the stopping of deep water formation in the Northern Adriatic, the deep waters of the Eastern Mediterranean being formed in the Northern Aegean. What might happen if the formation of deep waters near the coast comes to a stop due to global warming?

Localized environmental protection, such as that of Marine Protected Areas, surely cannot stop such disasters. Some people claim that a protected area will show more resistance (the tendency to resist an impact while maintaining own features) and resilience (the tendency to go back to own features after an impact has ceased to occur) in respect to global change. This might be true, in a sense. A healthy body is more resistant to disease, but we cannot say that being healthy is enough to prevent any kind of threat to our health. One does not practise jogging and stops smoking to prevent being intoxicated by a firm that is spoiling air quality in the area where s/he lives, even though a non smoking person that does some sport might answer better to air pollution than a sedentary smoker!

The presence of MPAs in the colder parts of the Mediterranean, however, might help in keeping the situation under control, tracking the changes and eventually indicating if measures taken at the global level are proving effective in the most sensitive parts of the planet to global warming.

MPAs main objective is to protect the extraordinary features of a certain piece of environment. In a way, each one is an island (and many are on islands!). Their positive impact, thus, is to be expected as being very localized and idiosyncratic. These might be called proximate goals of MPAs. The ultimate goals of MPAs, however, should be essentially two: to enhance public concern about environmental integrity and to act as sensors of environmental integrity. The levels of action of MPAs should therefore range from the proximate and local activities, to the ultimate and basin-scale activities. This second group of actions requires networking, leading to a shared strategy aimed at environmental protection.

7. HOW TO ENHANCE PUBLIC CONCERN ABOUT ENVIRONMENTAL INTEGRITY?

Knowledge is the way. If people know what the sea is giving us, in terms of goods and services, then they understand that their well being depends on environmental well being. Public outreach, thus, is essential. It has to concentrate on the peculiarities of the site, but it should also develop a shared message that is equal throughout the basin, with the production of collectively conceived posters (to donate to all schools) and simple manuals, integrating school textbooks. The proximate message is peculiar to each MPA, but the ultimate message is to be agreed upon by the network, so that people, in all countries, will ask for the same policy. This should be achieved by using all communication tools, especially television. More conscious people will take more conscious decisions, caring also for environmental gain, and not only for economic profit.

8. HOW TO SENSOR ENVIRONMENTAL INTEGRITY?

Marine environments are not as easy to monitor as terrestrial environments. Satellites can be used to obtain information about surface temperatures, or phytoplankton blooms, but we cannot infer from these data the maximal depth of the summer thermo cline, or the presence of jellyfish blooms. Scientists, furthermore, often do collect data aimed at answering very specific questions, posed by the financing of very specific research projects. If something “strange” happens, like a bloom of gelatinous plankton, or a mucilage event, usually they are not ready to record it, and the scientific literature is not very interested in these “simple” observations. Scientists are often looking for regularities, so to discover rules, and tend to disregard irregularities that cannot be predicted in a research project. If irregularities occur during a project on regularities, then they are not relevant to the project and are simply discarded. Let us explain this with a simple example. In the study of fisheries, the attention is invariably focused on the targeted fish, and the only impact is usually fisheries. A bloom of the by-the-wind sailor (*Velella velella*) might have a heavy impact on fisheries, since these floating hydroids feed on fish eggs and larvae. But the impact will be felt by fisheries only after the occurrence of the bloom, when the larvae that should have become adults will not have developed, since they ended up in the coelenteron of the predator. The effects of predation, thus, might be perceived when the predator is not around anymore. The cause is very far in time from the effect.

Organized amateurs, such as the Cornwall wildlife trust, sometimes record episodic events that pass unnoticed by the scientific community. The scientific literature paid no attention to the presence of *Velella* along the Cornwall coast. On the contrary, the page http://www.glaucus.org.uk/Velella.htm reports on the presence of the by-the-wind sailor during an extensive period of time! Such information, if available over a basin scale, might provide precious insight about the state of the environment, supplementing in an effective way the observations of the scientific community.

9. THE OBSERVATORIES OF BIODIVERSITY

MPAs should map their biodiversity at the habitat level with great precision, on a GIS standard, and the area of each habitat should be measured at proper intervals, so to perceive possible change. All-species inventories should be made for all MPAs, involving the scientific community. Such inventories should be repeated at proper intervals, too, to monitor the state of biodiversity at the species level. These monitoring should satisfy the proximate needs of each MPA, but might also play a relevant role as an alert system for phase shift at the basin level. Such phase shifts, in the Mediterranean, might be:

- From fish to jellyfish
- From algal canopies to sea-urchin barrens
- From temperate to tropical biota
- From artisanal to industrial fisheries
- From fisheries to aquaculture
- From predictable to impredictable seasons

Most of these phase shifts have been detected from isolate observation, and data are not spread enough on a basin scale to show if the trends are real (for instance, this is very true of the fish-jellyfish transition). Such information is only available to people who live permanently on the shore and work there, just as the managers of MPAs. The evaluation of a series of macrodescriptors, easy to evaluate at the basin level, through a network, might provide vital information on the state of the environment. A common monitoring programme, operating across a network of MPAs, might regard such macrodescriptors as:

- gelatinous plankton blooms

- mass mortalities
- harmful algal blooms (planktonic and benthic)
- ammasses of seagrass leaves and mollusc shells
- sea-urchin barrens
- arrival of alien species
- disappearance of native species
- any natural event covered by the press

If put into a common database, these data might provide for an instant evaluation of the state of the whole Mediterranean through the network of biodiversity observatories operating in each MPA.

10. A FURTHER STEP

The aims of MPAs are also scientific research and public education. Whenever possible, MPAs should become equipped with simple laboratories right on the shore, with water tables, a classroom, and the basic equipment for field courses at the university level. In this way, they might attract courses in marine sciences that might contribute to monitoring programmes, involving undergraduate and graduate students, and their professors, becoming the subject and not the object of scientific research, proposing problems to scientists and to their students while providing facilities for their institutional activities. These laboratories should become an instrument for continuous capacity building of the personnel of the MPA through the research centres operating in the area, triggering a fruitful symbiosis between research and conservation institutions.

11. SUMMARY

Marine Protected Areas are becoming the main tool for the protection of marine environments in the Mediterranean. Even if they do not suffice to warrant proper protection, especially of functionally important areas with no emotional appeal, MPAs are the irreplaceable tool for increasing public awareness towards the problem of marine protection and, also, have the potential to favour a much-needed return to field studies, after a too laboratory-concentrated activity of the scientific community, even at marine research stations.

The cooperation among MPA managers, through the formation of an extensive network, and the collaboration with the scientific community to solve both specific and general problems regarding marine protection, are the key to taking proper advantage of this unique occasion to protect the sea. Marine Protected Areas are a reality in almost all Mediterranean countries; they provide an occasion that should not be wasted by mismanagement and lack of proper knowledge.

12. POVZETEK

Zavarovana morska območja postajajo glavno orodje za zaščito morskih okolij v Sredozemlju. Tudi če ne jamčijo ustrezne zaščite posebno funkcionalno pomembnih območij, so zavarovana območja nenadomestljiva za dvigovanje ozaveščenosti javnosti na področju zaščite morskih okolij, hkrati pa imajo tudi potencial, da podprejo že tako zelo potrebno vrnitev k terenskim študijam po vse preveč laboratorijsko osredotočenim dejavnostim znanstvene skupnosti, celo na morskih raziskovalnih postajah samih.

Sodelovanje med različnimi upravljavci zavarovanih morskih območij prek oblikovanja obsežnih omrežij in sodelovanje teh upravljavcev z znanstveno skupnostjo, da bi skupaj poskusili rešiti tako specifične kot splošne probleme glede zaščite morskega okolja, je ključ k temu, da ustrezno izkoristijo prednost te enkratne priložnosti za zaščito morje. Zavarovana morska območja so realnost v skoraj vseh sredozemskih državah, saj jim dajejo priložnost, ki je ne bi smeli zapravljati z zgrešenim upravljanjem morskega okolja in pomanjkljivim znanjem.

13. LITERATURE

The literature on this topic is overwhelmingly vast. I decided not to quote any paper in the text because they are too many and any sub-sample would have omitted relevant contributions. Only some recent references from the Lecce group are reported here, containing extensive bibliographic sections.

1. Bevilacqua, S., A. Terlizzi, S. Fraschetti, G.F. Russo, F. Boero (2006): Mitigating human disturbance: can protection influence trajectories of recovery in benthic assemblages? Journal of Animal Ecology 75:908-920.
2. Bianchi, C.N., F. Boero, S. Fraschetti, C. Morri (2004): Il popolamento sommerso. In: A. Minelli (ed.): Coste marine rocciose. Quaderni Habitat 7. Ministero dell'Ambiente e Tutela del Territorio. 105-133.
3. Boero, F. (2001): Adriatic ecological history: a link between jellyfish outbreaks, red tides, mass mortalities, overfishing, mucilages, and thaliacean plankton? In: Briand F. (ed.): Gelatinous Zooplankton outbreaks: theory and practice. CIESM Workshop Series 14: 55-57.
4. Boero, F. (2002): Ship-driven biological invasions in the Mediterranean Sea. In: Briand F. (ed.): Alien marine organisms introduced by ships in the Mediterranean and Black Seas. CIESM Workshop Monographs 20: 87-91.
5. Boero, F. (2003): State of knowledge of marine and coastal biodiversity in the Mediterranean Sea. Project for the Preparation of a Strategic Action Plan for the conservation of biological diversity in the Mediterranean region. (Sap BIO). United Nations Environmental Programme, Regional Activity Centre for Specially Protected Areas. Tunis. 29 pp.
6. Boero, F. (2006): Ecologia della Bellezza. Besa Editore. Nardò. 162 pp.
7. Boero, F. (2007): Macrodescriptors: looking at simplicity to understand complexity. Rapports Commission Internationale Mer Méditerranée 38:81.
8. Boero, F., G. Belmonte, S. Bussotti, G. Fanelli, S. Fraschetti, A. Giangrande, C. Gravili, P. Guidetti, A. Pati, S. Piraino, F. Rubino, O. Saracino, J. Schmich, A. Terlizzi, S. Geraci (2004): From biodiversity and ecosystem functioning to the roots of ecological complexity. Ecological Complexity 2:101-109.
9. Boero, F., E. Bonsdorff (2007): A conceptual framework for marine biodiversity and ecosystem functioning. Marine Ecology 28(1):134-145.

10. Boero, F., J. Bouillon, C. Gravili, M.P. Miglietta, T. Parsons, S. Piraino (2008): Gelatinous plankton: irregularities rule the world (sometimes). Marine Ecology Progress Series 356:299-310.
11. Boero, F., S. Bussotti, P. D'Aambrosio, S. Fraschetti, P. Guidetti, A. Terlizzi (2005): Biodiversità e Aree Marine Protette. Biologia Marina Mediterranea 12(1):1-22.
12. Bussotti, S., G. Belmonte, S. Fraschetti, A. Terlizzi, P. D'Ambrosio, P. Guidetti, F. Denitto, F. Boero (2005): Submarine caves in southern Apulia as priority habitats for conservation purposes. Biologia Marina Mediterranea 12(1):130-134.
13. Della Tommasa, L., G. Belmonte, A. Palanques, P. Puig, F. Boero (2000): Resting stages in a submarine canyon: a component of shallow-deep-sea coupling? Hydrobiologia 440:249-260.
14. Fraschetti, S., C. N. Bianchi, A. Terlizzi, G. Fanelli, C. Morri, F. Boero (2001): Spatial variability and human disturbance in shallow subtidal hard substrate assemblages: a regional approach. Marine Ecology Progress Series 212:1-12.
15. Fraschetti, S., C. Gambi, A. Giangrande, L. Musco, A. Terlizzi, R. Danovaro (2006): Structural and functional response of meiofauna rocky assemblages to sewage pollution. Marine Pollution Bulletin 52:540-548.
16. Fraschetti, S., A. Terlizzi, L. Benedetti-Cecchi (2005): Patterns of distribuition of marine assemblages from rocky shores: evidence of relevant scales of variation. Marine Ecology Progress Series 296:13-29.
17. Fraschetti, S., A. Terlizzi, S. Bussotti, G. Guarnieri, P. D'Ambrosio, F. Boero (2005): Conservation of Mediterranean seascapes: analyses of existing protection schemes. Marine Environmental Research 59:309-332.
18. Fraschetti, S., A. Terlizzi, F. Micheli, L. Benedetti Cecchi, F. Boero (2002): Marine protected areas in the Mediterranean Sea: objectives, effectiveness and monitoring. Publlicazioni della Stazione Zoologica di Napoli I: Marine Ecology 23(1):190-200.
19. Fraschetti, S., Terlizzi A., F. Boero (2008) How many habitats are there in the sea (and where)? Journal of Experimental Marine Biology and Ecology 366:109-115.
20. Guidetti, P., S. Fraschetti, A. Terlizzi, F. Boero (2003): Distribution patterns of sea urchins and barrens in shallow Mediterranean rocky reefs impacted by the illegal fishery of the rock-boring mollusc *Lithophaga lithophaga*. Marine Biology 143:1135-1142.
21. Guidetti, P., F. Boero (2004): Desertification of mediterranean rocky reefs caused by date mussel, *Lithophaga lithophaga* (Mollusca: Bivalvia), fishery: effects on adult and juvenile abundance of a temperate fish. Marine Pollution Bullett 48:978-982.
22. Guidetti, P., S. Bussotti, F. Boero (2005): Evaluating the effects of protection on fish predators and sea urchins in shallow artificial rocky habitats: a case study in the northern Adriatic Sea. Marine Environmental Research 59:333-348.
23. Guidetti, P., G. Fanelli, S. Fraschetti, A. Terlizzi & F. Boero (2002): Coastal fish indicate human-induced changes in the Mediterranean littoral. Marine Environmental Research 53:77-94.
24. Guidetti, P., S. Fraschetti, A. Terlizzi, F. Boero (2004): Effects of Desertification caused by *Lithophaga lithophaga* (Mollusca) fishery on littoral fish assemblages along rocky coasts of southeastern Italy. Conservation Biology 18(5):1417-1423.
25. Guidetti, P., M. Milazzo, S. Bussotti, A. Molinari, M. Murenu, A. Pais, N. Spanò, R. Balzano, T. Agardy, F. Boero, G. Carrada, R. Cattaneo-Vietti, A. Cau, R. Chemello, S. Greco, A. Manganaro, G. Notarbartolo di Sciara, G. Russo, L. Tunesi (2008): Italian Marine Reserve effectiveness: does enforcement matter? Biological Conservation 141:699-709.
26. Piraino, S., G. Fanelli, F. Boero. (2002): Variability of species roles in marine communities: change of paradigms for conservation priorities. Marine Biology 140:1067-1074.
27. Terlizzi, A., S. Fraschetti, P. Guidetti, F. Boero (2002): The effects of sewage discharge on shallow hard substrate sessile assemblages. Marine Pollution Bulletin 44:544-550.

28. Terlizzi, A., M.J. Anderson, S. Fraschetti, L. Benedetti-Cecchi. (2007): Scales of spatial variation in Mediterranean subtidal sessile assemblages at different depths. Marine Ecology Progress Series 332:25-39.
29. Terlizzi, A., L. Benedetti-Cecchi, S. Bevilacqua, S. Fraschetti, P. Guidetti, M.J. Anderson. (2005): Multivariate and univariate asymmetrical analyses in environmental impact assessment: a case study of Mediterranean subtidal sessile assemblages. Marine Ecology Progress Series 289:27-42.
30. Terlizzi, A., Scuderi D., Fraschetti S., M.J. Anderson (2005) Quantifying effects of pollution on biodiversity: a case study of highly diverse molluscan assemblages in the Mediterranean. Marine Biology 148:293-305

Ferdinando BOERO
DiSTeBA (Dipartimento di Scienze e
Tecnologie Biologiche e Ambientali)
Universita' del Salento
73100 Lecce, Italy
boero@unisalento.it

COASTAL AND MARINE KEY HABITATS IN THE MEDITERRANEAN SEA

KLJUČNI OBREŽNI IN MORSKI HABITATI V SREDOZEMLJU

Gérard PERGENT

Key words: Mediterranean Sea, Northern Adriatic, biodiversity, habitats, seagrass meadow, coralligenous assemblages
Ključne besede: Sredozemsko morje, severni Jadran, biodiverziteta, habitati, travniki morske trave, koraligenske združbe

ABSTRACT

The Mediterranean Sea is known as a biodiversity hot spot in terms of species, as well as at the ecosystem level with varied and rich benthic habitats. If this high biological diversity can be mainly explained by environmental conditions (interface between tropical an temperate regions, hydrology, climate, habitat heterogeneity), the historical factors also played a major role (remnant of the Tethys Ocean, Messinian crisis, Atlantic Ocean connection, opening of the Suez Canal).
The diversity of Mediterranean benthic habitats is the basis of biological diversity. Among these habitats, seagrass meadows and coralligenous assemblages appear as key habitats, and have been taken into account in two action plans of the Regional Activity Centre for Specially Protected Area and Biodiversity (UNEP, MAP, RAC/SPA). If the extension of seagrass meadows in the Mediterranean basin has been estimated at 30,000 to 40,000 km^2, with considerable amounts of data concerning the location of main meadows, there are important gaps in knowledge concerning the composition and distribution of coralligenous assemblages and maërl beds. Data concerning coralligenous assemblages are sparse and most of the information is based on data obtained in the northwestern Mediterranean, with some data additionally available in southern Italy and the Alboran Sea.
The northern Adriatic constitutes a particular biogeographical sector due to its northern location, superficial depth, and important nutrient discharges from rivers. Extensive seagrass meadows, composed of four of the five species present in the Mediterranean basin, have been observed in this region; the lack of rocky substrate and the high sedimentation, however, seem to be unable to support extensive coralligenous assemblages.

IZVLEČEK

Sredozemsko morje je znano kot vroča točka biotske raznovrstnosti, tako zaradi vrst, ki živijo v njem, kot zaradi njegovih ekosistemov z zelo različnimi in bogatimi bentoškimi habitati. Če lahko to visoko biodiverziteto pojasnimo predvsem z okoljskimi razmerami (hidrologijo, klimo, raznovrstnostjo habitatov) v tej mešanici med tropskim in zmernim območjem, pa so eno glavnih vlog pri tem odigrali tudi zgodovinski dejavniki (ostanek oceana Tetida, mesinska kriza, povezava z Atlantskim oceanom, odprtje Sueškega kanala).
Raznolikost bentoških habitatov je temelj biodiverzitete Sredozemskega morja. Med temi habitati se travniki morske trave in koraligenske združbe zdijo kot ključni habitati, kar je tudi razlog, da so bili upoštevani v dveh akcijskih načrtih Regionalnega centra za posebna območja varstva in biodiverziteto

(UNEP, MAP, RAC/SPA). Medtem ko je bilo ocenjeno, da travniki morske trave v Sredozemskem bazenu pokrivajo med 30.000 in 40.000 km^2, pri čemer velika količina podatkov zadeva lokacije glavnih travnikov, pa obstajajo kar velike vrzeli v znanju o sestavi in razširjenosti koraligenskih združb in zaplat morskega dna, prekritih s kalcificiranimi algami (maerl). Podatki o koraligenskih združbah so redki, sicer pa največ informacij izhaja iz podatkov, pridobljenih v severozahodnem Sredozemlju, nekaj dodatnih podatkov pa tudi iz južne Italije in Alboranskega morja.
Severni Jadran oblikuje tako posebno biogeografsko območje zaradi svoje severne lege, majhne globine in pomembnih količin hranil, ki v morje pritekajo z rekami. V tem območju so bili locirani obsežni travniki morske trave, ki jih zastopajo kar štiri vrste, ki sicer uspevajo v Sredozemskem bazenu. Vendar vse kaže, da zaradi pomanjkanja skalnih matičnih podlag in visoke sedimentacije obstoj večjih koraligenskih združb ni mogoč.

1. BACKGROUND

As a semi-closed sea, located at the conjunction between the Black Sea, the Red Sea and the Atlantic Ocean, the Mediterranean is characterized by a limited surface and volume (0.8% and 0.3% of the oceans respectively). Located at the interface between a temperate and sub-tropical climate, the Mediterranean appears today as an extremely complex environment whose history has largely created its biological richness.

A remnant of the once extensive Tethys Ocean, the Mediterranean Sea was connected to the Indopacific Ocean until 10 Ma; the closure of the Atlantic connection (6 Ma) induced an important desiccation (Messinian crisis) until the re-opening of the Strait of Gibraltar (5 Ma); thereafter, the alternation of ice ages with warm interglacials and at last the opening of the Bosporus strait (7.500 B.P.) played a major role in this region (see synthesis in Bianchi et Morri 2000). The opening of the Suez Canal in 1869 restored the connection between the Mediterranean and the Indopacific Ocean via the Red Sea.

All these events were of great influence on the repartition and composition of Mediterranean species and habitats. Species and habitats are of three main origins: (i) endemic elements (paleoendemic and neoendemic species), (ii) Atlantic element (boreal, temperate and subtropical), (iii) Indo-Pacific element (panoceanic relic species and Red Sea migrants). These elements are distributed more or less abundantly in different parts of the Mediterranean and ten biogeographical sectors are usually distinguished (Figure 1, Bianchi et Morri 2000), although a new approach proposes fewer sectors (UNEP-MAP-RAC/SPA 2008).

Another factor to be taken into account is the diversity of available habitats; the Mediterranean Sea exhibits a large continental shelf as well as important depths (up to 5,124 m), with complex geological structures (two main basin separated by a shallow strait, several underwater dorsals, numerous islands, coastal lagoons, varied substrate and slopes). Temperature, light, water movement, nutrient availability and salinity act as forcing factors in species repartition. Finally, interaction between indigenous but also introduced species must be considered, as well as increasing levels of human activities (coastal management, discharges, pollution, exploitation of living resources, climate change...).

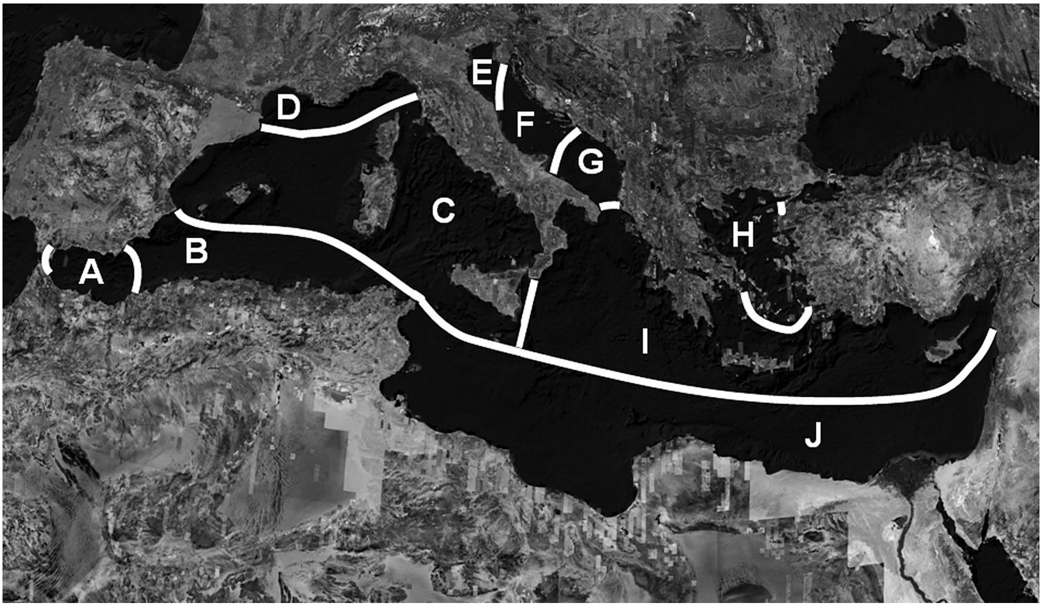


Figure 1: Biogeographical sectors of the Mediterranean Sea (according to Bianchi et Morri 2000). (A) Alboran Sea; (B) Algeria and southern Spain; (C) Balearic Sea to Tyrrhenian Sea; (D) Gulf of Lyon and Ligurian Sea; (E) North Adriatic; (F) Central Adriatic; (G) South Adriatic; (H) North Aegean; (I) Ionian Sea and South Aegean; (J) Gulf of Gabes to the Levant Sea.

Slika 1: Biogeografska območja Sredozemskega morja (po Bianchi in Morri 2000). (A) Alboransko morje; (B) Alžirija in južna Španija; (C) Balearsko območje in Tirensko morje; (D) Lyonski zaliv in Ligursko morje; (E) severni Jadran; (F) srednji Jadran; (G) južni Jadran; (H) severno Egejsko morje; (I) Jonsko in južno Egejsko morje; (J) Gabeški zaliv in Levantinsko območje.

2. MEDITERRANEAN HABITATS

The great number of habitats constitutes the basis of biological richness and the baseline of the benthic bionomics concept in the Mediterranean Sea (Peres et Picard 1964, Bellan-Santini et al. 1994, Relini 2000). These habitats are regularly used to evaluate sites of interest for conservation within the European framework (NATURA 2000), as well as for the Barcelona convention (UNEP-MAP-RAC/SPA 2002).

The Protocol concerning specially protected areas and biodiversity in the Mediterranean, adopted by the Contracting Parties of the Barcelona Convention in 1995, contains indications to prepare inventories at the national and regional levels (UNEP-MAP-RAC/SPA 1995). The Regional Activity Centre for Specially Protected Areas (RAC/SPA), in collaboration with Mediterranean experts, elaborated a reference list of species and habitat types, to select the sites to be included in national inventories, and a Standard Data Form (SDF) (UNEP-MAP-RAC/SPA 2002). From the technical point of view, the SDF is an adaptation of tools developed in the context of the European Union's NATURA 2000 and EMERAUDE networks of sites, to the specific Mediterranean features. With the objective of helping countries to identify and assess these marine habitats, the RAC/SPA initiated the production of a handbook to interpret marine habitats (Bellan-Santini et al. 2002). Finally, 18 biocenosis and 55 facies (associations or ecomorphoses) were included on the reference list (Table 1).

Table 1: Reference list of biocenosis to select sites to be included in the national inventories
Tabela 1: Referenčni seznam biocenoz za izbiro lokalitet, primernih za vključitev v nacionalne inventarje

SUPRALITTORAL	Biocenosis of supralittoral sands
MEDIOLITTORAL	Biocenosis of muddy sands and muds
	Biocenosis of mediolittoral coarse detritic bottoms
	Biocenosis of the upper mediolittoral rock
	Biocenosis of the lower mediolittoral rock
INFRALITTORAL	Euryhaline and eurythermal biocenosis
	Biocenosis of well sorted fine sands
	Biocenosis of superficial muddy sands in sheltered waters
	Biocenosis of coarse sands and fine gravels mixed by the waves
	Biocenosis of coarse sands and fine gravels under the influence of bottom currents
	Posidonia oceanica meadows
	Biocenosis of infralittoral algae
CIRCALITTORAL	Biocenosis of muddy detritic bottom
	Coralligenous biocenosis
	Semi-dark caves
BATHYAL	Biocenosis of bathyal muds
	Biocenosis of deep sea corals
	Caves and ducts in total darkness

Moreover, among the eight action plans adopted by the Contracting Parties of the Barcelona Convention, two are devoted to key habitats: the “Action plan for the conservation of marine vegetation in the Mediterranean sea” and the “Action plan for the conservation of the coralligenous and other calcareous bio-concretions in the Mediterranean sea” (UNEP-MAP-RAC/SPA 2005, 2008).

The first action plan focuses on *Posidonia oceanica*, one of the five seagrasses present in the Mediterranean Sea. The meadows composed of this species are considered the basis of the Mediterranean coastal waters’ richness due to the surface area they occupy (20-30% of the sea-floor between 0 and 50m depth) and owing to the essential part they play at the biological level in maintaining the coastal equilibrium and their concomitant economic activities (Boudouresque et al. 2006a). The role of *Posidonia oceanica* meadows in marine coastal environments is often correctly compared to that of a forest (Boudouresque et al. 2006b). Considerable data concerning the location of the main Posidonia meadows in the 18 countries is available, and an important number of natural monuments (barrier-reef, atolls) have been identified (Boudouresque et al. 1990). The actual challenge is (i) to ensure the conservation of this species (management, legal protection), (ii) to avoid loss and degradation of these meadows, and (iii) to ensure the conservation of marine vegetal assemblages that could be considered as natural monuments.

In the second action plan, coralligenous concretions are considered a typical Mediterranean underwater seascape comprising coralline algal frameworks that grow in dim light conditions and in relatively calm waters (Ballesteros 2006). Mediterranean maërl beds should be considered as sedimentary bottoms covered by a carpet of free-living calcareous algae (Corallinaceae or Peyssonneliaceae), which also develop in dim light conditions. Although there is an overall knowledge on the composition and distribution of coralligenous assemblages and maërl beds, there are also certain gaps in the existing knowledge. Concerning distribution, little data is available at small scale, data which would be important for an appropriate management of these structures. Regarding the composition of coralligenous and maërl assemblages, most of the information is based on data obtained in the northwestern Mediterranean, with some additional data collected in southern Italy and in the Alboran Sea, while other regions are poorly known. In order to improve this situation, the following actions are proposed: (i) to compile all existing information at all levels and scales on the distribution of coralligenous assemblages and maërl beds, and (ii) to conduct punctual field missions in potential places hosting extensive and mostly unknown coralligenous assemblages and maërl beds.

3. NORTHERN ADRIATIC HABITATS

The Adriatic Sea constitutes a particular biogeographical sector. It presents several specific characteristics: geographical situation (northernmost part of the Mediterranean Sea), coastal morphology (rocky in its eastern part with numerous islands, sandy with lagoons and estuaries in its western part) and bathymetry (low depth especially in the northern part). The Northern Adriatic also presents a relatively high tidal range (up to 1m), high temperature and salinity variations, wind-driven water circulation, important stratification of its water column, important nutrient discharges by rivers and high productivity (Stravisi 1983, Stachowitsch 1991). The human impact appears important in this region, given the intensive urbanization of the coastline.

These specific abiotic conditions, associated with high biological production, allow differentiation of a great number of key habitats (seagrass meadows, Cystoseira assemblage, coralligenous biocenosis), specific associations (*Fucus virsoides*), and a high biodiversity (nearly 2,000 animal species) (Lipej et al. 2006).

Seagrass meadows, located in lagoons (e.g. Venice lagoon) as well as in open sea, present a particular extension, where four of the five species present in the Mediterranean basin are identified. The presence of a relic of a Posidonia meadow (0.5 – 4.0 m depth) along the Slovenian coast indicates the presence of a much larger meadow in the past (identification of dead mattes at more than 10 m depth in the Gulf of Trieste). This northern Posidonia meadow, discovered recently, covers a surface of only 0.63 ha and appears to be threatened; its conservation represents a challenge for the future (Vukovič et Turk 1995, Makovec et Turk 2006).

Conversely, coralligenous biocoenosis, biogenous formations based on calcified algae (Peyssonelliaceae and Corallinaceae), appear less present due to the limited rocky substrate and the high sedimentation rate, at least in the northwestern part. As a rule, it is a precoralligenous stage (Bellan-Santini et al., 2002) that is reported. These precoralligenous formations occur under the biocenosis of infralittoral algae (8 to 10 m depth), in areas where more or less large boulders prevail (Gamulin-Brida 1967). The facies with *Cladocora caespitosa*, a typical Mediterranean anthozoan, has also been observed in these areas.

4. LITERATURE

1. Ballesteros, E. (2006): Mediterranean coralligenous assemblages: a synthesis of present knowledge. Oceanogr. Mar. Biol. Ann. Rev. 44: 123-195
2. Bellan-Santini, D., G. Bellan, G. Bitar, J.G. Harmelin, G. Pergent (2002): Handbook for interpreting types of marine habitat for the selection of sites to be included in the national inventories of natural sites of conservation interest. RAC/SPA edit., UNEP publ. 217 pp.
3. Bellan-Santini, D., J.C. Lacaze, C. Poizat (1994): Les biocénoses marines et littorales de Méditerranée, Synthèse, Menaces et perspectives. Museum national Histoire Naturelle édit, Secrétariat Faune Flore Publ. 246 pp.
4. Bianchi, N.C., C. Morri (2000): Marine Biodiversity of the Mediterranean Sea: Situation, Problems and Prospects for Future Research. Mar. Pol. Bul. 40(5): 367-376
5. Boudouresque, C.F., E. Ballesteros, N. Ben Maiz, F. Boisset, E. Bouladier, F. Cinelli, S. Cirik, M. Cormaci, A. Jeudy De Grissac, J. Laborel, E. Lanfranco, B. Lundberg, H. Mayhoub, A. Meinesz, P. Panayotidis, R. Semroud, J.M. Sinnassamy, A. Span, G. Vuignier (1990): Livre rouge "Gérard Vuignier" des végétaux, peuplement et paysages marins menacés de Méditerranée. UNEP/IUCN/ GIS Posidonie. MAP Technical Report Series N°43. UNEP, Athens. 250 pp.
6. Boudouresque, C.F., G. Bernard, P. Bonhomme, E. Charbonnel, G. Diviacco, A. Meinesz, G. Pergent, C. Pergent-Martini, S. Ruitton, L. Tunesi (2006a): Préservation et conservation des herbiers à *Posidonia oceanica*. RAMOGE pub. 202 pp.
7. Boudouresque, C.F., N. Mayot, G. Pergent (2006b): The outstanding traits of the functioning of the *Posidonia oceanica* seagrass ecosystem. In: Mediterranean Seagrass Workshop, May 29 – June 3. Marsascala. 16 pp.
8. Gamulin-Brida, H. (1967): The benthic fauna of the Adriatic Sea. Oceanogr. Mar. Biol. Ann. Rev. 5: 535-568
9. Lipej, L., R. Turk, T. Makovec (2006): Endangered species and habitat types in the Slovenian Sea. Zavod RS za varstvo narave. Ljubljana. 264 pp.
10. Makovec, T., R. Turk (2006): Mapping of the *Posidonia oceanica* meadow on the Slovenian Coast. In: Proceedings of the second Mediterranean symposium on marine vegetation (Athens, 12-13 December 2003). RAC-SPA edit. Tunis. P. 236-237
11. Peres, J.M., J. Picard (1964): Nouveau manuel de bionomie benthique de la Méditerranée. Rec. Trav. Stn. mar. Endoume, 31 (47): 137 pp.
12. Relini, G. (2000): Nuovi contributi per la conservazione della biodiversità marina in Mediterraneo. Biol. Mar. Medit. 7(3): 173-211
13. Strachowitsch, M. (1991): Anoxia in the Northern Adriatic Sea: rapid death, slow recovery. In: Tyson R.V., Pearson T.H. (Eds.): Modern and ancient continental shelf anoxia. Geol. Soc. Spe. Publ. 58: 119-129
14. Stravisi, F. (1983): Some characteristics of the circulation in the Gulf of Trieste. Thalas. Iugos. 19: 355-363
15. UNEP-MAP-RAC/SPA (1995): Protocol concerning specially protected areas and biological biodiversity in the Mediterranean. UNEP-MAP-RAC/SPA publ., Tunis. 46 p.

16. UNEP-MAP-RAC/SPA (2002): Standard data entry form (SDF) for national inventories of natural sites of conservation interest. RAC/SPA publ., Tunis. 58 pp.
17. UNEP-MAP-RAC/SPA (2005): Action plan for the conservation of marine vegetation in the Mediterranean Sea. RAC/SPA publ., Tunis. 47 pp.
18. UNEP-MAP-RAC/SPA (2008): Action plan for the conservation of the coralligenous and other calcareous bio-concretions in the Mediterranean Sea. RAC/SPA publ., Tunis. 21 pp.
19. Vukovič, A., R. Turk, (1995): The distribution of the seagrass *Posidonia oceanica* in the Gulf of Koper. Preliminary report. Rapp. Comm. int. Mer Medit 34: 49.

Gérard PERGENT
University of Corsica,
UMR CNRS 6134, Faculty of Sciences,
BP 52, 20250 Corte (France)
pergent@univ-corse.fr

MARINE PROTECTED AREAS IN THE NORTHERN ADRIATIC

ZAŠČITENA MORSKA OBMOČJA V SEVERNEM JADRANU

Robert TURK, Roberto ODORICO

Key words: marine protected areas, Northern Adriatic, human activities, impacts, joint basin management
Ključne besede: zaščitena morska območja, severni Jadran, človekove dejavnosti, vplivi, skupno upravljanje

ABSTRACT

Conservation of marine biodiversity requires some coastal and open ocean water areas to be retained in their natural state or as near to natural as possible. The same is true of sustainable use of coastal and marine resources. Safeguarding critical habitats for fish production, preserving genetic resources, protecting scenic and coastal areas, and enjoying natural heritage all may require the protective management of natural areas.

The creation of marine and coastal protected areas can be an effective tool for providing protection of species and habitats, enabling restoration and sustainable use of marine and coastal resources. In order to meet this target, the protected areas have to be representative, viable in terms of number, size, management and resources.

The Northern Adriatic is relatively shallow, considering that its depth does not exceed 50 m. It is earmarked by the stratification of its water column, great fluvial input, and high productivity. It is also a very sensitive ecosystem, for apart from the stated characteristics it is known for its intensive fisheries, tourism and maritime transport.

The paper presents the current situation in the Northern Adriatic concerning marine protected areas and discusses their role and possibility to have a major impact on the conservation of marine biodiversity and sustainable use of resources. Indirectly, through increasing public awareness and directly through sustaining and improving ecosystem services.

IZVLEČEK

Glede na določbe zaščite morske biotske raznovrstnosti moramo nekatere obalne vode in odprta morja ohraniti v njihovem naravnem ali vsaj v kolikor mogoče naravnem stanju. Enako velja za trajnostno rabo obalnih in morskih virov. Zaščita kritičnih habitatov za gojenje rib, ohranjanje genskih virov, zaščita obalnih območij in uživanje v naravni dediščini, vse to lahko terja zaščitno upravljanje naravnih območij.

Ustanavljanje zaščitenih morskih in obalnih območij je lahko učinkovito orodje za zagotavljanje varstva vrst in habitatov, ki omogoča obnovo in trajnostno rabo morskih in obalnih virov. Toda če hočemo doseči ta cilj, morajo biti zaščitena območja reprezentativna, sposobna za življenje glede na njihovo število, velikost, upravljanje in vire.

Severno Jadransko morje je razmeroma plitko, saj njegova globina ne presega 50 m. Zaznamujejo ga slojevitost vodnega stolpca, veliki rečni vnos in visoka produktivnost. Hkrati je tudi nadvse občutljiv ekosistem, saj je ob naštetih značilnostih poznan tudi po intenzivnem ribištvu, turizmu in pomorskem prometu.

Članek opisuje trenutno stanje v severnem Jadranu, kar zadeva zaščitena morska območja, in razpravlja o njihovi vlogi in možnosti, da v veliki meri vplivajo na ohranjanje morske biotske raznovrstnosti in trajnostno rabo virov – posredno prek ozaveščanja javnosti in neposredno prek ohranjanja in izboljševanja ekosistemskih storitev.

1. INTRODUCTION

Covering 70% of the planet's surface area, marine and coastal environments contain very diverse habitats that are the base of the abundance of marine life. Marine fish and invertebrates are among the last sources of wild food on the planet, moreover, the world's oceans host 32 of the 34 known phyla on Earth and contain somewhere between 500,000 and 10 million marine species. Species diversity is known to be as high as 1,000 per square metre in the Indo-Pacific Ocean, and new oceanic species are continuously being discovered, particularly in the deep sea. It is therefore not surprising that the genetic resources in the oceans and coasts are of actual and potential interest for commercial use. Life in our seas produces a third of the oxygen that we breathe, offers a valuable source of protein and moderates global climatic change. Marine and coastal habitats include mangrove forests, coral reefs, sea grass beds, estuaries in coastal areas, hydrothermal vents, seamounts and soft sediments on the ocean floor a few kilometres below the surface.

According to the Millennium Ecosystem Assessment, which dealt with the consequences of ecosystem change for human well-being, the world's oceans and coasts are highly threatened and subject to rapid environmental change. Major threats include land-based pollution and euthrophication, overfishing, destructive fishing, and illegal, unreported and unregulated (IUU) fishing, alterations of physical habitats, invasions of exotic species and global climate change. Overfishing is widely acknowledged as the greatest single threat to marine wildlife and habitats. The Food and Agriculture Organization of the United Nations reports that nearly 70% of the world's fish stocks are now fully fished, overfished or depleted. Moreover, overfishing and depletion of marine resources is moving seaward, into areas beyond national jurisdiction, into open ocean waters and to the deep sea bottom.

2. THE NORTHERN ADRIATIC

The Adriatic Sea, part of the Mediterranean Sea, linked with it through the Strait of Otranto, is a semi-enclosed sea forming a distinct sub-region within the Mediterranean Sea Region. With just a few exceptions, the Adriatic's western coast is more or less sandy, while its eastern coast is composed predominantly of limestone, except for its northernmost part, which is made up of flysch. The Adriatic Sea is divided into three larger geographical units, i.e. Northern, Central and Southern Adriatic.

The Northern Adriatic is limited by a fictitious diagonal between the towns of Karlobag and Ancona. As in the rest of the Adriatic, there is a clear difference between the geomorphology of its western part – flat and uniform coast – and its eastern part, which is rocky, steep and highly diversified with numerous islands, promontories and bays. The Northern Adriatic is a relatively shallow ecosystem, considering that its depth does not exceed 50 m. It is earmarked by the stratification of its water column, great fluvial input, and high productivity. In fact, from spring to fall, the estuarine areas and lagoons located in the Northern Adriatic provide nursery grounds for many economically important species, including *Solea solea*, *Platichthys flesus*, *Mugil* spp., *Dicentrarchus labrax*, *Sparus aurata* and *Sepia officinalis*. The shallow waters are also important spawning grounds for sardines and anchovies but also for numerous demersal species like red and stripped mullet, musky octopus, common squid and cuttlefish, and many others.

At the same time it has to be stressed that the Northern Adriatic is a very sensitive ecosystem, for apart from the stated natural characteristics it is known for the intensive urbanisation of its coasts, port facilities, tourism and fisheries. The absence of joint planning and management of different human activities makes harder to monitor their impacts and consequences and prevents an efficient implementation of conservation measures.

2.1 THREATS TO MARINE AND COASTAL BIODIVERSITY IN THE NORTHERN ADRIATIC

The threats to marine and coastal biodiversity in the Northern Adriatic are in line with those encountered in other parts of the Mediterranean and elsewhere in the world. Habitat degradation is one of the greatest problems. It is caused mainly by the increasing urbanisation, industrialisation, building of traffic and tourist infrastructure, and other forms of land-use. Fishery and mariculture, too, can have a marked impact on these habitats.

2.1.1 Urbanization

The Slovenian part of Piran Bay and the northernmost part of the Gulf of Trieste (Muggia, Trieste) are a characteristic example of a totally built up natural coastline. The approximate percentage of totally or partially urbanized Slovenian supra- and mediolittoral is 80%. Even the infralittoral has been only partially preserved from this direct degradation. Still strong, however, is the indirect impact on infralittoral habitat types and species, caused by poorly treated sewage run-offs, increasing maritime traffic and other human activities on sea and on land. Environmental pollution is one of the direct consequences of urbanization. The need of a modern purification plant system considering the heavy role of large urban areas (i.e. Monfalcone, Trieste, Koper, Piran) is crucial not only for the nature degradation herself but also for human activities (fishery, aquaculture, tourism). While there are same data on the impact of environmental pollution on certain marine species (*Mytilus galloprovincialis*, *Pagellus erythrinus*, *Conger conger*, *Caretta caretta*), only few concrete data on the impacts of environmental pollution on marine biodiversity as such are available. Problems with pollution in the Northern Adriatic are due also to the turnover time for water exchange that is not sufficiently fast to disperse pollution.

2.1.2 Fisheries and mariculture

Among the direct impacts on marine and coastal biodiversity, mariculture and some fishing practices are to be mentioned. The studies carried out in Piran Bay have shown that the breeding of European seabass and gilthead bream in cages led to the characteristic depletion in the abundance and structure of the meiofauna population and that there was almost no macrofauna under the fish cages. The negative impacts on the environment were felt up to 300 m from the cages. Bottom trawling, dredging with the so-called »ramponi« as well as date mussels collection are also causing major impact on habitats and species. Apart from direct damages, i.e. collection of date mussels, the consequences are also manifested in the habitat loss for a variety of algal and animal species. Recent studies have revealed that this type of poaching causes reduction in fish fauna. By-catch, which is usually connected with marine turtles and dolphins, has detrimental effects also on numerous other marine species, sharks among them, as well as on no commercial value species that fishermen throw overboard.

2.1.3. Oxygen depletion

One of the characteristic features of the Northern Adriatic is that it is richer in nutrients than other parts of the Adriatic Sea. The nutrients are being brought into the sea primarily by rivers and municipal sewage run-off. The superabundance of these substances, together with the distinct stratification of seawater during the warmer part of the year, is the base of oxygen depletion phenomena, resulting in almost yearly hypoxic or even anoxic conditions on the sea bottom that have long-term impacts on habitats, communities and species.

2.1.4. Climatic changes

The rising of sea temperature is one of the consequences of climatic changes and at the same time the major factor influencing the spreading of species towards the north. These are usually thermophilous species, characteristic of the southern parts of the Mediterranean, which owing to the gradual warming of this sea (and the Adriatic) spread their range northwards. The spreading of fish species is getting most of the attention.

In the last thirty years, more than 30 new fish species have been documented in the Adriatic Sea, the majority of which can be specified as migrants towards the north. Two of the most characteristic species in this respect are the triggerfish (*Balistes carolinensis*), which is today a well establish species in the Slovenian waters, and the ornate wrasse (*Thalassoma pavo*), recently registered on the edge of the Kvarner Archipelago.

2.1.5. Bioinvasion

Bioinvasion is defined as the arrival of non-indigenous organisms, introduced intentionally or unintentionally, into a new environment, outside the boundaries of their natural range. More than fifty non-indigenous species have been recorded in the Adriatic. Many experts believe that shipping is the most important vector of non-indigenous species introduction. This can happen mainly through ballast waters and epigrowth. With the development of mariculture in the last century, some non-indigenous species were introduced in the Adriatic, too. Today they are found outside breeding areas replacing their indigenous counterparts.

Such species are, for example, the manila clam (*Tapes philippinarum)* and the Japanese oyster *(Crassostrea gigas).*

2.1.6 Other factors

Sea traffic, which is to a certain extent the result of intensive urbanisation of coastal areas, exerts influence on maritime environment in several ways. The most important among them is the density of cargo vessels (1,900 yearly only in the Port of Koper), together with the ever-present danger of pollution with oil and other slicks stemming from the intense sea traffic. Comparing the accident rate in the Adriatic to other areas around the world shows that the Adriatic belongs to the highest accident frequency category.

In the same line of importance are tourist ports (approximately 50,000 moorings) and consequently pleasure boat traffic. Beside oil&fuel spills, underwater noise, solid waste and other direct and indirect negative impacts on the marine environment, direct collisions between vessels and some endangered species, such as bottlenose dolphin (*Tursiops truncatus*) and loggerhead turtle (*Caretta caretta*), are to be mentioned.

The diversity of impacts on the marine environment implies an extended set of measures and activities to be carried out on national as well as international levels. Applying the ecosystem approach and the precautionary principle within decisions at national level is of key importance, and joint programs and strategies between the three riverine states for different activities would be mostly welcome.

Marine protected areas, probably the best known although not often enough used measure, could significantly contribute to the sustainable use of marine environments and conservation of their biodiversity. At the same time they represent one of the measures that could be dealt with at both - national and international levels.

3. MARINE PROTECTED AREAS

The Convention on Biological Diversity defines a protected area as *"a geographically defined area, which is designated or regulated and managed to achieve specific conservation objectives."* The definition implies that conservation is a major goal for protected areas and that this goal is to be achieved through specific regulation and management. The definition of *conservation*, adopted within the framework of the Convention, and which states that "*in-situ Conservation is the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings"*, makes a clear link to biodiversity. Both concepts are somehow melted into the IUCN, the World Conservation Union definition of protected areas, that is *"areas of land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means."*

A short review of the history of marine protected areas shows that the first was most probably established as early as in 1935. This was Fort Jefferson National Monument on

Dry Tortugas Island, 65 miles off Key West (Florida, USA). At the end of the 1950s and 60s, the first nature marine reserves were established in the Bahamas and in Florida (Key Largo Reserve). In a short period, many others, particularly in North and Central Americas, Canada, Philippines, Malaysia and Antilles, followed, including the Australian Great Barrier Reef Marine Park, established in the year 1975 and covering no less than 207,000 km^2. The oldest marine protected area in the Mediterranean is the French Port-Cros National Park, situated on the island carrying the same name .The Mediterranean can boast in fact relatively few protected marine areas, situated mainly in the NW part of the basin. With few exceptions they are spatially more or less limited, covering only from few ten to few thousand hectares. The smallest among them are Red Coral Reserve in Monaco and Fungus Rock Nature Reserve on Malta, both covering approximately 1 ha, while the largest are National Marine Park Alonissos in Northern Sporades (Greece) with 2,265 km^2, and Pelagos between France, the Principality of Monaco and Italy, covering 87,000 km^2. The latter is in the first place intended for the protection of cetaceans and the conservation of their natural environment and is the first case of a protected area in the Mediterranean that encloses open sea as well.

We can see already from the above that marine protected areas differ greatly among each other in view of their size, natural characteristics, use, manner of their management etc., but pursue the very same goal, i.e. conservation of natural resources. Some of them are fishery reserves, while others have been established exclusively for nature conservation purposes. The “reserve” effect, which is in most cases perceived as protection of fish resources but has beneficial impact on other species and habitat types too, is a factor of sustainable development. In protected areas, fish live longer, are fatter and are more numerous. And indeed, larger specimens are better spawners: they produce more eggs and spawn more frequently than smaller ones. Their eggs and larvae drift to surrounding areas and they themselves can migrate outside the reserve. Scientific monitoring carried out over the last 20 years in the Natural Reserve of the Bouches de Bonifacio (Corsica, France), indicate a biomass index that is 6 times higher inside the protected and managed areas, compared to the freely exploited zones or to those that are protected but without surveillance.

Marine protected areas are a “hot spot” also within the Convention for the Protection of the Mediterranean Sea against Pollution (Barcelona Convention). A Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean was adopted by the Contracting Parties already in 1995. According to the general obligations, each Party shall take the necessary measures to

a) protect, preserve and manage in a sustainable and environmentally sound way areas of particular natural or cultural value, notably by the establishment of specially protected areas;

b) protect, preserve and manage threatened or endangered species of flora and fauna.

The objectives of specially protected areas, as defined in the Protocol, are to safeguard:

- representative types of coastal and marine ecosystems of adequate size to ensure their long-term viability and to maintain their biological diversity;

- habitats that are in danger of disappearing in their natural area of distribution in the Mediterranean or have a reduced natural area of distribution as a consequence of their regression or on account of their intrinsically restricted area;

- habitats critical to the survival, reproduction and recovery of endangered, threatened or endemic species of flora and fauna;

- sites of particular importance due to their scientific, aesthetic, cultural or educational interest.

In spite of the Convention and the protocol there are less than 80 marine protected areas in the Mediterranean that cover app. 4% of its surface - if Pelagos is taken into account. Without it, the surface of the Mediterranean covered with marine protected areas, is around 0.5%.

The regional and global importance of marine protected areas was clearly demonstrated with the adoption of the decision to have a representative and efficiently managed network of marine protected areas by the year 2012. The decision, known as the 2012 goal, was adopted within both - the Convention on biological diversity and the EU environmental policy. Within this framework, the Contracting Parties to the CBD adopted at their 9th Conference in Bonn in 2008 important decisions concerning the establishment and management of marine protected areas on regional and on global scale and proposed to the UN General Assembly to set the next steps towards a global, representative network of marine protected areas.

The scientific criteria for identifying ecologically or biologically significant marine areas that would build the representative network are: uniqueness and rarity, importance for life history stages of species, importance for threatened, endangered or declining species and/or habitats, vulnerability, fragility, sensitivity or slow recovery, biological productivity, biological diversity and naturalness. Marine protected areas should not be considered as pieces of nature placed under total protection but as tools in the service of the sustainable management of ecosystems, in this case of marine ecosystems in oceans and littoral spaces. If they protect sensitive environments and threatened species, they also contribute to increasing the productivity of fishing areas, to regulating the different uses of the sea, to fostering sustainable tourism and to creating new job-generating activities.

4. MPA IN THE NORTHERN ADRIATIC

Due to different definitions, categories, legislation etc., it is difficult to state the exact situation concerning the number of protected areas in the Northern Adriatic. Moreover, the different purposes, goals and conservation measures make it even harder to objectively evaluate their role and importance in conserving marine biodiversity and protecting endangered species and habitat types.

According to data gathered from governmental and nongovernmental organizations from the three riverine countries, there are 12 marine protected areas (or coastal protected areas with a marine component) in the Northern Adriatic (Table 1).

Table 1: Marine protected areas in the Northern Adriatic
Tabela 1: Zaščitena morska območja v severnem Jadranu

MPA	Country	Category	Size	Characteristics
Brijuni	Croatia	National Park	3,395 ha	Fourteen larger and small islands with Mediterranean and sub-Mediterranean vegetation. Typical marine flora and fauna of the Northern Adriatic.
Costa del Monte Conero	Italy	Nature park	6,011 ha	Specific geology and typical Mediterranean maquis. The area houses several rare and endangered bird species.
Cresko-Lošinjski arhipelag	Croatia	Area in the process of protection	52,576 ha	On the eastern side of Cres and Lošinj, including four smaller islands of Ćutin, Trstenik, Oruđa and Orjule, devoted mainly to the conservation of dolphins.
Debeli rtič	Slovenia	Nature Monument	25 ha	Peninsula with flysch cliffs, interesting geomorphological phenomena, seagrass meadows and typical hard bottom habitat types.
Donji Kamenjak i Medulinski arhipelag	Croatia	Typical landscape	375 ha	Southernmost part of Istrian peninsula, extremely diversified coastline with Mediterranean maquis hosts typical coastal habitat types and some endangered marine species.
Limski zaljev	Croatia	Protected area	600 ha	Picturesque deep sea bay, very narrow and sharp, important spawning ground and aquaculture area
Miramare	Italy	Nature Reserve	120 ha	Gulf of Trieste, between the tourist port of Grignano and Barcola beach. With a high level of marine biodiversity it represents most of the features and characteristics of the area.
Otok Prvić	Croatia	Ornithological Reserve	7,000 ha	Mainly terrestrial protected area, devoted mainly to the protection of bird species.
Rovinjski otoci	Croatia	Typical landscape	1,200 ha	Group of islands in front of the town of Rovinj. Protected area devoted mainly to the conservation of the typical landscape.
Rt Madona	Slovenia	Nature Monument	13 ha	Marine protected area in front of the town of Piran with specific habitat types and species composition and large colonies of stony coral.
Strunjan	Slovenia	Landscape Park	430 ha	Peninsula with coastal lagoon and salinas, and marine reserve with pristine natural conditions.
Tegnue	Italy	Natural reef (ZTB)	1,000ha (3,000ha)	Hard bottom of biogenic concretions managed by local law for scuba tourism (enlarged area in which fishery is forbidden).

As it can be seen from Table 1, the categories of the Northern Adriatic marine protected areas vary from national park (Briuni) to nature reserves (Miramare), nature monuments (Debeli rtič) and protected landscape (Rovinjski otoci). Together with that, they differ greatly also in terms of size, regulations and, last but not least, in terms of goals. Their conservation goals can be as broad as "conservation of characteristic landscape" as it is in the case of Strunjan, Rovinjski otoci and also Donji Kamenjak i Medulinski arhipelag, or "conservation of species and habitat types", as it is in Debeli rtič, Miramare and elsewhere. Two of the twelve areas, namely Tengue and Limski zaljev, differ slightly from the rest as they are important spawning grounds and thus their main goal is the conservation of fish stocks. The conservation measures for the marine parts of the protected areas show less diversity than it would be expected. In general, they address direct pollution and destruction of habitats (no mooring or/and anchoring), the taking of marine organisms (no spear fishing or professional fishing, collecting mussels etc.) and the protection of endangered species.

The listed areas are all sites of great natural value. They represent some typical habitat types and ecosystems of the northern Adriatic and host threatened or/and endangered species. However, in terms of conserving the biodiversity of the whole northern Adriatic, they are weak in both – number and representativeness. In terms of percentage, the situation is very much the same as in the whole Mediterranean. The protected areas cover 4% of the Northern Adriatic surface when Cresko-Lošinjski arhipelag is taken into account and only 0.4% without it. With the exception of Cresko-Lošinjski arhipelag, they are all coastal areas (or islands) that encompass only a relatively tiny belt of coastal sea. There are no protected areas in the open waters of the Northern Adriatic and also the western part of the basin is poorly represented.

5. STRENGTHS AND WEAKNESSES

Looking at the strengths and weaknesses of the existing protected areas, we can see that their strengths are mainly at the local level, while they reveal their weaknesses when we consider their role at a wider scale – in this case the Northern Adriatic.

Every single marine or coastal protected area is undoubtedly important for raising public awareness concerning the sustainable use of the marine environment. This is especially true when the protected area is properly managed. In this case they can be also key reservoirs of biodiversity, conserving typical habitat types, flora and fauna and protecting endangered species. In most cases, however, this is true only at the local level, considering their limited size and number. Due to the fact that marine protected areas usually display more or less pristine natural conditions, they have great potentials in terms of scientific research and educational activities. The last, together with activities devoted to public awareness, can on the long run strengthen the implementation of the basic principles of sustainable development and the integrated management of the coastal area.

At the same time, when we look at the marine protected areas having in mind the whole Northern Adriatic, with all the human activities impacting on its natural resources and biodiversity, we can see that some of the strengths are in a certain way diluted and much weaker. On one hand their number and size are too small to really make a difference in terms of management of the coastal area as part of the ecosystem of the Northern Adriatic. On the other hand, there is a huge gap in terms of representativity as well as in terms of conservation of resources. Last but not least, their number and size are also far from assuring the fulfilment of the 2012 goal – a network of representative, efficiently managed marine protected areas.

6. SUMMARY

For decades, the creation of marine protected areas has been considered the only tool to protect or restore natural communities and through that, protect marine ecosystems. As a consequence, the number of marine protected areas around the world is increasing at a rapid rate, and a similar pattern can be observed in the Mediterranean as well. Nevertheless, the number is still far from being adequate in order to ensure the conservation of its great specific biodiversity and high rate of endemism. This is especially true considering that different human activities, including marine based tourism, are growing even faster.

The Northern Adriatic is not an exception to the general situation observed in the world oceans and in the Mediterranean. In spite of the importance of the existing marine protected areas and the urgent need of creating new ones, the conservation of the biodiversity of the Northern Adriatic cannot depend only on this very useful tool. The reasons lie firstly in the fact that the human activities that have a negative impact on marine ecosystems grow and develop much faster to cope with. Secondly, the creation of marine protected areas is extremely demanding in terms of financial, technical and administrative resources and, last but not least, in terms of qualified personnel. Nevertheless, the three riverine countries should intensify their effort to create new marine protected areas and at the same time try to improve their representativeness. The increasing of conservation activities, including the creation of new protected areas, should be a direct consequence of the development of new and additional human activities in the basin.

Another tool that would improve our capability to better manage the Northern Adriatic and its coasts is scientific research. A much stronger and coordinated effort should be devoted to gain better knowledge of the ecosystem – its elements and functioning. An integrated and very important part of the research would be a common, long-term monitoring/observation system of physical, chemical and biological parameters of the basin.

The third and probably the most important tool that could really make the difference and contribute to overcome the weaknesses concerning the conservation of the biodiversity of the northern Adriatic would be a common strategy for the management of human activities and the use of natural resources. The implementation of the ecosystem approach, which is a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way, should be at the core of this common strategy, together with the precautionary principle. Political borders do not and should not count in terms of biodiversity conservation and health of marine ecosystems. Either we all win or we all lose. Or maybe we should say either they all win or they all lose – them, the marine species, habitat types, ecosystems. The northern Adriatic – and as a matter of fact, the whole Adriatic, is a unique entity. So if they lose, we all lose too.

POVZETEK

Ustanavljanje zavarovanih morskih območij je bilo desetletja uveljavljeno kot edino orodje za varovanje ali ohranjanje naravnih živalskih in rastlinskih skupnosti in s tem tudi za varstvo morskih ekosistemov. Posledica tega je naglo naraščanje števila zavarovanih morskih območij po vsem svetu, podoben vzorec pa se kaže tudi v Sredozemlju. Pa vendar število takšnih območij še zdaleč ni zadovoljivo do te mere, da bi lahko zagotovili varstvo njegove velike in zelo specifične biotske pestrosti kot tudi visoke stopnje endemizma. To še posebno drži ob dejstvu, da še veliko hitreje naraščajo različne človekove dejavnosti, vključno s turizmom, vezanim na morje in na morsko obalo.

Severni Jadran ni izjema v tej splošni situaciji, ki jo opažamo na vseh oceanih sveta in seveda tudi v Sredozemlju. Kljub velikemu pomenu obstoječih zavarovanih morskih območij in takojšnji potrebi po ustanavljanju novih pa ohranjanje biotske raznovrstnosti v severnem Jadranu ne more biti odvisno samo od tega sicer zelo uporabnega orodja. Razlogi za to ležijo, prvič, v dejstvu, da človekove dejavnosti, ki negativno vplivajo na morske ekosisteme, rastejo in se razvijajo tako hitro, da jih kratko malo ne moremo več obvladovati. Drugič, ustanavljanje zavarovanih morskih območij je izjemno zahtevna naloga glede na obstoječe finančne, tehnične in administrativne vire ter nenazadnje glede na usposobljene kadre. Pa vendar bi se morale države, ležeče ob Jadranskem morju, potruditi, da ustanovijo nova zavarovana območja in hkrati povečajo njihovo reprezentativnost. Povečanje naravovarstvenih dejavnosti, vključno z ustanavljanjem novih zavarovanih morskih območij, bi moralo vselej in nemudoma slediti razvoju novih in dodatnih človekovih dejavnosti v tem delu Jadranskega morja.

Drugo orodje, ki bi izboljšalo naše zmožnosti za upravljanje severnega Jadrana in njegovih obrežij, je znanstveno raziskovanje. Da bi izboljšali svoje znanje o tem ekosistemu – njegovih elementih in delovanju – bi bilo treba nemudoma vložiti precej več koordiniranega dela. Enoten in nadvse pomemben del raziskovanj bi bilo skupno, dolgoročno opazovanje in sledenje fizičnim, kemijskim in biološkim parametrom v severnem Jadranu.

Tretje in morda najpomembnejše orodje, ki bi lahko resnično nekaj spremenilo in pripomoglo k odpravi šibkih točk pri varstvu biodiverzitete v severnem Jadranu, bi bila skupna strategija za upravljanje s človekovimi dejavnostmi in za rabo naravnih virov. Ekosistemski pristop kot strategijo za enotno upravljanje kopnega, vode in živih virov, ki propagira pravično varstvo in trajnostno rabo, bi morali izpeljati pri jedru te skupne strategije, skupaj z načelom previdnosti. Kar zadeva zaščito biotske raznovrstnosti in zdravja morskih ekosistemov, politične meje ne obstajajo in tudi nikoli ne bi smele obstajati. Mi vsi bodisi dobimo ali pa izgubimo. Ali pa bi nemara morali reči oni – morske vrste, habitatni tipi in ekosistemi namreč. Severni Jadran – in seveda celotno Jadransko morje – je svojevrsten in enovit organizem. Torej, če izgubijo "oni", izgubimo mi vsi.

7. LITERATURE

1. Bellan-Santini, D., G. Bellan, G. Bitar, J.-G. Harmelin, G. Pergent (2002): Handbook for interpreting types of marine habitat for the selection of sites to be included in the national inventories of natural sites of conservation interest. UNEP, Action Plan for the Mediterranean. Regional Activity Centre for Specially Protected Areas, 217pp.
2. Forte, J. (2001): Vpliv gojišča rib na ekološke razmere notranjega dela Piranskega zaliva, Diplomsko delo, Univerza v Ljubljani, 51pp.
3. Guidetti P., S. Fraschetti, A. Terlizzi, F. Boero (2002): Effects of desertification caused by Lithophaga lithophaga (Mollusca). Fishery on littoral fish assemblages along rocky coasts of southeastern Italy. Conservation Biology 18(5):1417-1423.
4. Horvat, M., S. Covelli, J. Faganeli, M. Logar, V. Mandič, R. Rajar, A. Širca, D. Žagar (1999): Mercury in contaminated coastal environments; a case study: the Gulf of Trieste. Science of total environment 30 (237-238) 43-56.
5. Kovač, N., B. Vrišer, B. Črmelj (2001): Impacts of net cage fish farming on sedimentary biogeochemical and meiofaunal properties of the Gulf of Trieste. Annales Series historia naturalis 11(1), 65-72.
6. Lipej, L., J. Dulčić (2004): The current status of Adriatic fish biodiversity. In: Griffiths, H. et al. (ed.): Balkan biodiversity: pattern and process in the European hotspot. Kluwer Academic, Dordrecht. 291-306.
7. Lipej, L., R. Turk, T. Makovec (2006): Ogrožene vrste in habitatni tipi v slovenskem morju / Endangered species and habitat types in the Slovenian sea. Zavod RS za varstvo narave, Ljubljana, 264pp.
8. Malačič, V., J. Forte (2003): Distribution of the food surplus and faecal particles on the seabed below a fish farm in the Bay of Piran. Annales Series historia naturalis 13(1):3-8.
9. Malej, A., V. Malačič (1995): Factors affecting bottom layer oxygen depletion in the Gulf of Trieste (Adriatic Sea). Annales Series histories naturalis 7:33-42.
10. Ramade F. (1990). Conservation des Ecosystèmes méditerranéens - Enjeux et Perspectives. Les Fascicules du Plan Bleu, PNUE/PAM, 3: 1-144.
11. Fraschetti, S., A. Terlizzi, F. Micheli, L. Benedetti-Cecchi, F. Boero (2002): Marine Protected Areas in the Mediterranean Sea: Objectives, Effectiveness and Monitoring. Publicazioni della Stazione Zoologica di Napoli: Marine ecology, 23(1):190-200.
12. Milazzo, M., R. Chemello, F. Badalamenti, R. Camarda, S. Riggio (2002): The Impact of Human Recreational Activities in Marine Protected Areas: What Lessons Should Be Learnt in the Mediterranean Sea? Publicazioni della Stazione Zoologica di Napoli: Marine ecology, 23(1):280-290.
13. Salm, R.V., J. Clark, E. Siirila (2000): Marine and Coastal Protected Areas: A guide for planners and managers. IUCN. Washington DV. 371 pp.
14. Stachowitsch, M. (1984): Mass mortality in the Gulf of Trieste: The course of community destruction. Publicazioni della Stazione Zoologica di Napoli: Marine Ecology 5(3):243-264.
15. Stachowitsch, M. (1991): Anoxia in the Northern Adriatic Sea: rapid death, slow recovery. In:Tyson, r.v. & T. H. Pearson (ed.):Modern and Ancient continental Shelf anoxia. Geological Society Special Publication 58:119-129.
16. Stachowitsch, M., A. Fuchs (1995): Long term changes in benthos of the Northern Adriatic. Annals Annales Series historia naturalis 7:7-16.
17. Turk, R., A. Vukovič (1994): Preliminarna inventarizacija in topografija flore in favne morskega dela naravnega rezervata Strunjan. Annales Series historia naturalis 3:101-112.
18. Turk, R., 1999: Ocena ranljivosti slovenskega obrežnega pasu in njegova kategorizacija z vidika (ne) dopustnih posegov, dejavnosti in rabe. Annales Series historia naturalis 9:37-50.

19. www.medpan.org
20. www2.minambiente.it
21. www.cbd.int/marine
22. www.rac-spa.org
23. www.millenniumassessment.org
24. www.min-kulture.hr

Robert TURK
Zavod RS za varstvo narave, OE Piran
Tartinijev trg 12
SI- 6330 Piran, Slovenija
robert.turk@zrsvn.si

Roberto ODORICO
Area marina protetta di Miramare
Viale Miramare, 349
34014 Trieste
roberto.odorico@shoreline.it

INTEGRATED COASTAL ZONE MANAGEMENT (CASE STUDY ON THE SLOVENIAN MEDITERRANEAN)

CELOVITO UPRAVLJANJE OBALNEGA OBMOČJA

Mitja BRICELJ, Irena REJEC BRANCELJ

Key words: pressures, environmental limits, ecosystem services, integrated coastal zone management, Slovenia
Ključne besede: pritisk, okoljske omejitve, ekosistemske storitve, celovito upravljanje z obalnimi območji, Slovenija

ABSTRACT

A small percentage of Slovenia's surface area belongs to the Mediterranean basin, yet the undersea, marine and coastal area is an exceptionally important natural landscape. This region has an opportunity to actively integrate a relatively well conserved and biologically extremely diversified ecosystem into development planning. Ecosystem-based management is increasingly being used to establish links between the processes of integrated coastal zone management and based on the application of the regional-geographical approach. The starting point for Integrated Coastal Zone Management is that land developers take into account the stress and impacts that their plans could have on the coast and the marine ecosystem, and propose the most appropriate developmental solutions. The project takes, as its basis, measures to reduce pressures from land and maritime activities that affect the marine ecosystem. Research was oriented at the collection of data at the level of pollution of the sea from various substances and their sources. The effects of pollution on the marine environment and organisms were explored, and changes over time in the status of the marine environment were investigated. Afterwards, the collected data measures for environmental improvement were determined and the effectiveness of interventions was monitored. A lack of coordination in coastal zone management was ascertained. During the next steps, cooperation between ministries, regional and local authorities was aligned. The involvement of various stakeholders in the process of the regional programme of sustainable development preparation was of great relevance as well.

IZVLEČEK

Čeprav povodju Jadranskega morja in ožje, porečju jadranskih rek, pripada le majhen odstotek površine naše države, pa njen podvodni, morski in obalni svet oblikuje izjemno pomembno naravno pokrajino. Obalno območje, kot v članku poimenujemo porečje jadranskih rek, ima možnost, da se s svojim razmeroma dobro ohranjenim in biološko izjemno raznolikim ekosistemom vključi v razvojno načrtovanje. Ekosistemski pristop se čedalje pogosteje uporablja za vzpostavljanje povezav med procesi celovitega upravljanja obalnega pasu z regionalno-geografskim pristopom. Izhodišče celovitega upravljanja obalnega območja leži v načelu, da lastniki zemljišč upoštevajo, kako negativno lahko njihovi načrtovani projekti vplivajo na življenje na tem območju in morskem ekosistemu, in da predlagajo takšne razvojne rešitve, ki najbolj ustrezajo obstoječim razmeram. Vsekakor pa je potrebno že v začetku uvesti ukrepe, ki bodo zmanjšali pritiske s kopnega in iz različnih morskih dejavnosti, ki imajo močan vpliv na morski ekosistem. Raziskave so bile usmerjene k zbiranju podatkov glede onesnaževanja morja zaradi različnih snovi in njihovih virov. Raziskani so bili učinki onesnaževanja na organizme v morskem okolju in preučevane dolgoročnejše spremembe v stanju morskega okolja. Pozneje so bili zbrani podatki o ukrepih za izboljšanje okolja in nato spremljana njihova učinkovitost. Ugotovljeno je bilo pomanjkljivo

usklajevanje pri upravljanju obalnega pasu. V naslednjih korakih je bilo usklajevano sodelovanje med ministrstvi, regionalnimi in lokalnimi oblastmi. Zelo pomembna je bila tudi udeležba različnih zainteresiranih javnosti v procesu priprave regionalnega programa za trajnostni razvoj.

1. INTRODUCTION

The increased use of the coastal area and the sea, an increase in urbanisation and population, increasing tourist visits, and an increase in the number of tourist vessels and maritime transport require special attention in coastal and marine environment management. The impoverishment of marine ecosystems causes a loss of biological diversity, and it also decreases the stability and resistance of ecosystems. Furthermore, this consequently erodes the quality of human life in coastal areas.

Data on the state of the environment indicate that the Slovenian sea is not over-polluted with nutritional substances and other pollutants. Bacteriological pollution in areas of bathing water and water quality in mariculture areas are also within the limits of regulated values. The methodology for assessing the ecological state of surface water and the sea is still being prepared.

Protection of the marine and coastal environment is regulated by politics, implemented at European Community and Mediterranean levels. The three most important documents are: the Water Directive, the Marine Strategy Framework Directive, and the Mediterranean Action Plan for Sea Protection.

The environmental objectives for surface-water bodies within the framework of the Water Directive (2000/60/EC) are: protection, improvement and restoration of surface-water bodies in order to achieve a sound ecological and chemical state by 2015 and that the first review of the River Basin Management Plans should take place in 2020.

The Marine Strategy Directive (2008/56/EC) stipulates that it is necessary to provide for the following: protection and restoration of the functionality and structure of natural systems, their sound ecological state, no increase in the risk of emergence of harmful effects on humans and ecosystems through the level of environmental pollution, sustainable use of the sea and development of activities that influence the quality and encourage responsible management of the sea at the European Community level and globally.

The main objectives of the Mediterranean Action Plan for Sea Protection are: ensuring sustainable management of natural marine and land-based resources, integration of the environment in the social-economic development and spatial policy of the Mediterranean, protection of the marine environment and coastal areas through pollution prevention and a decrease or elimination of harmful emissions into the sea, protection of nature and areas of ecological and cultural value, strengthening the solidarity between Mediterranean countries in the management of common heritage and resources for the welfare of present and future generations, as well as contributing to the improvement of quality of life.

Beside the three indicated bases, the coastal and marine environment quality is regulated by numerous other sectoral documents, as shown in Figure 1.

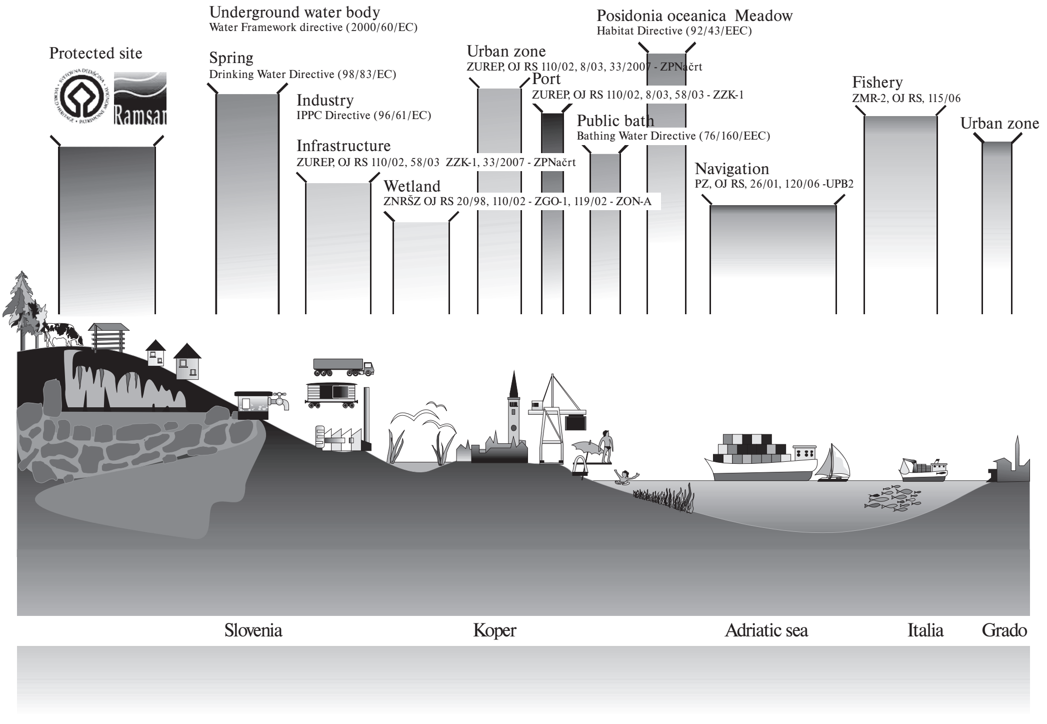


Figure 1: Legislative context of coastal and marine resources management
Slika 1: Zakonodajni okvir upravljanja z morskimi viri

2. METHODS

In dealing with the problems of marine and coastal areas management, we used the ecosystems approach (Bricelj 2008). Firstly, we analysed the individual influences of various activities and endeavoured to evaluate their cumulative pressures on ecosystems. We evaluated ecosystem functions and environmental limits in the light of existing ecological objectives. The main objective is to ensure healthy and resilient ecosystems.

Table 1 indicates the pressures and impacts of activities on the coastal and marine environment, identified within European Community.

Table 1: Pressures and impacts of activities on the coastal and marine environment (Environment Agency of the Republic of Slovenia 2008)
Tabela 1: Pritiski in vplivi različnih dejavnosti na obalni in morski ekosistem (Agencija RS za okolje 2008)

Pressures	**Impacts**
Urbanisation and tourism	Fragmentation and construction in the coastal area, seasonally variable impacts on the environment, loss of natural habitats, decrease of biodiversity, euthrophication, pollution due to intentional or unintentional discharges, underwater noise, increased water consumption, transport changes of sediments, increased amount of waste, pollution of the coast and the sea with floating waste, microbiological pollution

Pressures	**Impacts**
Marine traffic	Pollution due to intentional or unintentional discharges, introduction of non-indigenous species, waste pollution, underwater noise
Aquaculture and shellfish farming	Overfishing of marine organisms as food for cultivated species, introduction of non-indigenous species, genetic changes, introduction of diseases and parasites, pollution, euthrophication
Fishery	Overfishing of fish and other marine organisms, fishing of non-target species, destruction of demersal habitats, changes in ecosystem structure
Development of industry and infrastructure	Fragmentation and construction in the coastal area, loss of natural habitats, erosion, decreasing biodiversity, euthrophication, pollution, increased water consumption, transport changes of sediments, increased amount of waste, increased water turbidity, thermal pollution
Agriculture	Euthrophication, pollution, loss of natural habitats, decreasing biodiversity, salination, increased water consumption
Climate change	Increased probability of occurrence of floods, increased erosion level, rising sea level, change in the structure and arrangement of species and organisms, decreasing biodiversity

The main data sources of the state of the coastal and marine environment are reports on the regular monitoring of the environmental state, carried out on the basis of the Environmental Protection Act, Waters Act, and on the basis of requirements by the Convention on the Prevention of Mediterranean Sea Pollution from Land-based Sources. The Environment Agency of the Republic of Slovenia has been keeping the Common Database on Water Quality Monitoring. The reports include: assessment of the euthrophication level and general state of coastal sea quality, trends of pollution from dangerous substances, quality of the sea, brackish water and water for the life and growth of marine shellfish and marine gastropods, sanitary quality of bathing water and estimation of emissions from terrestrial point sources.

3. RESULTS

3.1 PRESSURES ON ECOSYSTEMS

3.1.1 Increasing population density in the coastal area

Nowadays, the entire coastal area is densely populated. The growing urbanisation of the coastal area is also mirrored in the transformation and solidification of the coastline. Less than 25% of the coast has been preserved in its natural state; the remaining part of the coast has been altered. In the coastal area, economic activities are increasing, along with infrastructural land development; the inflow of inhabitants and tourists is also increasing, accompanied by construction trends. On the other hand, the more inland areas are faced with various structural problems and issues, which represent developmental retardation.

With regard to the increasing number of inhabitants in coastal municipalities and in connection with the seasonal increase in tourism, we can expect a deterioration of the environmental state of this area, since along with increased pressures, conflicts of interest and use of space on land and sea are increasing as well.

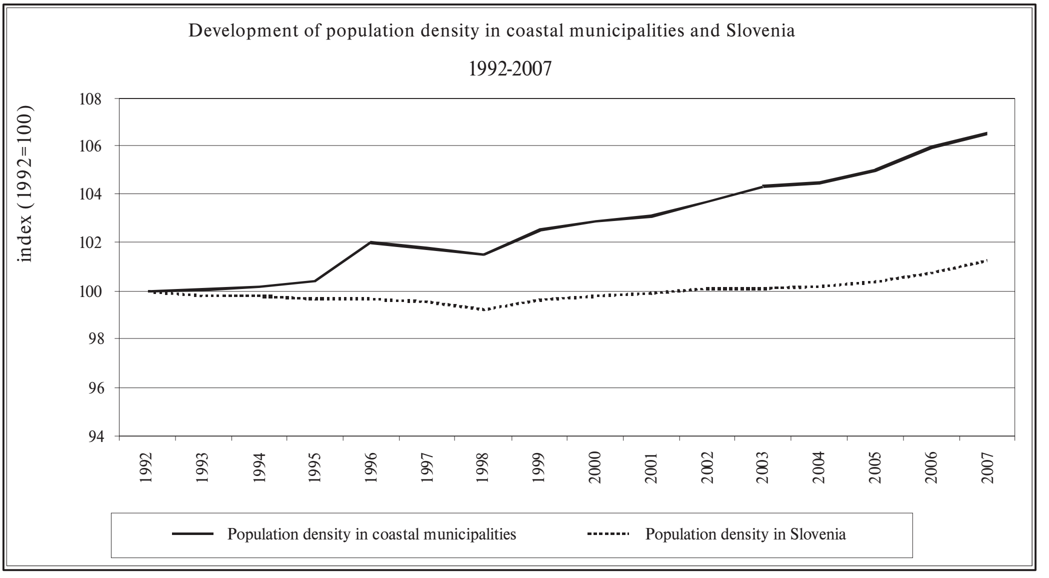


Figure 2: Development of population density in the coastal area during the 1992–2007 period (Data source: SI-STAT 2009)

Slika 2: Razvoj gostote prebivalstva v obalnem območju med letoma 1992 in 2007 (vir: SI-STAT 2009)

3.1.2 Equipping of settlements with treatment plants is inadequate

In the catchment area of Adriatic rivers with the sea, there are 108 settlements with a population greater than 50 population equivalents. Only 24 of these settlements are connected to municipal treatment plants. According to the size of the population, 75% of inhabitants in the settlements live without municipal treatment plants; however, this does not include the number of tourists. According to the available data from the Environment Agency of the Republic of Slovenia, the majority of treatment plants (82%) only provide the first purification level, which removes particles >0.1 mm and only partially (up to 30%) decomposes organic substances. Other treatment plants (18%) also provide the secondary purification level, where organic substances as well as some nutritional substances are removed or partially removed.

The results indicate a significant increase in emissions of substances due to releases from treatment plants, which emitted effluents directly into the sea or into the vicinity of the sea in 2002; in the later phase, a slowly decreasing trend of emissions of nitrogen and suspended substances has been indicated (MOP 2003). In the 2003–2005 period, emissions of nutritional substances and suspended substances from rivers into the sea slightly decreased, while the data also indicate a decreasing trend of phosphorus emissions from industrial sources. The entire area of Adriatic rivers indicates only modest equipping of settlements with treatment plants, while the existing treatment plants have a low purification level.

3.1.3 Phosphorus emissions from industrial waste water have been decreasing

The catchment area of Adriatic rivers indicates 40 point releases from industry, with the release of easily degradable organic and nutritional substances. A total of 18 of these releases have exceeded the limit value for release in surface water according to regulations. According to the available data, 15 releases with effluents directly into the sea have been indicated (liable to emission monitoring). The data indicate that in the last five years phosphorus emissions have been decreasing, while ammoniacal nitrogen emissions in these releases have been increasing.

The catchment area of Adriatic rivers also records 133 industrial releases of dangerous substances after data from the Environment Agency of the Republic of Slovenia. The stipulated emission values have been exceeded in 23 releases. The majority of releases are from the food industry, timber and wood-processing industry, chemical industry and releases from laundry and cleaning (Report for Slovenia ... 2007).

3.1.4 Increasing maritime transport

A large part of the area of Koper Bay is occupied by Luka Koper, which has become an important international port in Central Europe over its fifty years of existence. In 1970, the amount of transhipment cargo reached 2 mil t; in 1990, 6 mil t; and in 2006, 14 mil t. This growth has been especially intensive in the last ten years, as indicated in Figure 3. In relation to the developmental trends of "motorways of the seas", it is expected that transport will increase. In connection with this, the risk of accidents and unintentional sea pollution is increasing as well. Increasing maritime transport also causes an increase in submarine noise.

In the 1978–2006 period, the number of berths in marinas increased from 100 in 1978 to 1,365 in 2006. Three marinas have a total aquatorium surface of 183,000 m2.

In 2006, all three marinas recorded a total of 6,773 vessels, 1,629 of them with long-term contracts and 5,144 anchored transitionally. In all, 1,722 vessels in Slovenian marinas were located on land, while 5,051 vessels used the arranged shores of marinas for berths (Statistične informacije 2007).

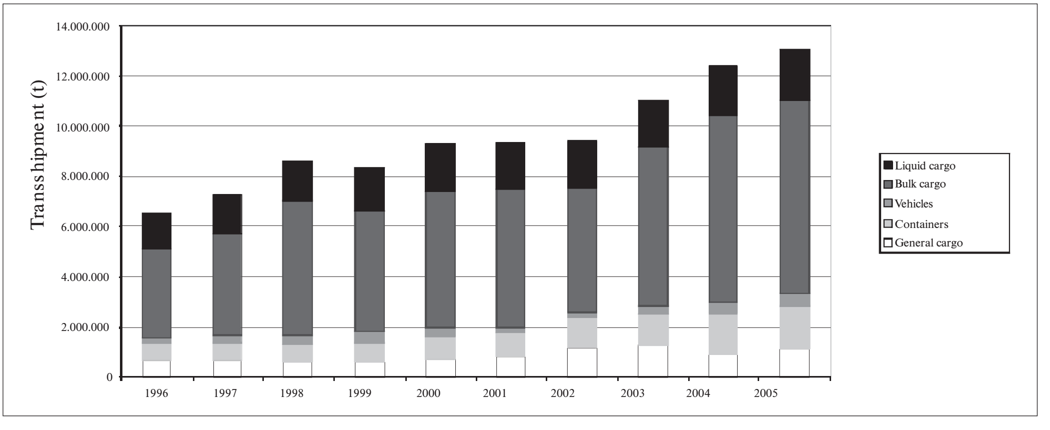


Figure 3: Transhipment cargo through Luka Koper in relation to the type of cargo (Data source: Ladijski pretovor 2009)
Slika 3: Pretovor blaga v Luki Koper glede na vrsto blaga (vir: Ladijski pretovor 2009)

Transport in marinas is the most intense during the spring and summer months. The majority of laytime days in all three Slovenian marinas are attributable to nautical tourists in April, May and June. In July, the majority are transitional vessels, while in October, towards the end of the season, permanent vessels prevail. According to the statistical data, the laytime in marinas has been getting longer in recent years.

3.1.5 Increasing number of tourists and significantly increased water consumption during the summer

Numerous problems are connected to the increasing number of tourists, such as: air pollution due to increased traffic density, increased quantity of waste, nature pollution due to uncontrolled dumping of waste, noise, increased potable water consumption and increased amounts of waste water.

The largest share of potable water comes from the Rižana water distribution system (71%); however, the latter does not provide for a sufficient water distribution. During this period, the water distribution system has been receiving a substantial recharge from the Karst (8%) and the Istrian water distribution system in Croatia (21%). The shortage of potable water in the coastal area amounts to 21% at the annual level.

The greatest demand for water is evident during the summertime. Besides a consumption increase in households and agriculture, this is connected primarily to the increasing number of tourists in this period. The majority of tourists come to Piran (65%), with fewer tourists visiting Izola (18%) and Koper (17%). In relation to the population and total number of tourists, water consumption is changing, fluctuating between 51 l/person/day in winter to 150 l/person/day in summer. The relationship between the number of tourists and water consumption is indicated in Figure 4.

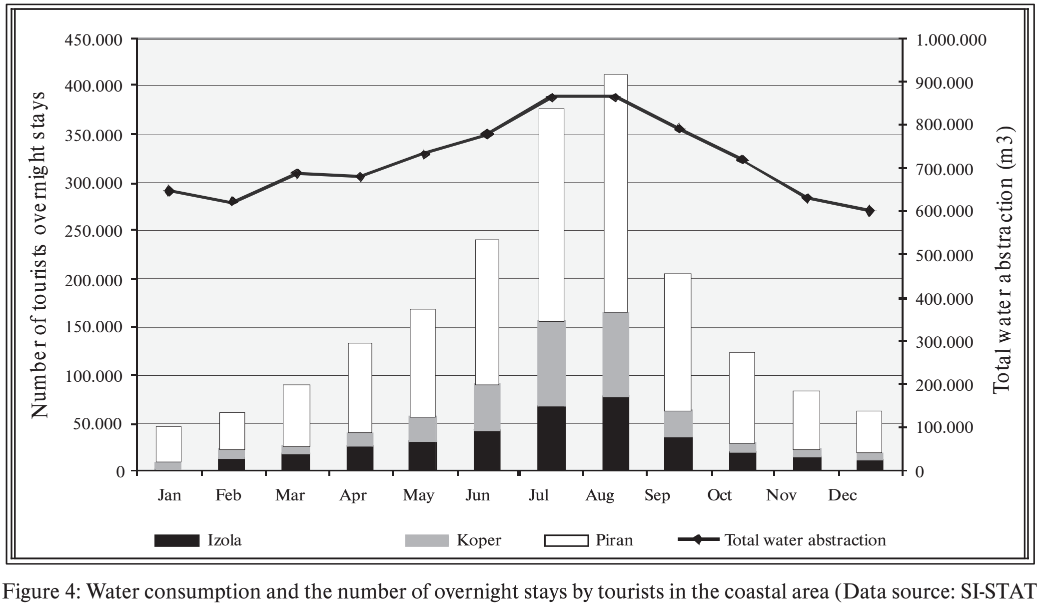


Figure 4: Water consumption and the number of overnight stays by tourists in the coastal area (Data source: SI-STAT 2009, Environment Agency of the Republic of Slovenia 2007)

Slika 4: Poraba vode in število nočitev s strani turistov v obalnem območju (vir: Agencija RS za okolje 2007)

3.1.6 Decreasing fish catch and mariculture

In the beginning of the nineties, the catch began to decrease rapidly, falling from 6,000 tonnes in 1990 to less than 2,000 tonnes in 1993. In the following years, the annual catch remained at around 2,000 tonnes. After 1998, the catch had been gradually decreasing and reached its lowest value, with 808 tonnes, in 2004. In the last two years, however, the catch has slightly increased; nevertheless, it has still remained below the limit of 1,000 tonnes. The reasons for the rapid decrease of the catch in the beginning of the nineties are primarily the loss of markets in the former Yugoslavia and the reduced fishing area (SI-STAT 2009).

Numerous areas are designated for fish and shellfish culture. Until 2004, the breeding of aquatic animals had increased, while since 2004, the statistic data has indicated a decreasing trend. The breeding of gilthead seabream (Sparus auratus) has been abandoned; now the breeding of molluscs and European seabass (Dicentrarchus labrax) prevails.

In the area of shellfish farms, regular water quality monitoring is being conducted in accordance with legislation. The assessment of water quality for the life and growth of marine shellfish and marine gastropods in recent years has indicated that the water at shellfish farms complies with the stipulated criteria.

3.1.7 Increasing pollution from ships and other vessels

From 1977 until 2006, the Office for the Protection of Coastal Waters took action in 656 cases, of which 307 involved oil pollution. The agent of pollution was known in 146 cases, and unknown in 510 cases. According to the collected data, it is apparent that releases of smaller amounts of oil into the sea prevail in Slovenia. In the light of the sensitivity of our sea, such pollution can have a negative impact on the marine environment, especially in comparison to the open sea.

The indicated data and facts in connection with the existing cases of release under the detection limit of the EU-standard (release of more than 7 tonnes) do not imply that in Slovenia or in the direct vicinity of our sea larger pollution cannot occur – at a global scale, the northern Adriatic is becoming one of the most important navigation routes for oil and its derivatives and other more or less dangerous substances. This can present a high risk to our sea due to possible larger and sudden releases of these substances (Sotlar 2007).

The introduction of non-indigenous and pathogenic species due to maritime transport constitutes a constant danger to the natural environment. The transfer of organisms through maritime transport can occur primarily due to the presence of organisms in ballast waters and related sediments. Organisms can also be transferred through attachment to the hull and other parts of a ship.

In the northern Adriatic, the occurrence of 46 species of non-indigenous organisms has been recorded. It is hard to prove the transfer of these organisms, although in numerous cases it can be connected to various carriers. Among the 46 indicated species in the Adriatic, 31 are connected to a ship as the carrier, of which 25 are connected with the ship's hull surface and 19 with ballast water.

The main part of the released amount of ballast water in the Slovenian sea is associated with the release of ballast water from ships in Luka Koper and its berths, and only a small quantity in the Izola shipyard. The Gulf of Trieste area is also influenced by the activities of Italian ports, especially ports in Trieste and Monfalcone (David et Jakomin 2003).

3.2 ENVIRONMENTAL LIMITS, VALUING ECOSYSTEM SERVICES

3.2.1 Semi-enclosed, shallow bay with a small volume and weak exchange of water mass

Slovenia is linked with European and global seas and is a maritime country, although our coast covers only 0.1% of the Mediterranean Sea coast. The Slovenian sea is part of the Gulf of Trieste. Nowadays, the sea is eroding the land in two larger bays: the Bays of Koper and Piran, and in two smaller bays: Strunjan and Portorož. An important characteristic of the Slovenian sea is its shallowness. This also accounts for its continental characteristics – rapid warming and cooling as well as ecological sensitivity (Orožen Adamič, Rejec Brancelj 1998). As is characteristic of the Gulf of Trieste, with an average depth of 18.7 meters, the depth in the Slovenian part is also very small. A 20-meter depth curve divides the gulf into its external and internal parts. In the external part, the sea reaches depths of 20 meters or more, while in its internal part the depth is mainly 10 meters or even less. Up to now, the greatest measured depth of the sea is at Punta Piran (Cape Madona) – 37.25 meters, due to which it was named "Underwater Triglav" (Orožen Adamič 2000). The Slovenian part of the Gulf of Trieste contains slightly less than 4 km3 of water (Radinja 1990). The prevailing sea current moves along the Slovenian coast in the direction of Trieste, where it turns and moves along the Italian coast towards the south. The average speed of the current is 0.8 knots (1.5 km/h). In the opposite direction, a weaker current appears periodically with a speed of 0.5 knots (0.9 km/h) (Orožen Adamič 1998). The sea currents are stronger near the capes due to the shape of the local relief. The prevailing direction of the currents depends upon the tide, which is the greatest in this part of the Adriatic. Due to smaller depths, the currents' direction and speed also depend on the weather, especially wind. The water mass dynamics of the inshore belt is also influenced by freshwater influents.

Modest effects – shallowness, small water volume and weak currents in the Slovenian part of the Gulf of Trieste – are also manifested in environmental sensitivity. The inflow of terrestrial water with large amounts of nutritious substances, some direct releases and releases from treatment plants have subsequently influenced the Slovenian sea. The most polluted area is the interior of the Gulf of Koper, to which the Rižana and Badaševica contribute their share with direct waste-water streams from settlements and industry (Rejec Brancelj 2003).

The catchment area of Adriatic rivers with the sea is classified in the aquatic area of the Adriatic Sea. The surface of the catchment area is 1,509.1 km2, which comprises approximately 7.5% of the territory of the Republic of Slovenia (Bernot 1990). The length of all water courses in the catchment area of Adriatic rivers is 1,499.0 km, or 5.1% of the length of all water courses in Slovenia. A little more than two thirds of the catchment area surface (71%) are covered by forests. Agricultural land spreads over 26% of the catchment area. Wetlands are also present in this part of Slovenia; however, the share is small.

The coast is intertwined with natural, tourist and various levels of construction and urban as well as industrial areas, which burden the coastal sea to various degrees. Important traditional economic activities in the coastal area are agriculture, salt-making in salt-pans, shipbuilding and fishery, which are all profoundly connected with natural resources. These activities have shaped the traditional terraced landscape pattern of the Slovenian coastal area, which is still preserved in some areas.

3.2.2 Water quality for the life and growth of marine shellfish and gastropods is appropriate

Water quality assessment for the life and growth of marine shellfish and marine gastropods for the 2003–2005 period indicated that the water complied with regulation criteria at all three sampling sites. The basic physical-chemical parameters did not derogate from the stipulated limit values, the same as faecal coliform and the content of halogenated organic substances. Heavy metals in water were present at all sampling sites; however, the concentration was low and below the limit value at all sites (Ambrožič et al. 2007).

3.2.3 Chlorophyll-*a* in the coastal sea indicates over-pollution

The northern Adriatic, which also encompasses the Slovenian coastal sea, belongs to the most productive part of the Mediterranean Sea. The consequences of water over-pollution by nutritional substances are visible in the phytoplankton bloom, exceptional algal bloom, demersal oxygen deficiency, destruction of demersal organisms, occurrence of toxic algal species, production of mucilaginous aggregates and increased coverage of the sea bed with fast-growing green algae.

The greater part of the Gulf of Trieste, especially its eastern Slovenian part, is primarily a poor marine ecosystem with nutritional substances with lesser signs of over-pollution. This is especially obvious in smaller semi-enclosed bays, into which municipal sewage water is being discharged. Considering the average annual value of sea transparency and chlorophyll-***a*** under 2.5 μg/l, the Slovenian coastal sea can be classified according to the OECD classification as a poor coastal zone with nutritional substances. The measured concentration is fairly variable, but within the framework of similar values. The highest values have been measured in the colder part of the year in periods of typical seasonal highs of phytoplankton. The results indicate a concentration decrease of chlorophyll-*a* in the 1997–2005 period and consequently a decrease in over-pollution at selected monitoring stations.

In comparison with the assessed indicators in the Baltic and North Seas, the values in the Slovenian sea are low; however, according to the selected locations in the European part of the Mediterranean Sea, they exceed the average and are significantly higher (Čermelj 2006a).

3.2.4 Improving chemical and trophic state of the sea

In the 2003–2005 period, metal analysis in the water and sediments and analysis of priority substances and indicative parameters in the water were carried out at selected sampling sites on the sea. The results indicate that the content of priority substances and indicative parameters in the water remained below the detection limit of the implemented analytical methods, and below the limit value stipulated in the national chemical regulations. The content of heavy metals was determined at all sites; however, the acquired values did not exceed the limit values. On the basis of the analysis results, the chemical state at all sampling sites in the sea during the 2003–2005 period was solid.

The trophic condition of the sea in the period since 2000 has been gradually improving. The best trophic condition of the sea was indicated at the southern part of the Gulf of Trieste, and it was also similar at the basic sampling site in the centre of the Gulf. A slightly worse state was recorded at the sampling site in the centre of Piran Bay, and the worst at the sampling site in Koper Bay (Ambrožič et al. 2007a).

3.2.5 Oxygen in the demersal layer has been appearing only exceptionally

The frequency of the appearance of low concentrations of oxygen in the demersal layer in the coastal and marine environment of the Gulf of Trieste does not indicate a definite trend. In the period from 1989 to 2005, an oxygen deficiency had periodically appeared in the central part of the Gulf in late summer and autumn, namely in 1989, 1990, 1994, 1995, 2000 and 2001 (Figures 57-1 and 57-2). In the south-eastern part of the Gulf, the deficiency appeared in the same period only twice, in 1989 and 1990. At all test sites, oxygen deficiencies reached less than 3% of all measured values. At depths of less than 20 m, oxygen deficiencies have not been recorded (Čermelj 2006).

3.2.6 Underwater noise has been increasing with increasing maritime transport

Marine animals are highly exposed to underwater noise generated by boats, ships and other vessels that emit a wide spectrum of noise into the environment. Excessive underwater noise reduces the orientation capability of underwater animals, while in the long run it also influences reproduction and survival by causing stress, reducing animals' ability to find food, forcing them to leave their habitats, and even causing physical injuries.

The research has indicated that the noise level in seas has been increasing primarily as a consequence of increasing maritime transport. Ship transport causes underwater noise at frequencies in the spectrum used by marine animals for communication over long distances. The number of underwater noise sources is high. In the area of the Slovenian sea, this primarily derives from ship transport, including tourist and other vessels.

3.2.7 Protected areas are important for the preservation of biodiversity in coastal and marine areas

The first efforts to protect the sea date back to 1990, when the Strunjan Nature Reserve was established as part of Strunjan Landscape Park. It incorporates the 4-km-long northern coast of the Strunjan Peninsula with a 200-meter belt of coastal sea between the bays of San Simon and Strunjan. The most picturesque part of the reserve are the 80-meter-high cliffs, which happen to be among the highest flysch cliffs in the Adriatic. In the same year, Cape Madona with a 200-meter belt of underwater flora and fauna was protected as a natural monument. In 1991, Debeli Rtič, with its shallow sea and smaller underwater ridge, also became a natural monument. The Škocjanski zatok (Škocjan Inlet) is also a nature reserve, while certain smaller areas are protected by Natura 2000, such as Sv. Nikolaj (Ankaran) and the underwater meadows with posidonia seagrass (Posidonia oceanica) at Žusterna (Medobčinski zavod 1999). The largest protected area are the Sečovlje Salt-pans.

Sečovelje Salt-pans are the only surviving part of the former lively salt production activity on the margins of the Gulf of Trieste – the wide, vast flat alluvial plains along the effluents of inshore rivers, no over-inflow of freshwater from land, favourable climatic conditions and favourable transport connections with the interior enabled the development of salt production from Servola, Aquilinia, Muggia, Koper, Izola, Strunjan and Lucija to Sečovlje (Rejec Brancelj 1991). The salt production area was surrounded on all sides by a 3-meter-high dike, strengthened by rocks and supported by clay. The land side contained a deep trench, which collected freshwater from the interior area. On the marine side, sea water was released into the salt-pans, which was controlled by release through pools that had a gradually lower bed in the direction of the sea. Where it was necessary, water was collected with the assistance of wooden pumps driven by the wind. The circulation of water from pan to pan made the water denser, and at density of between 26‰ and 30‰, table salt was extracted in the form of small crystals. Salt was collected from the pans using special rakes. The Sečovelje salt-pans were among the largest in Istra. In the middle of the 19th century, 493 salt houses could be counted in the area of the pans, where inhabitants of Piran, mostly of Italian nationality, lived seasonally. Farmers from the immediate vicinity came to the salt evaporation ponds, firstly as helpers and later as salt-makers, not earlier than at the turn of the 20th century. Evidence of the former lively economic activity in this area can be seen in one of the salt houses, which has been turned into the Museum of Salt-making. In recent years, the Sečoveljske Soline Landscape Park has served as a model of cooperation between the economy and nature protection.

4. DISCUSSION

The Slovenian sea is an exceptional natural resource for numerous activities, such as tourism, transport, production of food and other goods that are sometimes excluded from the use of the sea and inshore land.

The unique importance of the Slovenian sea is also evident by virtue of the fact that numerous legislative documents from various sectors limit the use of the sea and inshore land under various legal regimes. The drafting of rules, which are then implemented through various regulations, stipulates the method of enjoyment of the allocated rights of use and related obligations.

In general, a legal regime concerning natural or built (dike, in-fill, excavation, etc.) national assets is in force for the sea, the purpose of which is to enable general use by any person to the same degree and under the same conditions. Individual regulations control this general use for the benefit of everyone. The legislation on marine fishery stipulates the areas of fishing reserves (Strunjan and Portorož), where primarily fishery and navigation speed are limited, and areas where the water quality is suitable for the life and growth of marine shellfish and marine gastropods – basically, areas where shellfish farms are already functioning or are being developed.

Areas for nature conservation and protection of cultural heritage are protected by various acts (for instance, nature reserve, landscape park, archaeological area, planned nature conservation area, ecologically important area, and Natura 2000 areas). Examples of larger protected areas are: Sečoveljske Soline Landscape Park, Strunjan Landscape Park, Škocjanski Zatok Nature Reserve and Cape Madona and Debeli Rtič natural monuments. The marine ecosystem is constantly endangered due to lively marine activities, either due to the introduction of non-indigenous species or due to intentional or uncontrolled releases from ships.

The use of the sea in the greater part of Koper Bay and in certain important smaller areas near other coastal settlements is governed by legal regimes in accordance with the maritime code (navigation routes, port of public transport, local port, etc.), which primarily refers to unobstructed navigation and other limited uses (bathing, fishery, etc.). Maritime transport has been increasing; as already mentioned, annual transhipment through Luka Koper reached 14 million tonnes in 2006. Transport is the one of the most limiting functions to access to the sea as a national asset – along 12% of the coast such access is not possible due to special protection regimes (customs piers, Luka Koper). A legal regime of bathing waters and bathing areas is in force for safe bathing in the sea, whereby special attention is devoted to water quality.

Environmental objectives oblige us to provide good water status and protection of the marine environment. One of the most effective tools for this is the preparation of a management plan for the coastal area with international cooperation. This surpasses the traditional sectoral approach and establishes cooperation by all interested parties. Successful steps in this direction have already been taken with the preparation of the coastal zone management programme within the framework of the CAMP Slovenia project. The following has been prepared: spatial development concept for the Southern Primorska region and spatial arrangement of the coastal zone, management of the protected nature areas, a regional strategy for the sustainable development of tourism, a regional programme for environmental protection and sensitivity maps of the Slovenian coast (Kušar 2007).

5. SUMMARY

The increasing use of the coastal zone and sea, increasing urbanisation and population growth, increasing tourist visits and a greater number of tourist vessels and maritime transport require special attention in the coastal and marine environment management. Weakening of marine ecosystems causes a loss of biodiversity, as well as the ecosystems'

decreasing stability and resistance. Furthermore, this also erodes the quality of human life in the coastal areas.

The importance of Integrated Coastal Zone Management is that land developers take into account the stress and impacts that their plans could have on the coast and marine ecosystem, and propose the most appropriate developmental solutions. The project takes, as its basis, measures to reduce pressures from land and maritime activities that affect the marine ecosystem. The research was oriented at the collection of data at the level of pollution of the sea from various substances and their sources. The effects of pollution on the marine environment and organisms were explored, and changes over time in the status of the marine environment were investigated. Afterwards, the collected data measures for environmental improvement were determined and the effectiveness of interventions was monitored. A lack of coordination in coastal zone management was ascertained. During the next steps, cooperation between ministries, regional and local authorities was aligned. The involvement of various stakeholders in the process of the regional programme of sustainable development preparation was of great relevance as well.

POVZETEK

Povečana raba obalnega pasu in morja, vse večja urbanizacija in rast prebivalstva, nenehno povečevanje števila turistov ter morskih prometnih in turističnih plovil, vse to terja posebno pozornost v upravljanju obalnega in morskega okolja. Posledica oslabitve morskih ekosistemov je izguba biotske raznovrstnosti, z njo pa tudi njihova vse manjša uravnoteženost in odpornost. Poleg tega pa to tudi načenja kakovost človekovega življenja v obalnih območjih.

Pri celovitem upravljanju obalnega pasu je pomembno, da lastniki zemljišč upoštevajo, kako negativno lahko njihovi načrtovani projekti vplivajo na življenje v tem pasu in morskem ekosistemu, in da predlagajo takšne razvojne rešitve, ki najbolj ustrezajo obstoječim razmeram. Vsekakor pa je treba že v začetku uvajati ukrepe, ki bodo zmanjšali pritiske s kopnega in iz različnih morskih dejavnosti, ki imajo močan vpliv na morski ekosistem. Raziskave so bile usmerjene k zbiranju podatkov glede onesnaževanja morja zaradi različnih snovi in njihovih virov. Raziskani so bili učinki onesnaževanja na organizme v morskem okolju in preučevane dolgoročnejše spremembe v stanju morskega okolja. Pozneje so bili zbrani podatki o ukrepih za izboljšanje okolja in nato spremljana njihova učinkovitost. Ugotovljeno je bilo pomanjkljivo usklajevanje pri upravljanju obalnega pasu. V naslednjih korakih je bilo usklajeno sodelovanje med ministrstvi, regionalnimi in lokalnimi oblastmi. Zelo pomembna je bila tudi udeležba različnih zainteresiranih javnosti v procesu priprave regionalnega programa za trajnostni razvoj.

6. LITERATURE

1. Agencija RS za okolje (2007): Data on total water abstraction. Ljubljana. 1 pp.
2. Agencija RS za okolje (2008): Material for state of environment report. Ljubljana. 163 pp.
3. Ambrožič, Š., J. Grbović, P. Mihorko, M. Tehovnik-Dobnikar. (2007): Quality of water required for growth of marine bivalves and gastropods. Agencija Republike Slovenije za okolje. http://kazalci.arso.gov.si/kazalci/index_html?Kaz_id=154&Kaz_naziv=Kakovost%20vode%20za%20življenje%20in%20rast%20morskih%20školjk%20in%20polžev&Sku_id=25&Sku_naziv=MORJE&tip_kaz=1#KAZALEC_TOP, 9. 3. 2009.
4. Ambrožič, Š., J. Grbović, P. Mihorko, M. Tehovnik-Dobnikar (2007a): Chemical and trophic state of the sea. Agencija Republike Slovenije za okolje. http://kazalci.arso.gov.si/kazalci/index_html?Kaz_id=153&Kaz_naziv=Kemijsko%20in%20trofično%20stanje%20morja&Sku_id=25&Sku_naziv=MORJE&tip_kaz=1#KAZALEC_TOP, 9. 3. 2009.
5. Bricelj, M. (2008): Geografske zasnove za upravljanje z vodnimi viri Slovenije. Doktorska disertacija, Univerza v Ljubljani, Filozofska fakulteta. Ljubljana. 110 pp.
6. Bernot, F. (1990): Hidrografske značilnosti morja ob slovenski obali, Primorje. Zbornik 15. zborovanja slovenskih geografov. Portorož. 29–34.
7. Čermelj, B. (2006): Bottom oxygen concentrations. Agencija RS za okolje. http://kazalci.arso.gov.si/kazalci/index_html?Kaz_id=87&Kaz_naziv=Kisik%20v%20pridnenem%20sloju&Sku_id=25&Sku_naziv=MORJE&tip_kaz=1#KAZALEC_TOP

9. 3. 2009.

8. Čermelj, B. (2006a): Chlorophyll-a in the coastal sea. Agencija RS za okolje. http://kazalci.arso.gov.si/kazalci/index_html?Kaz_id=86&Kaz_naziv=Klorofil-<i>a</i>%20v%20obalnem%20morju&Sku_id=25&Sku_naziv=MORJE&tip_kaz=1#KAZALEC_TOP, 9. 3. 2009.
9. David, M., L. Jakomin (2003): Ballast water threat in the North Adriatic - approaching risk assessment. In: Fabjan, D. (ed.) ICTS 2003 : zbornik referatov = conference proceedings. Fakulteta za pomorstvo in promet. Portorož. 1-11.
10. Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for community action in the field of water policy (Water Framework Directive). OJ L 327, 22. 12. 2000. 72 pp.
11. Directive 2008/56/EC of the European Parliament and of the Council of 17 June 2008 establishing a framework for community action in the field of marine environmental policy (Marine Strategy Framework Directive). OJ L 164, 25. 6. 2008. 22 pp.
12. Kušar, U. (2007): Morsko in obalno okolje. In: Rejec Brancelj I., Zupan N. (eds.): Okolje na dlani. Slovenija. Ministrstvo za okolje in prostor, Agencija RS za okolje. Ljubljana. 76-85.
13. Ladijski pretovor v Luki Koper od leta 1996 do leta 2005 v tonah. http://www.luka-kp.si/slo/terminali-in-tovor, 9. 3. 2009.
14. Medobčinski zavod za varstvo naravne in kulturne dediščine Piran (1999): Naravni spomenik, Rastišče pozejdonke pri Kopru. Ljubljana. 2 pp.
15. MOP (2003): Okolje v Sloveniji 2002. Ministrstvo za okolje, prostor in energijo. Ljubljana. 103 pp.
16. Orožen Adamič, M. (1990): Podvodni relief Tržaškega zaliva in varovanje naravne dediščine, Primorje. Zbornik 15. zborovanja slovenskih geografov. Portorož. 7–12
17. Orožen Adamič, M. (1998): Tržaški zaliv. Slovenija - pokrajine in ljudje. Mladinska knjiga. Ljubljana. 282–294.
18. Orožen Adamič, M., I. Rejec Brancelj (1998): Morje. Geografski atlas Slovenije, Država v prostoru in času. DZS. Ljubljana. 96–97.
19. Radinja, D. (1990): Dimenzije Tržaškega zaliva in slovenskega morja ter njihov regionalni pomen, Primorje. Zbornik 15. zborovanja slovenskih geografov. Portorož. 13–20.

20. Rejec Brancelj, I. (1991): Antropogeno spreminjanje obalne linije v okolici Kopra, Annales 1/91. Koper. 13–18.
21. Rejec Brancelj, I. (2003): Morje. In: Uhan J., Bat M. (eds.): Vodno bogastvo Slovenije. Ministrstvo za okolje prostor in energijo, Agencija RS za okolje. Ljubljana. 69-73.
22. Report for Slovenia for the Years 2004 and 2005. New reporting format for the implementation of the Barcelona Convention and its Protocols (2007). Ministry of the environment and spatial planning. Ljubljana. 114 pp.
23. SI-STAT podatkovni portal. Statistični urad Republike Slovenije. http://www.stat.si/pxweb/Dialog/statfile2.asp, 9. 3. 2009.
24. Sotlar, Z. (2007): Accidental oil tanker spills. Agencija RS za okolje. http://kazalci.arso.gov.si/kazalci/index_html?lang=1&Kaz_id=28&Kaz_naziv=Onesnaževanje%20z%20ladij&Sku_id=25&Sku_naziv=MORJE&tip_kaz=1#KAZALEC_TOP, 9. 3. 2009.
25. Statistične informacije (2007): Navtični turizem, Slovenija, 2006. Statistične informacije, št. 24, 21 turizem, št. 2. Statistični urad Republike Slovenije. Ljubljana. 5 pp. http://www.stat.si/doc/statinf/21-si-079-0701.pdf, 9. 3. 2009.

Mitja BRICELJ in Irena Rejec BRANCELJ
Ministry of the Environment and Spatial Planning,
Dunajska 48
SI- 1000 Ljubljana, Slovenia
mitja.bricelj@gov.si, irena.rejec-brancelj@gov.si

BENTHIC MACROALGAE AS BIOINDICATORS OF THE ECOLOGICAL STATUS IN THE GULF OF TRIESTE

BENTOŠKE MAKROALGE KOT BIOINDIKATORJI EKOLOŠKEGA STANJA V TRŽAŠKEM ZALIVU

Martina ORLANDO-BONACA, Lovrenc LIPEJ

Key words: macroalgae, EEI (Ecological Evaluation Index), ecological status, monitoring programme, Gulf of Trieste

Ključne besede: makroalge, EEI (Indeks ovrednotenja ekološkega stanja), ekološko stanje, program monitoringa, Tržaški zaliv

ABSTRACT

A preliminary assessment of macroalgae in Slovenian coastal waters led to a selection of seven sampling sites for the monitoring programme. The aim of the study was to verify whether the monitoring results confirm the first evaluation of the ecological status (ES) according to macrophytes. The ES was reconfirmed as *High/Good*.

IZVLEČEK

Na osnovi predhodne ocene makroalg v slovenskih obalnih vodah je bilo izbranih sedem vzorčnih mest za program monitoringa. Namen študije je bil preveriti ali rezultati monitoringa potrjujejo prvo oceno ekološkega stanja (ES) glede na makrofite. ES je bilo potrjeno kot *Zelo dobro/Dobro.*

1. INTRODUCTION

In the Mediterranean infralittoral rocky belt, two ecological quality indices are mostly used for assessing the ecological status (ES) of macroalgal communities: the Greek EEI (Ecological Evaluation Index) proposed by Orfanidis et al. (2001, 2003) and Panayotidis et al. (2004), and the Spanish CARLIT (cartography of littoral and upper-sublittoral rocky communities) proposed by Ballesteros *et al*. (2007). The EEI, which is a multimetric scale-based biotic index that reveals the response of macrophytes to anthropogenic stress, has been successfully used to assess the ES of Slovenian coastal waters (Orlando-Bonaca et al. 2008) and it is also planned to be used in the Italian part of the Gulf of Trieste (A. Falace, *pers. comm.*). Recently, the EEI was tentatively tested in Croatian Istrian waters as well (Iveša et al. 2008). Its basic concept, according to which "nutrients shift the ecosystem from a pristine state, where late-successional species are dominant, to a degraded state, where opportunistic species" prevail, is well documented (Giaccone 1993, Chryssovergis et Panayotidis 1995, Arévalo et al. 2007).

The results of the preliminary assessment of benthic macroalgae in Slovenian coastal waters (Orlando-Bonaca et al. 2008) led to a selection of seven sampling sites on km-scale, dominated by late-successional species, for the surveillance monitoring programme, following the EEI successional model and according to the European Water Framework Directive.

The aim of the study was to verify whether the results of the first year monitoring programme confirm the preliminary assessment of benthic macrophytes or indicate different conditions/situation of benthic macroalgae in Slovenian coastal waters.

2. MATERIAL AND METHODS

2.1 STUDY AREA AND SAMPLING PROCEDURE

The Gulf of Trieste is characterized by the largest tidal differences (semidiurnal amplitudes approach 30 cm) and the lowest winter temperatures (below 10°C) in the Mediterranean Sea (Boicourt et al. 1999). The Slovenian coastal sea covers the southern part of the Gulf of Trieste. Its coastline is approximately 46.7 km long. It is a shallow semi-enclosed gulf with a maximum depth of ca. 33 m in waters off Piran. The Slovenian coastal sea is affected by freshwater inflows and local sources of pollution (Turk 1999). In recent decades, it has suffered from many anthropogenic impacts such as intensive farming, mariculture, and sewage outfalls (Turk 1999). Many activities such as urbanisation and massive tourism have modified the natural shoreline.

During 2007, benthic macroalgae were sampled at seven monitoring sites selected in two water bodies: SI5VT4 and SI5VT5 (Figure 1). The first were characterized as "rocky shallow moderately exposed", the second as "sedimentary shallow moderately exposed". The sites have been located at regular distances of less than 5 km apart from each other, dominated by late-successional species. All the sites were sampled twice: in spring and in late summer. As a sampling site, an area of 10 x 10 m was considered. At each site, in a depth range of 2 to 4 m, three samples were randomly scraped from the bottom (20 x 20 cm). Such a surface (400 cm^2) is considered to be the minimal sampling area in the case of the Mediterranean infralittoral communities (Boudouresque et Belsher 1979). All samples were collected between 8 and 12 a.m. Each collected sample was placed in a plastic bag and all the material transported to the Marine Biology Station of the National Institute of Biology laboratory for analysis. The samples were then fixed in ethanol (70%).

Species identification of macroalgae was carried out in the laboratory by using a binocular microscope and a microscope in accordance with Ribera et al. (1992), Gallardo et al. (1993), Gomez Garreta et al. (2001) and Bressan et Babbini (2003). Each sample was sorted carefully and the surface covered by each species (the vertical projection) was quantified in cm^2 (4 cm^2 = 1% of the sampling surface). Only species covering at least 1% of the sampling area were assessed. In cases where the coverage of morphologically similar species could not be measured precisely, these species were grouped together (as spp.).

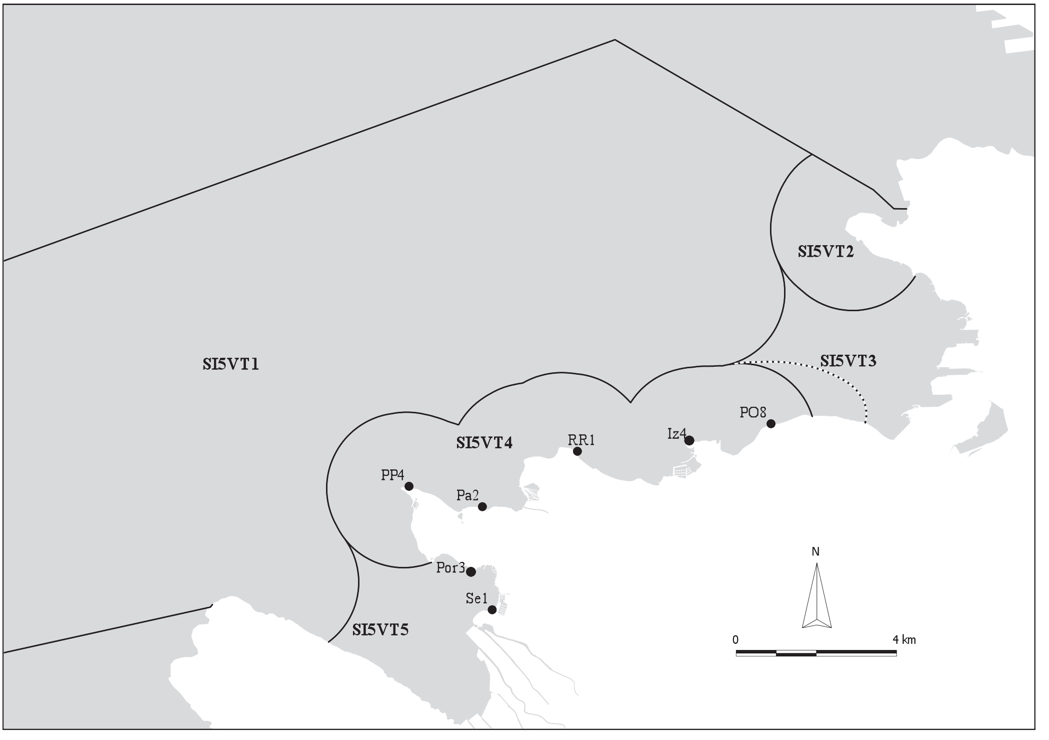


Figure 1: The study area (Slovenian coastal waters) with seven sampling sites for the 2007 monitoring programme.
Figure 1: Obravnavano območje (slovenske obalne vode) s sedmimi vzorčnimi mesti za program monitoringa v letu 2007.

2.2 DATA ANALYSIS

The macrophyte species were divided into two Ecological State Groups (ESG). In ESG I, the thick leathery, articulate upright calcareous and crustose calcareous species, most of them *k*-selected species, were grouped. In ESG II were grouped the foliose, the filamentous and the coarsely branched upright species, most of them *r*-selected species.

The EEI is a number ranging from 2 to 10. To determine the EEI of water bodies, the following procedure was used (Orfanidis et al. 2001, 2003):

The sampling area (where the bottom is rocky) was divided into non-overlapping permanent lines (PL) and several relevées of benthic vegetation were obtained from each. According to the Impress (2003), the length of each segment of rocky coast was defined with regard to known and possible pressures (maritime traffic, mariculture, municipal waste waters, harbours, industry, agriculture, etc.) as well as geomorphology of the coast and seabed.

In each relevé, the absolute abundance (%) of each ESG was estimated by its coverage.

The average coverage (%) of ESG I and II are cross compared in a matrix to determine the ES of the PLs in a range of five categories from high to bad. A numerical scoring system was used to express the ES categories to a numerical value (bad = 2, low = 4, moderate = 6, good = 8, high = 10).

The length of each PL was multiplied by its ES value and divided by the sum of all the lengths of the PLs. The length-weighted values were then summed to obtain EEI and the ES category of each water body (> 8 = high, 8->6 = good, 6->4 = moderate, 4->2 = low, 2 = bad).

3. RESULTS

3.1 STRUCTURAL AND FUNCTIONAL ANALYSIS

The list of macrophyte species and their average coverage (%) recorded in 2007 is presented in Table 1. Forty-one (41) taxa were identified in total, with 20 Rhodophyceae (dominating qualitatively), 12 Phaeophyceae (dominating quantitatively) and 9 Chlorophyceae.

Twenty-four (24) of the taxa belong to ESG I and 17 to ESG II. Using EEI, the seven sampling sites were classified into five Ecological Status Classes (Figures 2 and 3). Five sites were evaluated as *High*, while two were assessed as *Moderate*.

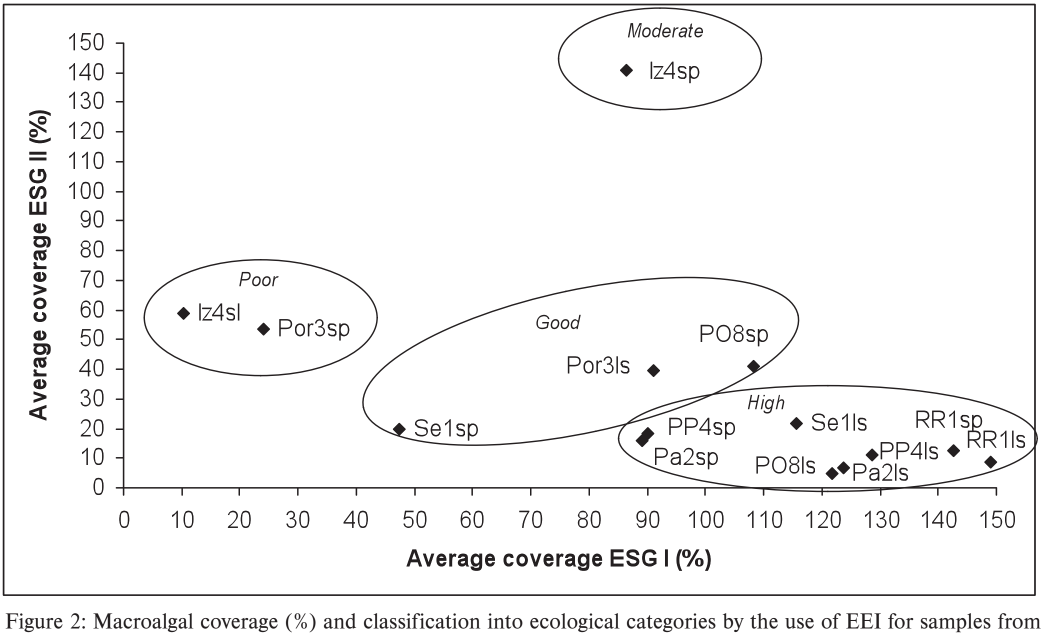


Figure 2: Macroalgal coverage (%) and classification into ecological categories by the use of EEI for samples from 2007 (sp = spring samples, ls = late summer samples).

Slika 2: Pokrovnost makroalg (%) in razvrstitev v ekološke kategorije z uporabo EEI za vzorce iz leta 2007 (sp = spomladanski vzorci, ls = poznopoletni vzorci).

At three sampling sites (RR1, Pa2 and PP4), the ES of macroalgae was evaluated as *High* during spring and late summer as well (Figure 2). In the spring period, *Cystoseira* species were dominant, while in the late summer *Halopithys incurva* and *Padina pavonica* were the most abundant species.

Table 1: List of species and average coverage (42 samples) of macrophytes at monitoring sampling sites in 2007 expressed as % of the sampling surface. ESG = Ecological State Groups.

Tabela 1: Seznam vrst in povprečna pokrovnost (42 vzorcev) makrofitov na vzorčnih mestih v letu 2007, izražena kot % vzorčevalne površine. ESG = Ecological State Groups (ekološki razredi).

ESG	SPECIES	Coverage (%)
ESG I	*Acetabularia acetabulum* (Linnaeus) P.C. Silva	0.08
	Alsidium corallinum C. Agardh	4.54
	Anadyomene flabellata J.V. Lamouroux	0.02
	Corallina officinalis Linnaeus	0.27
	Cystoseira barbata (Stackhouse) C. Agardh	7.75
	Cystoseira compressa (Esper) Gerloff & Nizamuddin	10.92
	Cystoseira corniculata (Turner) Zanardini	0.46
	Cystoseira sauvageauana G. Hamel	0.83
	Cystoseira sp.	0.27
	Flabellia petiolata (Turra) Nizamuddin	0.75
	Halimeda tuna (J. Ellis & Solander) J.V. Lamouroux	4.79
	Haliptilon virgatum (Zanardini) Garbary & H.W. Johansen	3.46
	Halopithys incurva (Hudson) Batters	19.71
	Hydrolithon spp.	0.85
	Jania sp.	0.85
	Lithophyllum spp.	0.06
	Lithothamnion spp.	0.63
	Padina pavonica (Linnaeus) Thivy	30.08
	Peyssonnelia polymorpha (Zanardini) F. Schmitz	1.42
	Peyssonnelia squamaria (S.G. Gmelin) Decaisne	2.73
	Phyllophora sp.	0.48
	Pseudolithophyllum sp.	0.21
	Rhodymenia sp.	0.10
	Zanardinia prototypus (Nardo) Nardo	0.29
ESG II	*Ceramium* spp.	0.15
	Chondria spp.	0.04
	Cladophora spp.	6.21
	Codium bursa (Olivi) C. Agardh	0.06
	Codium vermilara (Olivi) Chiaje	1.79
	Dictyota dichotoma (Hudson) J.V. Lamouroux	5.85
	Dictyota linearis (C. Agardh) Greville	0.85
	Dictyopteris polypodioides (A.P. de Candolle) J.V. Lamouroux	2.52
	Gelidium spp. J.V. Lamouroux	0.06
	Gigartina sp.	5.42
	Halopteris spp. Kützing	0.38
	Laurencia spp.	0.15
	Polysiphonia spp.	0.08
	Pterocladiella capillacea (S.G. Gmelin) Santelices & Hommersand	0.02
	Sphacelaria spp.	5.06
	Ulva spp.	0.19
	Valonia utricularis (Roth) C. Agardh	0.71

At two sampling sites (PO8 and Se1), the spring *Good* ES turned into *High* Ecological Status during the late summer (Figure 2). At both sites, *Cystoseira* species were missing, while *H. incurva, Alsidium corallinum* and *P. pavonica* dominated quali-quantitatively. At Por3 site, the spring *Poor* ES improved into a Good ES in late summer, principally due to a very high coverage of *P. pavonica.*

At Iz4 site, the spring *Moderate* Ecological Status, with *Cystoseira compressa* as the dominant ESG I species, deteriorated into a *Poor* ES during the late summer, with a high coverage of species from ESG II and a drastic decrease in the coverage of *C. compressa*.

Using spatial scale weighted EEI, the two water bodies were classified in Ecological Status Classes (Table 2). While the ESC in water body SI5VT4 was evaluated as *High*, the ESC in water body SI5VT5 was assessed as *Good*.

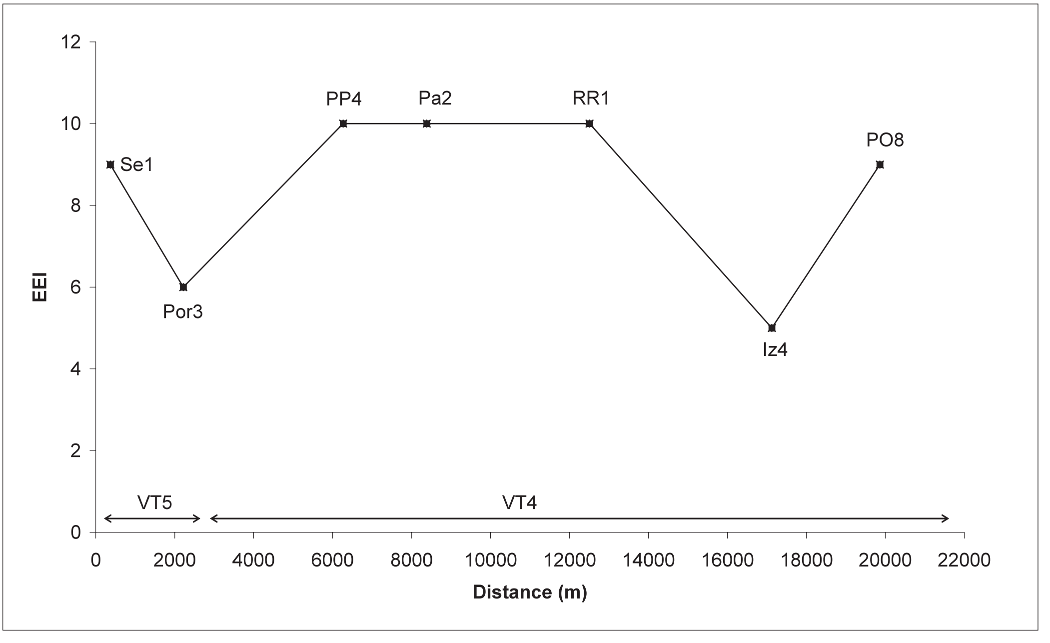


Figure 3: Classification of monitoring sampling sites for the year 2007 into ecological categories by the use of EEI.
Slika 3: Razvrstitev vzorčnih mest za monitoring v letu 2007 v ekološke razrede po EEI.

Table 2: Ecological status achieved by two Slovenian coastal water bodies in 2007.
Tabela 2: Ekološko stanje, ki sta ga leta 2007 dosegli dve obalni vodni telesi.

WB	Site	Length (m)	EEI	Length x EEI	Weighted EEI	ESC
SI5VT4	PO8	2934.10	9	26406.89	**9.24**	**HIGH**
	Iz4	1470.25	5	7351.23		
	RR1	3203.80	10	32037.96		
	Pa2	2485.25	10	24852.52		
	PP4	3391.24	10	33912.41		
SI5VT5	Por3	889.96	6	5539.78	**7.26**	**GOOD**
	Se1	645.80	9	5812.19		

4. DISCUSSION

The EEI results for five of the seven sampling sites confirm those from the preliminary study (Orlando-Bonaca et al. 2008). The 2007 sampling allowed the observation of seasonal differences in species composition and coverage between spring and late summer samples. At almost all sampling sites, the ES was higher in late summer, with the exception of Iz4. At this site, the late summer situation was worse than that in spring, while in the late summer of 2006 the ES was evaluated as *High,* with *A. corallinum* as the dominant species. In 2007 samples, this red alga covered only 6% of the sampling area (average value). We suppose that in 2007 the Iz4 site was subject to high nutrients inputs. This assumption would explain why in spring samples, only *C. compressa* was present and very abundant among *Cystoseira* species (with thallus almost 70 cm high). The morphological plasticity of the thallus of *C. compressa*, with a luxuriant form with erect fronds in spring and a rosette-shaped form in late summer, autumn and winter, was previously described for the Gulf of Trieste by Falace et al. (2005). Giaccone et al. (1994) reported that under particular ecological conditions other species than *C. crinita* become very abundant in the association *Cystoseiretum crinita*e Molinier, 1958, forming recognisable subassociations. *Cystoseiretum crinitae* subass. *Cystoseiretosum compressae* was defined as dominant at unperturbed sites with mild pollution (Giaccone et al. 1994, Cormaci et al. 2003). The coexistence of the late-successional and opportunistic species (*e.g.* intermediate disturbance hypothesis by Connell 1978) forms communities that are indicative of intermediate conditions, which reflects the situation at Iz4 site.

For Por3 site, the 2007 results indicate that the ES evaluated in 2006 was too high. *P. pavonica* was confirmed as the dominant species from ESG I. The species is representative of the association *Cystoseiretum crinita*e Molinier, 1958, but it forms large enclaves where the environmental factors prevent the growth of *Cystoseira* species. The turbid conditions at Por3 site (*own observations*) reduce the light penetration and thus prevent development of the highest photophilic layer, composed mostly of brown algae with thick blades and branches. Since long-lived genera like those from the order Fucales follow long-term periodicity, their absence from a site should be regarded as indicative of environmental degradation, when correlated with key abiotic parameters, like nutrient inputs and light attenuation (see Gibson *et al*. 2000).

Despite the above mentioned differences for two sampling sites, the EEI assessment of the ES of two water bodies in 2007 is in agreement with the preliminary study (Orlando-Bonaca et al. 2008) and existing human pressures. On the basis of the obtained data for the year 2007, the ES of Slovenian coastal waters was reconfirmed as *High/Good* in terms of the European Water Framework Directive criteria. This result is generally in agreement with the preliminary evaluation of the ES of the Istrian coast near Rovinj (Iveša et al. 2008), where a *Good* ES was achieved with sampling macroalgae within the very same depth range. Iveša et al. (2008), like Arévalo et al. (2007), expressed scepticism about the correct evaluation of the role of algae *C. compressa* and *Corallina elongata* that belong to ESG I, but in the CARLIT method they are associated with intermediate ES levels. In Slovenian coastal waters, these algae do not provide equivocal results. Our data for Iz4 site demonstrate that where a relevant nutrient input is present, *C. compressa* is surrounded by a thick layer of algae from ESG II. According to EEI, this site was evaluated as *Moderate,* which is the ES that would probably be reached by CARLIT as well. *C. elongata* was not found in Slovenian coastal waters, but the congeneric *C. officinalis* is usually present (although never abundant) only in samples evaluated as *Good/High* ES (Orlando-Bonaca et al. 2008).

Since monitoring programmes are the main drivers to determine long-term changes in coastal environment due to natural cycles or anthropogenic activities, and since no long-term data series for benthic macrophytes are available for the Slovenian coastal waters, these long-term field investigations are recommended to be carried on.

5. SUMMARY

The Ecological Evaluation Index (EEI) has been used to assess the Ecological Status (ES) of Slovenian coastal waters. The results of this preliminary assessment of benthic macroalgae led to a selection of seven sampling sites, dominated by late-successional species, for the surveillance monitoring programme. The aim of the study was to verify if the results of the monitoring programme confirm the first assessment or indicate different conditions of benthic macroalgae in Slovenian coastal waters. The sampling was performed seasonally, in spring and late summer. Despite variations for two sampling sites, the EEI assessment of the ES in 2007 is in good agreement with the preliminary study and was reconfirmed as *High/Good*. Since monitoring programmes are the main drivers to determine long-term changes in coastal environment due to natural cycles or anthropogenic activities, it is recommended that these long-term field investigations are carried on.

POVZETEK

Za oceno ekološkega stanja (ES) slovenskih obalnih voda je bil uporabljen Indeks ovrednotenja ekološkega stanja (EEI). Na podlagi rezultatov predhodne ocene bentoških makroalg je bilo za nadzorni monitoring izbranih sedem vzorčnih mest, s prevladujočimi vrstami z dolgo vegetacijsko dobo. Namen študije je bil preveriti ali rezultati monitoringa potrjujejo prvo oceno ali pa kažejo na drugačno stanje bentoških makroalg v slovenskih obalnih vodah. Vzorčenje je bilo opravljeno sezonsko, spomladi in pozno poleti. Kljub razlikam na dveh vzorčnih mestih je ocena ES v letu 2007 potrdila rezultate predhodne študije in je ES bilo potrjeno kot *Zelo dobro/Dobro*. Upoštevaje dejstvo, da so programi monitoringa glavno gonilo pri ugotavljanju dolgoročnih sprememb v obalnem okolju zaradi naravnih ciklov ali antropogenih vplivov, je nadvse priporočljivo, da se dolgoročne terenske raziskave nadaljujejo.

6. ACKNOWLEDGEMENTS

The authors would like to thank Žiga Dobrajc and Marko Tadejević for their help during the fieldwork. The study was financially supported by the Environmental Agency of the Republic of Slovenia.

7. LITERATURE

1. Arévalo, R., S. Pinedo, E. Ballesteros (2007): Changes in the composition and structure of Mediterranean rocky-shore communities following a gradient of nutrient enrichment: descriptive study and test of proposed methods to assess water quality regarding macroalgae. Marine Pollution Bulletin 55: 104-113
2. Ballesteros, E., X. Torras, S. Pinedo, M. García, L. Mangialajo, M. de Torres (2007): A new methodology based on littoral community cartography dominated by macroalgae for the implementation of the European Water Framework Directive. Marine Pollution Bulletin 55: 172-180
3. Bressan, G., L. Babbini (2003): Corallinales del Mar Mediterraneo: Guida alla determinazione. Biologia Marina Mediterranea 10(2). 237 pp.
4. Boicourt, W.C., M. Kuzmić, T.S. Hopkins (1999): The Inland Sea: Circulation of Chesapeake Bay and the Northern Adriatic. In: Malone, T.C., A. Malej, L.W.Jr. Harding, N. Smodlaka, R.E. Turner (*Eds.*): Ecosystems at the Land-Sea Margin: Drainage Basin to Coastal Sea. Coastal and Estuarine Studies 55: 81-129
5. Boudouresque, C.F., T. Belsher (1979): Le peuplement algal du port de Port-Vendres: Recherches sur l'aire minimale qualitative. Cah. Biol. mar. 20: 259-269
6. Chryssovergis, F., P. Panayotidis (1995): Évolution des peuplements macrophytobenthiques le long d'un gradient d'eutrophisation (Golfe de Maliakos, Mer Égée, Gr ce). Oceanologica Acta 18: 649–658
7. Connell, J. H. (1978): Diversity in tropical rain forests and coral reefs. Science 199: 1302-1309
8. Cormaci, M., G. Furnari, G. Giaccone (2003): Macrofitobenthos. In: Gambi M.C., Dapiano M. (*Eds.*): Manuale di metodologie di campionamento e studio del benthos marino mediterraneo. Biol. Mar. Medit. 10(Suppl.): 233-262
9. Falace, A., E. Zanelli, G. Bressan (2005): Morphological and reproductive phenology of *Cystoseira compressa* (Esper) Gerloff & Nizamuddin (Fucales, Fucophyceae) in the Gulf of Trieste (North Adriatic Sea). Annales Series Historia Naturalis 15(1): 1-8
10. Gallardo, T., A. Gómez-Garreta, M.A. Ribera, M. Cormaci, G. Furnari, G. Giaccone, C.F. Boudouresque (1993): Check-list of Mediterranean seaweeds. 2. *Chlorophyceae.* Botanica Marina 36(5): 399-421
11. Giaccone, G. (1993): The vertical zonation along the phytal system in the Mediterranean sea and the effects of municipal and industrial wastewater disposal on phytobenthos communities. Fifth Optima Meeting, Istanbul 5: 47–56
12. Giaccone, G., G. Alongi, F. Pizzuto, A. Cossu (1994): La vegetazione marina bentonica fotofila del Mediterraneo: II. Infralitorale e Circalitorale. Proposte di aggiornamento. Bollettino Accademia Gioenia Scienze Naturali Catania 27: 111-157
13. Gibson, G.R., M.L. Bowman, J. Gerritsen, B.D. Snyder (2000): Estuarine and coastal marine waters: bioassessment and biocriteria technical guidance. EPA 822-B-00-024. US Environmental Protection Agency, Office of Water. Washington D.C. http://www.epa.gov/waterscience/biocriteria/States/estuaries/estuaries.pdf (3. mar. 2009)

14. Gómez Garreta, A., T. Gallardo, M.A. Ribera, M. Cormaci, G. Furnari, G. Giaccone, C.F. Boudouresque (2001): Checklist of the Mediterranean seaweeds. III. *Rhodophyceae*. Botanica Marina 44: 425-460
15. Impress (2003): Guidance Document No. 3, Analysis of Pressures and Impacts, 157 pp.
16. Iveša, L., D.M. Lyons, M. Devescovi (2008): Assessment of the ecological status of north-eastern Adriatic coastal waters (Istria, Croatia) using macroalgal assemblages for the European Union Water Framework Directive. Aquatic Conservation: Marine and Freshwater Ecosystems, DOI: 10.1002/aqc.964
17. Orfanidis, S., P. Panayotidis, N. Stamatis (2001): Ecological evaluation of transitional and coastal waters: A marine benthic macrophytes-based model. Mediterranean Marine Science 2(2): 45-65
18. Orfanidis, S., P. Panayotidis, N. Stamatis (2003): An insight to the ecological evaluation index (EEI). Ecological Indicators 3: 27-33
19. Orlando-Bonaca, M., L. Lipej, S. Orfanidis (2008): Benthic macrophytes as a tool for delineating, monitoring and assessing ecological status: the case of Slovenian coastal waters. Marine Pollution Bulletin 56(4): 666-676
20. Panayotidis, P., B. Montesanto, S. Orfanidis (2004): Use of low-budget monitoring of macroalgae to implement the European Water Framework Directive. Journal of Applied Phycology 16: 49-59
21. Ribera, M.A., A. Gómez-Garreta, T. Gallardo, M. Cormaci, G. Furnari, G. Giaccone (1992): Check-list of Mediterranean Seaweeds. I. *Fucophyceae*. Botanica Marina 35: 109-130
22. Turk, R. (1999): An assessment of the vulnerability of the Slovene coastal belt and its categorisation in view of (in)admissible human pressure, various activities and land-use. Annales, Series historia naturalis 15: 37-50

Martina ORLANDO-BONACA, Lovrenc LIPEJ
Marine Biology Station
National Institute of Biology
Fornače 41
SI– 6330 Piran, Slovenia
orlando@mbss.org

TOWARDS IDENTIFICATION OF THE BOTTLENOSE DOLPHIN (*TURSIOPS TRUNCATUS*) POPULATION STRUCTURE IN THE NORTH-EASTERN ADRIATIC SEA: PRELIMINARY RESULTS

IDENTIFIKACIJA POPULACIJSKE STRUKTURE VELIKE PLISKAVKE (*TURSIOPS TRUNCATUS*) V SEVEROVZHODNEM JADRANU: PRVI REZULTATI

Tilen GENOV, Annika WIEMANN, Caterina M. FORTUNA

Keywords: *Tursiops truncatus*, bottlenose dolphin, Adriatic, photo-identification, conservation, population structure
Ključne besede: *Tursiops truncatus*, velika pliskavka, Jadran, fotoidentifikacija, varstvo, populacijska struktura

ABSTRACT

Two longitudinal studies on the ecology of bottlenose dolphins (*Tursiops truncatus*) are being implemented in the Northern Adriatic Sea. One has been carried out since 1987 in the Kvarnerić, Croatia, the other since 2002 in Slovenian and adjacent waters. Standard photo-identification procedures enabled us to identify 238 and 55 individual dolphins, respectively. The aim of this study was to determine the potential distribution overlap in two local populations studied and to gain insight into the ranging patterns of bottlenose dolphins in the North-eastern Adriatic Sea. Photo-identification catalogues were compared in order to determine possible matches. First results indicate little overlap between the dolphins observed in the two study areas. This information is essential for future management and conservation strategies. Further comparative studies between the two study sites and other areas will be carried out to provide more information on the status of bottlenose dolphins in the North-eastern Adriatic Sea.

IZVLEČEK

Trenutno v severnem Jadranskem morju potekata dve longitudinalni študiji o ekologiji velike pliskavke (*Tursiops truncatus*). Prva je dobila zagon že leta 1987 v Kvarneriću, Hrvaška, druga pa leta 2002 v slovenskih in sosednjih vodah. Standardni fotoidentifikacijski postopki so omogočili avtorjem pričujočega članka prepoznati 238 osebkov te vrste v Kvarneriću in 55 v slovenskih in sosednjih vodah. Namen študije je bil ugotoviti morebitno medsebojno prekrivanje obeh preučevanih lokalnih populacij in zagotoviti nov vpogled v vzorce njunih arealov v severovzhodnem Jadranskem morju. Pri ugotavljanju morebitnega mešanja med populacijama so si avtorji pomagali s primerjavami fotografij v dveh fotoidentifikacijskih katalogih. Prvi rezultati so pokazali, da je mešanje med delfini, opaženimi v dveh preučevanih območjih, majhno. To pa je podatek, ki je nadvse pomemben za prihodnje varstvene strategije, ki zadevajo veliko pliskavko v tem delu Jadrana. Sicer pa so z namenom, da se zagotovijo nadaljnji podatki o statusu velike pliskavke v severovzhodnem Jadranskem morju, v načrtu že nove primerjalne študije v obeh preučevanih in tudi drugih območjih.

1. INTRODUCTION

The bottlenose dolphin (*Tursiops truncatus*) is the only cetacean species regularly observed in the Northern Adriatic Sea in recent times (Kryštufek et Lipej 1993, Notarbartolo di Sciara et al. 1993, Bearzi et Notarbartolo di Sciara 1995, Bearzi et al. 2004) and one of the most studied cetacean species in the world (Shane et al. 1986, Leatherwood et Reeves 1990, Connor et al. 2000, Bearzi et al. 2009). However, the knowledge on the status of this species in the Adriatic Sea is still far from complete.

The first long-term study on the ecology of bottlenose dolphins in the Adriatic started in 1987 by the Tethys Research Institute and is now being implemented in the Kvarnerić, Croatia, by the Blue World Institute of Marine Research and Conservation (Bearzi et al. 1997, 1999, Mackelworth et al. 2003, Rako 2006, Fortuna 2006). The size of the local bottlenose dolphin population has been estimated to approximately 100-130 dolphins (Fortuna 2006). The animals are present in the area year-round and the local population has been resident at least over the last 20 years (Bearzi et al. 1997, Fortuna 2006).

A similar study was initiated in Slovenian waters in 2002 by Morigenos – Marine Mammal Research and Conservation Society (Genov et Fortuna 2005, Genov et Wiemann 2005, Genov et al. 2008). The project was initially focused on Slovenian waters, but soon expanded to the neighbouring areas in Croatia and Italy, due to the small size of Slovenian waters alone and the transboundary nature of dolphins' ranging patterns. The project focuses on bottlenose dolphin distribution, abundance, social structure, behaviour, fishery interactions and influence of maritime traffic on dolphins. Land-based and boat-based surveys were carried out between 2002 and 2008. Group follow protocol (Mann 1999, 2000) was used each time the dolphin groups were encountered and standard photo-identification procedures (Würsig et Jefferson 1990) were carried out. Dolphins can be seen in the study area year-round. Resighting rates within and between years suggest that at least some individuals are resident in the area and the size of the local bottlenose dolphin population has been estimated to approximately 70 dolphins (Genov et al. 2008). Observations of feeding behaviour and mother-calf pairs suggest that the area is used for feeding, breeding and nursing (Genov et al. 2008).

The aim of this study was to determine whether these were the same or different dolphins and therefore if the two local populations mix or overlap in distribution.

2. MATERIAL AND METHODS

Study areas are shown in Figure 1. Survey protocols and field methods for these studies are described in detail in Fortuna (2006) and in Genov et al. (2008). In both studies, non systematic boat surveys and photo-identification were applied. Photo-identification catalogues (Figure 2) of both local populations were compared in order to determine the presence of possible matches and thus an overlap between the animals inhabiting the two respective study areas. Only Morigenos dataset from 2002 to 2005 and Blue World dataset from 2001 to 2005 were considered for this particular analysis. Considering that the two datasets time-frame was the same, any bias due to mark-loss was believed to be minimal. All photographs in the two catalogues were visually examined. Each catalogue was examined independently in turn, thus datasets were cross-checked for possible matches.

Figure 1: Study areas. The two study areas are roughly 150km apart.
Slika 1: Preučevani območji sta med seboj oddaljeni približno 150km.

Figure 2: A bottlenose dolphin (Tursiops truncatus) showing distinct identifying marks on the dorsal fin. (Photo: Tilen Genov)
Slika 2: Velika pliskavka (Tursiops truncatus) z vidnimi identifikacijskimi znamenji na hrbtni plavuti. (Foto: Tilen Genov)

3. RESULTS AND DISCUSSION

During the study period, a total of 51 sightings were recorded and 55 individuals photo-identified in Slovenian and adjacent waters. A total of 263 sightings were recorded and 238 individuals photo-identified in the Kvarnerić. No matches between the two study areas were found for that study period. These preliminary results suggest that two separate local populations are present in the two study areas, and they appear to mix rarely. However, these results should be considered preliminary. They certainly do not mean that the two local populations are completely separated or genetically isolated. In fact, genetic evidence has shown that all Adriatic dolphins likely belong to a single genetic population (Natoli et al. 2005). Furthermore, there is a possibility of future matches, as the number of identified individuals in Morigenos' catalogue has recently increased to 101 animals (Genov et al. 2008). Moreover, adjacent areas in western Istria are additionally being covered as a result of a cooperative project, carried out since 2005 by the Blue World and Morigenos, which could lead to potential future matches.

The two study areas are roughly 150 km apart (Figure 1). The significance of this distance is debatable for bottlenose dolphins, which often live in relatively restricted home ranges, but are known to be capable of travelling long distances in short time. For example, Würsig (1978) reported bottlenose dolphins travelling more than 300 km in one direction and then returning to the original site. They therefore made at least a 600 km round trip. However, a resident local population of bottlenose dolphins around Île de Sein (Brittany, France) always stays within an area not larger than 5 km^2 and another local population in the nearby Molene archipelago uses a range of about 70 km^2 (Liret et al. 1996). In Moray Firth (Scotland), individual bottlenose dolpihins were seen travelling 218 km in 2 days, 190 km in 5 days and 65 km in 1 day, respectively (Wilson et al. 1997, 2004). All these cases represent »coastal« form of bottlenose dolphins. In the south-eastern United States, an »offshore« form male bottlenose dolphin, tracked with a satellite-linked transmitter, travelled 4,200 km in 47 days, while an »intermediate « form (intermediate form between »coastal« and »offshore« form) male bottlenose dolphin travelled 2,050 km in 43 days (Wells et al. 1999). Therefore, the ranges of bottlenose dolphins seem to vary a great deal. Although many bottlenose dolphins clearly concentrate their activities within certain ranges, it is still unclear how limiting these ranges are. For now, long-distance movements or seasonal migration have not been observed in the North-eastern Adriatic. However, dolphins seem to have relatively large permanent ranges, which (in both studies) appear to be bigger than the chosen study areas (Bearzi et al. 1997, Genov et al. 2008). Our coverage of the dolphins' range is therefore limited.

Photo-identification data from the Kvarnerić has shown that dolphins using the »inside« part of the archipelago (between islands) also occasionally use the west side of the island (»outside« the island chain). But other animals found occasionally on the west side (often just once) and considered "visitors", were never or rarely seen inside the archipelago. It is therefore possible that Lošinj and the other islands form some sort of a natural barrier (a bottleneck), which reduces the amount of flow between these areas, at least to some extent. However, it should also be noted that the areas west of Lošinj are ecologically somewhat more similar to the area of the Gulf of Trieste and western Istria, while the areas east of Lošinj (inside the archipelago) are substantially different in terms of depth, bottom topography and habitat types. This could suggest that the two local populations or »social groups« have different ecologies. In fact, the behaviour, feeding activities and intermixing of groups in both areas appear to differ (Bearzi et al. 1997, Genov et al. 2008).

The comparisons with other areas are needed in order to gain additional insights into the ranging patterns of the Northern Adriatic bottlenose dolphins. For example, 42 bottlenose dolphins have been identified off Venice by the Tethys Research Institute (S. Bonizzoni, pers. comm.). Comparison with that catalogue could potentially provide more matches between Morigenos' catalogue and Venice catalogue for two reasons. Firstly, the distance between the two areas is shorter. Secondly, the lack of natural barriers, such as the islands delimiting the Kvarnerić archipelago and/or the presence of one of the main Adriatic currents along the outer margins of Kvarnerić islands could be responsible for differences in ecologies and therefore distribution of different groups or local populations of bottlenose dolphin.

The question remains regarding the population structure of bottlenose dolphins in the North-eastern Adriatic. Several hypotheses are possible: a) one single and very large population with small local populations or sub-populations (social groups); b) scattered and distinct local populations; c) slightly overlapping local populations; d) one single continuous, but relatively small local population. The answer to this question has direct conservation implications. For the bottlenose dolphin, fluid social groups are regarded typical, but dolphins do not disperse far from their natal groups (Natoli et al. 2004, Connor et al. 2000). Differences in the distribution of prey, reflecting differences in habitat, may be defining the geographical range and patterns of association in local populations. Local populations of bottlenose dolphins are habitat dependent in a way that likely defines patterns of movement. They have been shown to favour specific habitat types, which is consistent with our observations.

The degree of mixing or genetic isolation between populations can only be determined after individual population units have been identified through consideration of (ideally) behaviour, morphology and genetics (Shane et al. 1986). Therefore, other forms of evidence are needed to confirm the results of photo-identification. But even if Adriatic dolphins belong to just a single genetic population, local populations might still be sufficiently separated in social terms to be considered as separate conservation units.

4. CONCLUSION

This study clearly represents only the first step in the attempt to define the population structure and ranging patterns of the North-eastern Adriatic bottlenose dolphins. As the number of photo-identified individuals in Morigenos catalogue is still rising, further comparative studies between the two study sites and other areas will be carried out. Yet this study represents an important step in understanding their distribution and population structure and this has implications on the management and conservation of Adriatic dolphins. In one way, the absence of matches could be a positive result, indicating the likely existence of a »bigger« population in relative terms. It is worth noting that the Kvarnerić population is small and showing a declining trend in abundance between 1995 and 2003 (Fortuna 2006). Future research in the region, taking both photo-identification and genetics into account, will provide additional insights into the population structure of the Adriatic bottlenose dolphins. This information is essential for future management and conservation strategies.

5. SUMMARY

Two long-term studies on the ecology of bottlenose dolphins (*Tursiops truncatus*) are being implemented in the northern Adriatic Sea. One is being carried out since 1987 in the Kvarnerić, Croatia, the other since 2002 in Slovenian and adjacent waters. Standard photo-identification procedures enabled us to identify 238 and 55 individual dolphins, respectively. The local Kvarnerić population has been estimated at approximately 100-130 animals, the local population from Slovenian and adjacent waters at approximately 70 animals. The aim of this study was to determine the potential distribution overlap in two local populations studied and to gain insight into the ranging patterns of bottlenose dolphins in the north-eastern Adriatic Sea. Photo-identification catalogues were compared in order to determine possible matches. Only datasets collected between 2001 and 2005 were considered for this particular analysis. The resulting lack of matches indicates little overlap between the dolphins observed in the two study areas, although it is unlikely that the two local populations are completely genetically separated. This information is essential for future management and conservation strategies, as the two local populations should be regarded as two separate conservation units. Further comparative studies between the two study sites and other areas will be carried out to provide more information on the status of bottlenose dolphins in the North-eastern Adriatic Sea.

POVZETEK

Trenutno v severnem Jadranskem morju potekata dve longitudinalni študiji o ekologiji velike pliskavke (*Tursiops truncatus*). Prva se je začela že leta 1987 v Kvarneriću, Hrvaška, druga pa leta 2002 v slovenskih in sosednjih vodah. Standardni fotoidentifikacijski postopki so omogočili avtorjem pričujočega članka prepoznati skupaj 238 osebkov te vrste v Kvarneriću in 55 v slovenskih in sosednjih vodah. Sicer pa je lokalna populacija v Kvarneriću ocenjena na 100-130, v slovenskih in sosednjih vodah pa na približno 70 velikih pliskavk. Namen študije je bil ugotoviti morebitno medsebojno prekrivanje obeh preučevanih lokalnih populacij in zagotoviti nov vpogled v vzorce njunih arealov v severovzhodnem Jadranskem morju. Pri ugotavljanju morebitnega mešanja med populacijama so si avtorji pomagali s primerjavami fotografij v dveh fotoidentifikacijskih katalogih. Za pričujočo analizo so bili upoštevani le podatki, pridobljeni med letoma 2001 in 2005. Ugotovljeno pomanjkanje prekrivanja med obema katalogoma kaže na majhno mešanje med delfini, opazovanimi v obeh preučevanih območjih, vendar je možnost, da sta lokalni populaciji genetsko povsem ločeni, majhna. Ta podatek je vsekakor nujen za prihodnje strategije upravljanja in varstva, saj je treba na dve lokalni populaciji gledati

kot na dve ločeni enoti varstva. Z namenom, da se zagotovijo nadaljnji podatki o statusu velike pliskavke v severovzhodnem Jadranskem morju, pa so v načrtu že nove primerjalne študije v obeh preučevanih in tudi drugih območjih.

6. LITERATURE

1. Bearzi, G., G. Notarbartolo di Sciara (1995): A comparison of the present occurrence of bottlenose dolphins, *Tursiops truncatus*, and common dolphins, *Delphinus delphis*, in the Kvarnerić (Northern Adriatic Sea). Annales (Annals for Istrian and Mediterranean Studies) 7: 61–68
2. Bearzi, G., G. Notarbartolo di Sciara, E. Politi (1997): Social ecology of bottlenose dolphins in the Kvarneric (northern Adriatic Sea). Marine Mammal Science 13: 650–668
3. Bearzi, G., E. Politi, G. Notarbartolo di Sciara (1999): Diurnal behavior of free-ranging bottlenose dolphins in the Kvarneric (northern Adriatic Sea). Marine Mammal Science 15: 1065–1097
4. Bearzi, G., D. Holcer, G. Notarbartolo di Sciara (2004): The role of historical dolphin takes and habitat degradation in shaping the present status of northern Adriatic cetaceans. Aquatic Conservation: Marine and Freshwater Ecosystems 14: 363–379
5. Bearzi, G., C.M. Fortuna, R.R. Reeves (2009): Ecology and conservation of common bottlenose dolphins *Tursiops truncatus* in the Mediterranean Sea. Mammal Review 39(2):92-123
6. Connor, R.C., R.S. Wells, J. Mann, A.J. Read (2000): The bottlenose dolphin: social relationships in a fission-fusion society. In: Mann J., Connor R.C., Tyack P.L., Whitehead H. (eds.): Cetacean societies. University of Chicago Press. Chicago. 91-126
7. Fortuna, C.M. (2006): Ecology and conservation of bottlenose dolphins (*Tursiops truncatus*) in the north-eastern Adriatic Sea. PhD thesis, University of St. Andrews, Scotland. 256 pp.
8. Genov, T., C.M. Fortuna (2005): Towards the definition of the northern Adriatic bottlenose dolphin (*Tursiops truncatus*) home range. European Research on Cetaceans 19 - Proceedings of the 19th annual conference of the European Cetacean Society, La Rochelle, France, 2-7 April 2005.
9. Genov, T., A. Wiemann (2005): A comparative study of bottlenose dolphin cross-border movements in the north east Adriatic Sea. In: Abstract of the 16th Biennial Conference on the Biology of Marine Mammals, San Diego CA, USA, 12-16 December 2005
10. Genov, T., P. Kotnjek, J. Lesjak, A. Hace, C.M. Fortuna (2008): Bottlenose dolphins (*Tursiops truncatus*) in Slovenian and adjacent waters (northern Adriatic Sea). Annales, Series Historia Naturalis 18(2): 227-244
11. Kryštufek, B., L. Lipej (1993): Whales (Cetacea) in the northern Adriatic. Annals for Istrian and Mediterranean Studies 3: 9-20
12. Leatherwood, S., R.R. Reeves (1990): The Bottlenose Dolphin. Academic Press. San Diego. 653 pp.
13. Liret, C., P. Creton, G. Le Moal, V. Ridoux (1996). Dolphin home range and reserve zonation: do we need field studies to define management policy? European Research on Cetaceans 10: 15-19
14. Mackelworth, P., C.M. Fortuna, D. Holcer, A. Wiemann, L. Giannoni, B. Lazar (2003): The identification of critical habitats and the analysis of the management procedures for the future Lošinj-Cres marine protected area. Report prepared for the Ministry of the Environment & Physical Planning, under the contract KLASA 112-04/02-01/134, Ur.br. 531-06/1-02-1. 47 pp.
15. Mann, J. (1999): Behavioral sampling methods for cetaceans: a review and critique. Marine Mammal Science 15: 102–122
16. Mann, J. (2000): Unravelling the dynamics of social life: long-term studies and observational methods. In: Mann, J., Connor R.C., Tyack P.L., Whitehead H. (eds.): Cetacean societies. University of Chicago Press. Chicago. 45–64

17. Natoli, A., V.M. Peddemors, A.R. Hoelzel (2004): Population structure and speciation in the genus *Tursiops* based on microsatellite and mitochondrial DNA analyses. J. Evol. Biol. 17: 363–375
18. Natoli, A., A. Birkun, A. Aguilar, A. Lopez, A.R. Hoelzel (2005): Habitat structure and the dispersal of male and female bottlenose dolphins (*Tursiops truncatus*). Proceedings of the Royal Society B 272: 1217-1226
19. Notarbartolo di Sciara, G., M.C. Venturino, M. Zanardelli, G. Bearzi, J.F. Borsani, B. Cavalloni (1993): Cetaceans in the central Mediterranean Sea: distribution and sighting frequencies. Italian Journal of Zoology 60: 131–138
20. Rako, N. (2006): Annual characterization of the sea ambient noise (S.A.N.) in Lošinj-Cres archipelago (Croatia) as a potential source of bottlenose dolphin behavioural disturbance. MSc. Thesis. University of Trieste. Trieste. 114 pp.
21. Shane, S.H., R.S. Wells, B. Würsig (1986): Ecology, behavior and social organisation of the bottlenose dolphin: a review. Marine Mammal Science 2: 34–63
22. Wells, R.S., H.L. Rhinehart, P. Cunningham, J. Whaley, M. Baran, C. Koberna, D. Costa (1999): Long distance offshore movements of bottlenose dolphins. Marine Mammal Science 15: 1098–1114
23. Wilson, B., P.M. Thompson, P.S. Hammond (1997): Habitat use by bottlenose dolphins: seasonal distribution and stratified movement patterns in the Moray Firth, Scotland. Journal of Applied Ecology 34: 1265-1374
24. Wilson, B., P.S. Hammond, R.J. Reid, K. Grellier, P.M. Thompson (2004): Considering the temporal when managing the spatial: a population range expansion impacts protected areas-based management for bottlenose dolphins. Animal Conservation 7: 1-8
25. Würsig, B. (1978): Occurrence and group organization of Atlantic bottlenose porpoises (*Tursiops truncatus*) in an Argentine bay. Biological Bulletin 154: 348-359
26. Würsig, B., T.A. Jefferson (1990): Methods of photo-identification for small cetaceans. Report of the International Whaling Commission, Special Issue 12: 43–52

Tilen GENOV
Morigenos – Marine Mammal Research and Conservation Society
Jarška cesta 36/a
SI-1000 Ljubljana, Slovenia
tilen.genov@gmail.com

Annika WIEMANN
Blue World Institute of Marine Research and Conservation,
Kaštel 24, Veli Lošinj,
51551, Croatia

Caterina M. FORTUNA
Blue World Institute of Marine Research and Conservation,
Kaštel 24, Veli Lošinj,
51551, Croatia
Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA)
via di Casalotti 300
00166 Rome, Italy and
Tethys Research Institute,
Viale G.B. Gadio 2,
Milan, 20121, Italy

CONTRIBUTION TO THE KNOWLEDGE OF THE CHTHAMALIDS (CRUSTACEA, CIRRIPEDIA) ON THE SLOVENE ROCKY SHORE (GULF OF TRIESTE, NORTH ADRIATIC SEA)

PRISPEVEK K POZNAVANJU VITIČNJAKOV (CRUSTACEA, CIRRIPEDIA) NA KAMNITEM SLOVENSKEM OBREŽJU (TRŽAŠKI ZALIV, SEVERNO JADRANSKO MORJE)

Claudio BATTELLI, Nataša DOLENC-ORBANIĆ

Key words: *Chthamalus depressus* (*Euraphia depressa*), *Chthamalus montagui*, *Chthamalus stellatus*, vertical distribution, Slovene coast, North Adriatic Sea
Ključne besede: *Chthamalus depressus* (*Euraphia depressa*), *Chthamalus montagui*, *Chthamalus stellatus*, vertikalna razširjenost, slovensko morsko obrežje, severno Jadransko morje

ABSTRACT

In the supralittoral and mediolittoral of the Slovene coast, three species of chthamalids were recorded. The article discusses the species occurrence, vertical distribution patterns on two different substrata (sandstone and limestone) and presents a table for identification of recorded species.

IZVLEČEK

V supralitoralu in mediolitoralu slovenskega obrežja so bile zabeležene tri vrste vitičnjakov. Članek obravnava pojavljanje vrst ter vzorce vertikalne razširjenosti na dveh različnih podlagah (peščenjaku in apnencu) ter podaja tabelo za identifikacijo zabeleženih vrst.

1. INTRODUCTION

The Adriatic Sea is a long semi-enclosed basin of the Mediterranean Sea, whose northern part (North Adriatic) terminates in a relatively flat shelf with a mean depth of about 50 m. The Gulf of Trieste is a shallow marginal sea and the northernmost part of the Adriatic Sea surrounded by land on three sides. It contains relatively little water (only 0.4% of the Adriatic basin). It is characterized by high variations of salinity (32 to 38 PSU) and temperature (6,5°C in winter and 28°C in summer) and by high freshwater input mainly from the Soča (It. Isonzo), Tilment (It. Tagliamento), Rižana and Dragonja (Bussani et al. 2003) rivers. The tidal range is approximately 90 cm (Agencija RS za okolje 2009), while in the rest of the Mediterranean area the mean tidal amplitude is about 20-30 cm. The gulf is influenced mainly by the "burja" wind, blowing from the north-east to north-north-east, and "jugo", blowing from the south-south-east (Malačič et Jeromel 2005). The entire coast is also subject to intensive anthropogenic activity. All this make the gulf extremely sensitive to ecological changes.

The rocky substratum of the northern coast of the Gulf of Trieste consists mainly of limestone, while the southern part is composed of flysch layers with soft marl and solid sandstone (Pavlovec 1985, Ogorelec et al. 1997). The Slovenian coast, situated in the eastern part of the Gulf of Trieste, is characterized mainly by two rock types: flysch and limestone. This provides a useful area to test the role that the substrate plays in determination of community composition, distribution and density.

Recent studies reported that the main constituents among different species of the *Chthamalus* barnacles from the supralittoral and mediolittoral of the northern Adriatic rocky shores are: *Chthamalus depressus* (*Euraphia depressa*) (Poli), *C. stellatus* (Poli) and *C. montagui* Southward (Relini 1981, Zavodnik 1998, Zavodnik et al. 2005). The position and extension of chthamalids belts on the shore are generally related to tidal range and grade of exposure of the coast (Pannacciulli et Relini 2000).

Along the Slovene coast, only *C. depressus* for the supralittoral and *C. stellatus* for the mediolittoral zones are mentioned (Lipej et al. 2004). The first occurrence of the species *C. montagui* on the Slovene rocky shore was reported by Battelli et Dolenc-Orbanić (2008).

The purpose of this study was: a) to investigate the species composition and the distribution (at different tidal levels of the supralittoral and the mediolittoral zones) of the chthamalid communities on two different types of substrate (sandstone and limestone) and b) to give a general description of the identified species of chthamalids based on the external morphological features.

2. MATERIALS AND METHODS

Sampling was carried out in spring 2008 at three locations along the Slovene coast: Koper Bay – Ankaran (Lo1), Izola Bay – along the Koper-Izola coast (Lo2) and Piran Bay - Seča (Lo3) (Figure 1). The location Lo1 (Ankaran: 45° 34′ 17″ N, 13° 44′ 32″ E) was located on the northern side of Koper Bay, generally exposed to wave action generated by southwesterly and southeasterly winds. The location Lo2 (Koper-Izola coast: 45° 32′ 49″ N, 13° 41′ 11″ E) was situated on the southern part of Koper Bay. The shore was exposed to wave action and winds blowing from the north, west and northeast. The location Lo3 (Seča: 45° 30′ 01″ N, 13° 35′ 15″ E) was placed along the coast of Piran (Seča) Bay and exposed to wave action and winds blowing mainly from the west.

Although the mediolittoral zone of the Mediterranean rocky shore is usually divided into two parts (the upper mediolittoral, above the mean tidal level and the lower mediolittoral, under the mean tidal level) (Bellan-Santini et al. 1994 in UNEP, 1998), the authors of this study recognized three distinct parts (horizons) of the mediolittoral zone (upper, middle and lower). Each horizon is characterized by different tidal levels and horizontal banding of particular kinds of organisms (Figure 2).

On each location, one site on limestone and one site on sandstone were selected at the four shore heights (supralittoral and upper, middle and low mediolittoral). At each site, three 10 x 10 cm replicate squares were used to estimate densities for each species separately at each of these four heights. Only surfaces poor in vegetation and fauna, but abundant in chthamalids, were selected. Each square was scraped clean using a paint scraper. Samples were preserved in seawater-ethanol (80%) for later study. Determination of the samples took part in the laboratory, with stereo microscope, according to the works of Southward (1976) and Relini (1980) based on the morphological features. In this study, we took into consideration only the external morphological features, as follows: the shape of the opercular opening and of the adductor muscle scar and the position and the curvature of the articulation between terga and scuta. The collected material is kept in the laboratory of the Faculty of Education of Koper.

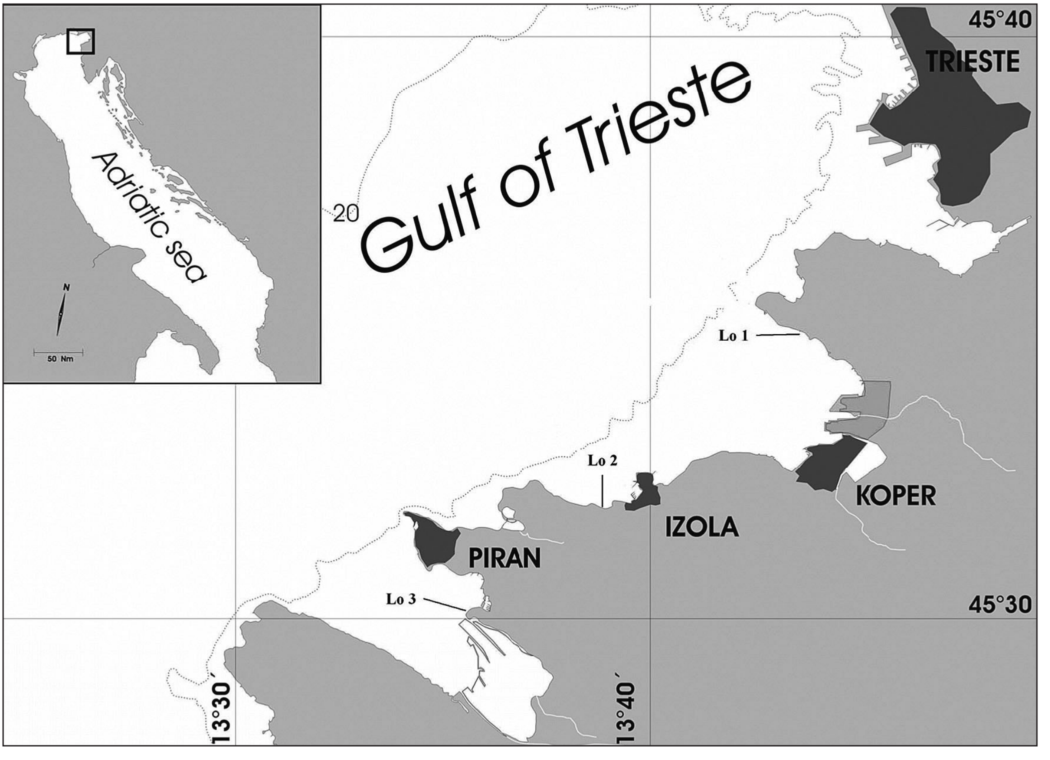


Figure 1: Map of the investigated area indicating sampling localities (Lo1, Lo2 and Lo3)
Slika 1: Zemljevid preučevanega območja z vrisanimi vzorčišči (Lo1, Lo2 in Lo3)

3. RESULTS AND DISCUSSION

Zonation patterns of the investigated sites

The **supralittoral zone** extends over a width of about 20 cm above the mean high water spring tide level (MHWS). The assemblages of this zone were represented mainly by the small prosobranchia periwinkle *Littorina neritoides* and the detritus feeding isopod *Ligia italica*. In its lower part, chthamalids associated to various communities of microscopic cyanobacteria (especially *Calothrix* sp.) were extended down to the mediolittoral zone.

The vertical extent of the **mediolittoral zone** was approximately 90 cm. It extends between the mean high water spring tide level (MHWS) and mean low water spring tide level (MLWS).

The **upper horizon** of this zone ranges from MHWS to mean high water neap tide level (MHWN) over a width of about 20 cm. It was characterized by dense populations of chtamalides and macrobenthic green algae communities (mainly belonging to the genera *Blidingia*, *Ulva*, *Chaetomorpha* and *Cladophora*).

The **middle horizon** extends from MHWN to mean low water neap tide level (MLWN) to over 40 cm in width. The chthamalids of this horizon were mixed with other faunal species as the gastropods (*Monodonta* sp., *Gibbula* sp.), limpets (*Patella* sp.) and anthozoans (*Actinia equina*). The most common macrobenthic algae were red algae belonging to the genera *Gelidium* and *Polysiphonia*. Among the green algae, the species *Ulva compressa* and *Cladophora* sp. were the most abundant. The most characteristic was the brown algae *Fucus virsoides* that generally occupies the entire horizon.

The **lower horizon** ranges from MLWN to MLWS. The width of this horizon was approximately 30 cm. It was mainly occupied by dense aggregates of the bivalve *Mytilus galloprovincialis* and by the green algae *Ulva laetevirens*.

The width of these zones and horizons were different in relation to the slope of the shore, variations in light and shade, exposure to waves, spray blown from waves and tidal range.

Description of the identified *Chthamalus* species

During the investigation, three different species of chthamalid barnacles were identified: *C. depressus*, *C. stellatus* and *C. montagui*. Table 1 illustrates the identification procedure of these three species based on external morphological features.

C. depressus

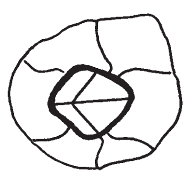
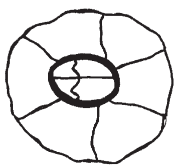
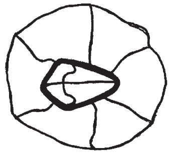
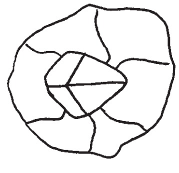
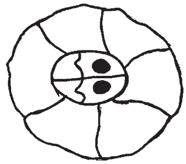
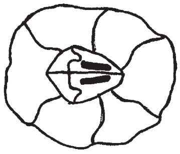
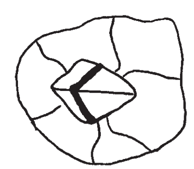
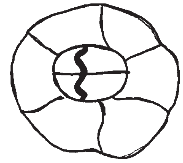
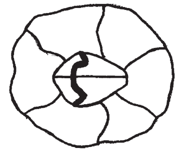
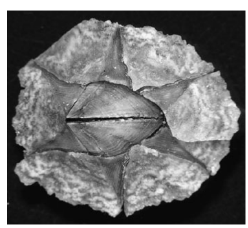
The shell is up to 10 – 12 mm in size and composed of 6 wall plates (rostrum, carina, 2 rostrolaterals plates, and 2 carinolaterals plates). The opercular opening is kite-shaped. The adductor muscle scare (visible on the scuta) is not deep, sometimes absent. The joint between the terga and scuta crosses the centre line less than one third of the opercular opening (from the carina to the rostrum). The tergum is bigger than the scutum. The apical angle is less than 90° (Relini 1980).

C. montagui

The shell of this species is of more angular appearance due to the kite-shaped opercular opening. It is up to 6 mm in size (max distance from the rostrum to the carina) and composed of 6 coarsely ridged wall plates (rostrum, carina, 2 rostrolaterals plates, and 2 carinolaterals plates). It is often difficult to distinguish the single plates owing to corrosion and overgrowth of algae, endolithic and epilithic cyanobacteria and lichens. Adductor muscle pits (visible on the scuta) are long, narrow and close to the occludent margin. The articulations between the terga and scuta cross the centre line quite close to the carina, less than one third the distance to the rostrum. Scuta are longer than wide, while terga are short and wide. The apical angle is usually less than 90° (Southward 1976, Relini 1980).

Table 1: General synoptic table indicating the basic external morphological features for identification of *C. depressus*, *C. stellatus* and *C. montagui*

Tabela 1: Splošna sinoptična tabela z osnovnimi morfološkimi značilnostmi za identifikacijo C. depressus, C. stellatus in C. montagui

Criteria for identification		***Chthamalus depressus***		***Chthamalus stellatus***		***Chthamalus montagui***	
Shape of the opercular opening		Kite-shaped		Oval or circular		Kite-shaped	
Adductor muscle pit		Not deep or absent		Wide, deep and rounded		Long, narrow and close to the occludent margin	
Articulation between terga and scuta	position	Less than one third of the opercular opening (from the carina to the rostrum)		One third or more of the opercular opening (from the carina to the rostrum)		Less than one third of the opercular opening (from the carina to the rostrum)	
	curvature	Forms an angle < 90° towards opercular opening		Convex towards rostral plate		Concave towards rostral plate	
Figure (60 x)							

C. stellatus

The shell of this species is of utterly round appearance, with oval or sub circular opercular opening. The distance from the rostrum to the carina is about 8 mm. The shell is composed of 6 coarsely ridged wall plates (rostrum, carina, 2 rostrolaterals plates, and 2 carinolaterals plates). The adductor muscle scare (visible on the scuta) is wide, deep and rounded. The joint between the terga and scuta crosses the centre line at one third or more the distance down from the carina to the rostrum and the main curve is convex towards the rostrum. The scutum is short and wide, while the tergum is very deep relative to its width. The apical angle is usually close to 90° (Southward 1976, Relini 1980).

Vertical distribution and abundance of *Chthamalus* species

According to the observations of the investigated sites, results showed that *Chthamalus* populations occupied distinct bands of the rocky shore, although the distribution and abundance of the single species, at various tidal levels, were different (Figure 2).

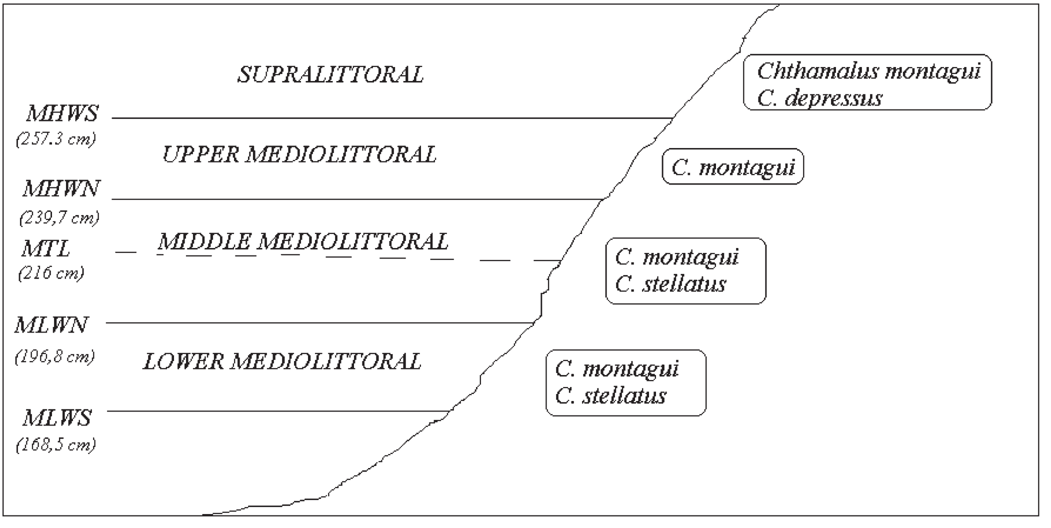


Figure 2: Figure shows the principal zones of the investigated sites and the distribution at various tidal levels on the shore of the identified *Chthamalus* species. (Legend: MHWS = Mean High Water Spring; MHWN = Mean High Water Neap; MTL = Mean Tide Level; MLWN = Mean Low Water Neap; MLWS = Mean Low Water Spring). (Source of mean values of the sea levels: Agencija RS za okolje 2009; analysis of data: Harpha Sea, d.o.o. 2006.)

Slika 2: Prikaz glavnih pasov preučevanih lokalitet in razširjenost identificiranih vrst iz rodu Chthamalus na različnih plimnih ravneh. (Vir srednjih vrednosti ravni morja: Agencija RS za okolje 2009; analiza podatkov: Harpha Sea, d.o.o. 2006.)

As illustrated in Figure 2, *C. depressus* was restricted only to the lower limit of the supralittoral zone and co-occurred with *C. montagui*. The species *C. stellatus* occurred only in the middle and in the lower horizon of the mediolittoral; while *C. montagui* had a great vertical distribution. It occupied all zones (from the lower part of the supralittoral to the lower horizon of the mediolittoral zone) and all tidal levels (from MHWS to MLWS).

In general, *C. montagui* tended to occupy slightly higher tidal levels and *C. stellatus* lower tidal levels, which is in accordance with the studies conducted by Southward (1976) and Crisp et al. (1981) for the Mediterranean (Figures 3 and 4).

The analysis of the percentage composition revealed that *C. montagui* was the most abundant species at all the levels and showed peaks in density in the upper and in the middle horizons of the mediolittoral on the selected substrata, limestone and sandstone. On limestone it was slightly more abundant in the supralittoral zone, while on sandstone it was more abundant in the lower horizon of the mediolittoral zone.

C. stellatus appeared to be very scarce in the middle horizon of the mediolittoral on limestone; while its abundance increased lower down, in the lower horizon, as stated in previous studies by Pannacciulli et Relini (2000) for the Italian part of the Gulf of Trieste, but in contrast with the studies by Benedetti-Cecchi et al. (2000) and Menconi et al. (1999). They claimed that *C. stellatus* was the most common sessile invertebrate in mediolittoral rocky shore assemblages of the northwest Mediterranean and that these organisms may occur at various heights on the shore but, on average, are more abundant in high-shore habitats.

On sandstone, *C. stellatus* occurred only in the lower horizon of the mediolittoral, but was less abundant than on limestone (Figures 3 and 4).

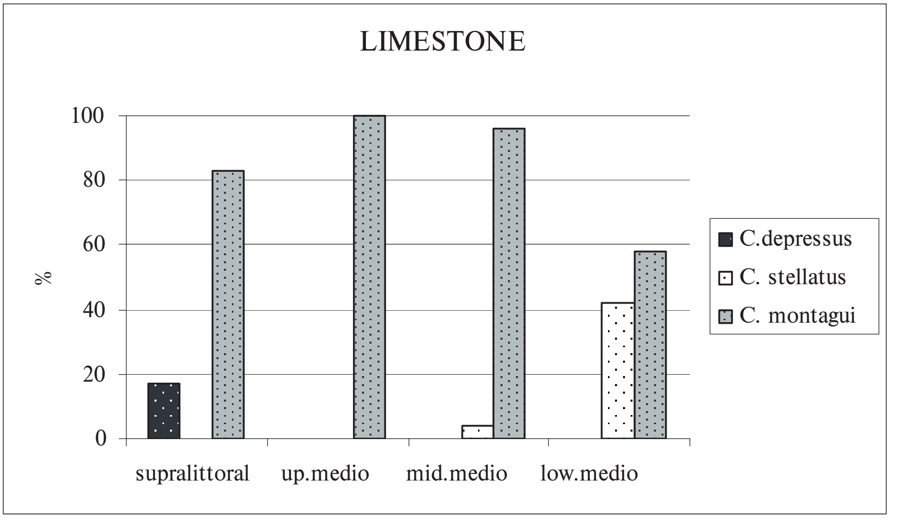


Figure 3: Percentage composition of C. depressus, C. stellatus and C. montagui at different heights on the shore (supralittoral, upper, middle and low mediolittoral) on limestone

Slika 3: Odstotna sestava vrst C. depressus, C. stellatus in C. montagui na različnih višinah obrežja (supralitoral, gornji, srednji in spodnji mediolitoral) na apnenčasti podlagi

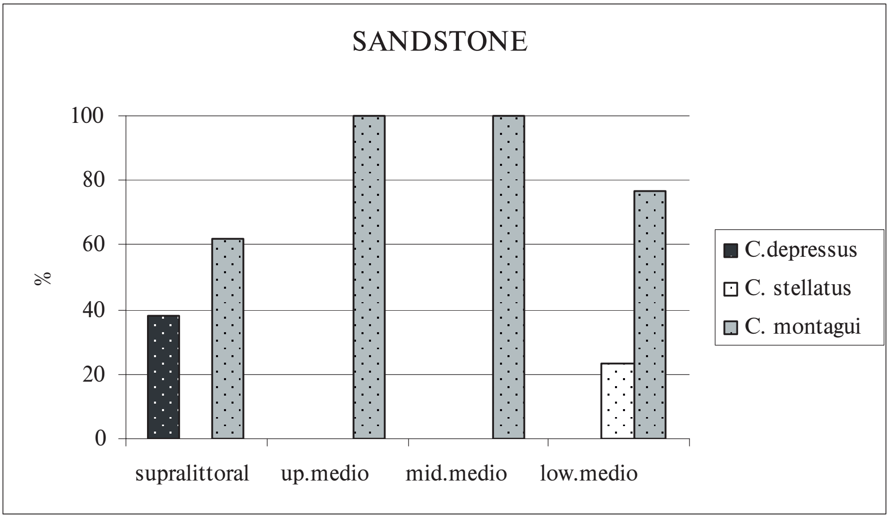


Figure 4: Percentage composition of C. depressus, C. stellatus and C. montagui at different heights on the shore (supralittoral, upper, middle and low mediolittoral) on the sandstone.
Slika 4: Odstotna sestava vrst C. depressus, C. stellatus in C. montagui na različnih višinah obrežja (supralitoral, gornji, srednji in spodnji mediolitoral) na peščenjaku

Figures 3 and 4 show that *C. depressus*, present only in the supralittoral zone, was more abundant on sandstone than on limestone.

Conclusions

On the bases of the carried out investigation it can be concluded that along the Slovene rocky shore:

1. *C. montagui* was significantly denser than *C. depressus* and *C. stellatus* on all investigated substrata and at all tidal levels.

2. *C. stellatus* density was always higher at low-tide level compared with the other tidal levels.

3. There were no significant differences between limestone and sandstone in vertical distribution and abundance of *Chthamalus* species.

4. SUMMARY

The present study deals with the vertical distribution of three species of Chthamalids, *Chthamalus depressus* (*Euraphia depressa*) (Poli, 1791), *Chthamalus stellatus* (Poli, 1791) and *Chthamalus montagui* Southward, 1976, which are the main constituents of the barnacle belt along the Slovene rocky shore (Gulf of Trieste, North Adriatic Sea). Chthamalids populations were monitored in spring 2008 on three sites along the Slovene coast (Koper bay, Izola bay and Piran bay). On each site two different kinds of substratum were selected (sandstone and limestone). Barnacles were counted up at four different shore heights (supralittoral and upper,

middle and lower mediolittoral). The result shows that *C. montagui* is present in the supralittoral and in the mediolittoral zone, but dominates especially in the upper and middle mediolittoral zone. *C. depressus* is present only in the supralittoral, while *C. stellatus* inhabits only the lower mediolittoral. A moderate difference in the number of single species among the sites and between the two different kinds of substratum was found. Thus the study presents a synoptic table for the identification of these three species, based on the external morphological features.

POVZETEK

Pričujoča študija obravnava vertikalno razširjenost treh vrst vitičnjakov, *Chthamalus depressus* (*Euraphia depressa*) (Poli, 1791), *Chthamalus stellatus* (Poli, 1791) in *Chthamalus montagui* Southward, 1976, ki so glavni graditelji pasu vitičnjakov na slovenskem morskem obrežju (Tržaški zaliv, severno Jadransko morje). Njihove populacije so bile spremljane spomladi 2008 na treh lokacijah vzdolž slovenske obale (Koprski, Izolski in Piranski zaliv). Na vsaki lokaciji sta bili izbrani dve vrsti podlage, peščenjak in apnenec. Vitičnjaki so bili prešteti na štirih različnih višinah obrežja (v supralitoralu in zgornjem, srednjem in spodnjem mediolitoralu). Rezultati so pokazali, da se vrsta *C. montagui* pojavlja v supralitoralu in mediolitoralu, a da prevladuje predvsem v zgornjem in srednjem mediolitoralu. *C. depressus* se pojavlja zgolj v supralitoralu, *C. stellatus* pa le v spodnjem mediolitoralu. Ugotovljena je bila majhna razlika v številu posameznih vrst med lokalitetami kot tudi med dvema različnima vrstama substrata. Študija tako predstavlja sinoptično tabelo za identifikacijo teh treh vrst, izdelano na osnovi zunanjih morfoloških značilnosti teh vitičnjakov.

5. LITERATURE

1. Agencija Republike Slovenije za okolje (2009): Morje. In: Kobold M., Uhan J., Trček R., Knez J. (eds): Hidrološki letopis Slovenije 2005. Agencija RS za okolje. Ljubljana. 213-220. http://www.arso.gov.si/vode/poro%c4%8dila%20in%20publikacije/Hidroloski%202005%20-%20II_del%20D.pdf (10. mar. 2009).
2. Battelli, C., N. Dolenc-Orbanić (2008): First record of *Chthamalus montagui* Southward, 1976 (Crustacea, Cirripedia) on the Slovenian coast (Gulf of Trieste, Northern Adriatic Sea). Ann, Ser. hist. nat. 18(1): 73-78.
3. Bellan-Santini, D., J.C. Lacaze, C. Poizat (1994): Les Biocénoses marines et littorales de Méditerranée. Synthese, menaces et perspectives. Museum National d'Histoire Naturelle. Paris. 264 pp.
4. Benedetti-Cecchi, L., S. Acunto, F. Bulleri, F. Cinelli (2000): Population ecology of the barnacle *Chthamalus stellatus* in the northwest Mediterranean. Mar. Ecol. Prog. Ser. 198: 157-170
5. Bussani, A., M. Celio, C. Comici (2003): Climatological analysis (1991-2002) of the thermohalines characteristics in the Marine Reserve of Miramare (Gulf of Trieste). Boll. Geof. Teor. Appl. 44(1):11-17
6. Crisp, D., A.J. Southward, E. Southward (1981): On the distribution of the intertidal barnacles *Chthamalus stellatus*, *Chthamalus montagui* and *Euraphia depressa*. J. mar. biol. Ass. U.K. 61: 359–380

7. Lipej, L., M. Orlando Bonaca, T. Makovec, (2004): Raziskovanje biodiverzitete v Slovenskem morju. Nacionalni inštitut za biologijo, Morska biološka postaja. Piran. 136 pp.
8. Malačič, V., M. Jeromel (2005): Vetrovi ob Slovenski obali-tablice. Nacionalni inštitut za biologijo, Morska biološka postaja. Piran. 2 pp.
9. Menconi, M., L. Benedetti-Cecchi, F. Cinelli (1999): Spatial and temporal variability in the distribution of algae and invertebrates on rocky shores in the northwest Mediterranean. J. Exp. Mar. Biol. Ecol. 233: l-23
10. Ogorelec, B., J. Faganeli, M. Mišič, B. Čermelj (1997): Recostruction of paleoenvironment in the Bay of Koper (Gulf of Trieste, Northern Adriatic). Ann. Istr. Medit. Studies, Nat. Hist. 11: 187-200
11. Pannacciulli, F.G., G. Relini (2000): The vertical distribution of *Chthamalus montagui* and *Chthamalus stellatus* (Crustacea, Cirripedia) in two areas of the NW Mediterranean Sea. Hydrobiologia 426: 105-112
12. Pavlovec, R. (1985): Numulitine iz apnencev pri Izoli (SW Slovenija). Razprave SAZU, IV. razred, 26: 219-230
13. Relini, G. (1980): Cirripedi Toracici. Guide per il riconoscimento delle specie animali delle acque lagunari e costiere italiane, 2. Report No. CNR-AQ-1/91. CNR. Roma. 118 pp.
14. Relini, G. (1981): Distribution of *Chthamalus montagui* in the Mediterranean Sea. Rapp. Comm. Int. Mer Medit. 27(2): 149-150
15. Southward, A.J. (1976): On the taxonomic status and distribution of *Chthamalus stellatus* (Cirripedia) in the northeast Atlantic region: with a key to the common intertidal barnacles of Britain. J. mar. biol. Ass. U.K. 56: 1007-1028
16. U.N.E.P. - P.A.M. 1998. Rapport reunion d'expert sur les types d'Habitats marins dans la region Méditerranéenne. UNEP (OCA) MEDW. 149/5. CAR/ASP, Tunis.
17. Zavodnik, D. (1998): Prilozi morskoj fauni Riječkog zaljeva. 7. Raci brumbuljci (Crustacea: Cirripedia: Balanomorpha) – Contributions to the marine fauna of Rijeka Bay (Adriatic Sea). 7. Barnacles (Crustacea: Cirripedia: Balanomorpha). In: Arko-Pijevac, M., Kovačić, M. Crnković, D. (eds.): Zbornik prirodoslovna istraživanja riječkog područja. Prirodoslovni muzej Rijeka. Rijeka. 633-637
18. Zavodnik, D., A. Pallaoro, A. Jaklin, M. Kovačić, M. Arko-Pijevac (2005): A benthos of the Senj Archipelago (North Adriatic Sea, Croatia). Acta Adriat. 46 (suppl. 2): 3-68

Claudio BATTELLI, Nataša DOLENC-ORBANIĆ
University of Primorska,
Faculty of Education Koper,
Cankarjeva 5,
SI- 6000 Koper,
claudio.battelli@pef.upr.si, natasa.dolenc@pef.upr.si

RECENT CHANGES IN THE ADRIATIC FISH FAUNA - EXPERIENCES FROM SLOVENIA

RECENTNE SPREMEMBE V JADRANSKI RIBJI FAVNI – IZKUŠNJE IZ SLOVENIJE

Lovrenc LIPEJ, Borut MAVRIČ, Martina ORLANDO BONACA

Key words: ichthyofauna, new techniques and approaches, meridionalisation, bioinvasion, Slovenian Sea

Ključne besede: ribja favna, nove tehnike in pristopi, meridionalizacija, bioinvazija, slovensko morje

ABSTRACT

Some neglected, rare and less known fish species were recorded in Slovenian part of the Gulf of Trieste. Some of them were recorded for the very first time in the area by virtue of performing new approaches and techniques. Other fish species were related to certain processes in the Adriatic Sea, such as bioinvasion and tropicalisation.

IZVLEČEK

Pred kratkim so bile v slovenskem delu Jadrana odkrite nekatere spregledane, redke in manj poznane vrste rib. Nekatere izmed njih so bile sploh prvič potrjene v danem območju spričo uporabe novih pristopov in metod. Druge odkrite ribje vrste pa so povezane s procesoma meridionalizacije in bioinvazije.

1. INTRODUCTION

During the last few decades, the various anthropogenic activities have exposed the Mediterranean marine biodiversity to certain changes. Together with climate change driven phenomena, those activities affect the structure of fauna and flora of the Mediterranean basin. The same applies for Slovenian part of the Adriatic Sea, which comprises the southern part of the Gulf of Trieste. Recently, several new species for the area and many rare or less known species were discovered in the Slovenian sea. In this paper we would like to present the factors, which are to our opinion the main reasons for the increase in species richness of the area.

2. NEW TECHNIQUES OF INVESTIGATION

The increasing number of fish (and invertebrate species, as well) should be attributed to new research approaches and field techniques (Lipej et Dulčić 2004). The observations of marine biodiversity *in situ* allow marine biologists to study coastal fish communities in their native habitats. Nowadays, the marine fauna and flora, and habitat types as well, could be sampled by non-destructive techniques such as the visual census method (Harmelin 1987, Harmelin-Vivien et Francour 1992). Linear visual transects are generally conducted by pairs of skilled biologists - divers. The use of such techniques allows identifying new species and specially cryptobenthic species, which are generally hidden under stones, in cracks, crevices and cavities in rocky habitats. Such fish species are mainly representatives of coastal fish families such as clingfishes (Gobiesocidae), gobies (Gobiidae) and blennies (Blenniidae) (Table 1).

Table 1: Rare, less-known or non-indigenous fish species recorded recently in Slovenian part of the Adriatic Sea.
Tabela 1: Redke, manj znane in tujerodne vrste rib, pred kratkim ugotovljene v slovenskem delu Jadranskega morja.

	Species	**factor**	**Source**
Carcharhinidae	*Carcharhinus plumbeus*	Increased research effort	Lipej *et al.* 2000
Dasyatidae	*Dasyatis violacea*	Meridionalisation?	Mavrič *et al.* 2004
Terapontidae	*Terapon theraps*	Lessepsian migration	Lipej *et al.* 2008c
Poecillidae	*Gambusia hoolbroki*	Biocontrol	Leiner *et al.* 1995
Balistidae	*Balistes carolinensis*	Meridionalisation	Dulčić et Lipej 1997
Clupeidae	*Sardinella aurita*	Meridionalisation	Jenko, *pers. comm.*
Haemulidae	*Plectorhincus mediterraneus*	Meridionalisation?	Lipej *et al.* 1996
Gobiesocidae	*Apletodon incognitos*	New techniques	Lipej *et al.* 2005
Gobiidae	*Millerigobius macrocephalus*	New techniques	Lipej *et al.* 2005
	Pomatoschistus bathi	New techniques	Lipej *et al.* 2005
	Gobius roulei	New techniques	Lipej *et al.* 2005
	Thorogobius ephippiatus	Increased research effort	Lipej *et al.* 2005
Carangidae	*Campogramma vadigo*	Increased research effort	Dulčić *et al.* 2003a

3. INCREASED RESEARCH EFFORT

The discovery of new species in Slovenian coastal waters could be further linked to the increased research effort by marine biologists (Table 1). The cooperation between icthyologists, divers, underwater photographers and especially fishermen offers a great opportunity to monitor the fish fauna of the area. This cooperation was crucial in discovering new species for the area but also for the detection of many rare and less-known fish species. Such a species is for example the pelagic stingray (*Dasyatis violacea*) (Mavrič et al. 2004), which inhabits the southwestern areas of the Mediterranean Sea. In Slovenian part of the Adriatic Sea, it feeds mainly on anchovies (*Engraulis encrasicolus*) and red bandfish (*Cepola rubescens*). Many new data also emerged for the bull ray (*Pteromylaeus bovinus*). Some specimens were the heaviest and the largest bull rays ever measured (Dulčić et al. 2008a, Lipej et al. 2008a). The cooperation between fishermen and ichthyologists has also brought new insights into the significance of the area as a nursery ground for certain species of sharks. The sandbar shark (*Carcharhinus plumbeus*) was considered a rare shark species in the Adriatic Sea in general. Since the Northern Adriatic is actually a nursery ground for this species, as demonstrated by neonates and juveniles with still unhealed umbilical scars (Lipej et al. 2000, Costantini et

Affronte 2003), the sandbar shark seems to inhabit the area at least seasonally. The rarity of data on the species is probably more related to the rarity of captures than to the real rarity of these sharks (Lipej et al. 2008b).

4. BIOTIC GLOBALISATION

One of the reasons known to cause the increment of species in the area is biotic globalisation. In this respect we can discriminate between two causes: the first is related to the phenomena of meridionalisation (also tropicalisation), the other to bioinvasion.

4.1 MERIDIONALISATION

Meridionalisation is a temperature related factor, which affects the changes in fish species distribution. Some warm water fish species were recorded to spread from southern to northern areas. Such changes in species distribution due to temperature fluctuations were reported for different parts of the Mediterranean (see Francour et al. 1994) and also in the Adriatic Sea (Dulčić et al. 1999, Lipej et Dulčić 2004). Changes in fish distributions are a good indicator of the effect of temperature change, since fishes are unable to regulate their temperature independently of the surrounding water (Stebbing et al. 2002). One of the tropicalisation indicators is the triggerfish (*Balistes carolinensis*), which has been occurring regularly in the Slovenian coastal sea since the 1970s. The other typical faunistic element of tropicalisation is the ornate wrasse (*Thalassoma pavo*), which is slowly approaching the Slovenian coastal sea. In September 2008, it was recorded for the very first time in waters off Pula. In the last decade, there has been an evidence of regular occurrence of the dolphin fish (*Coryphaena hippurus*), a fish species previously considered a Southern Adriatic species. It is also worth mentioning the spreading of the rainbow wrasse (*Coris julis)*, initially recorded in Cape Madona Natural Monument (Piran) in 2000. Nowadays, the species occurs in different habitat types in the biocoenosis of photophilous algae. In September 2006, this species was recorded for the very first time in the Miramare (Trieste) Marine Reserve (Piron et al. 2007). Let us underline that our Italian colleagues have been performing a regular monitoring of the Miramare Natural Reserve for no less than 25 years. According to some biologists, working in the field of marine fisheries, an ongoing trend of species replacement has been noticed by fishermen, evidenced by the decrease in sardine stock *Sardina pilchardus* and increase of *Sardinella aurita* abundance (R. Jenko, *pers. comm.*). The latter seems to be an indicator of water warming in the Mediterranean Sea (sensu Sabates et al. 2006).

4.2 BIOINVASION

Bioinvasion is a recent process, which could be related to different factors. It refers to a (non-indigenous) newcomer species, which originates from other biogeographical province, and when the area of species distribution is disjunct. One of the main factors (although not the only one) is again the temperature. However, there are different other factors that can facilitate the introduction such as salinity, other hydrological conditions, unsaturated ecological niches and others (Mavruk et Avsar 2008). The non-indigenous species could have arrived in the new area from the Erythrean province through the Suez Canal. This process is known as Lessepsian migration, named after Ferdinand Marie De Lesseps, a French engineer responsible for the construction of Suez Canal (1859-1869). The temperature is the most important abiotic factor in determining the dispersal of Lessepsian fish. There are many Lessepsian organisms known to occur in the Adriatic Sea, with at least 11 fish species among them (Dulčić et al. 2003b). The last one, *Terapon theraps* was discovered in waters off Piran in July 2007 and is the first record ever of this species in the Mediterranean Sea, as well as the first record of a lessepsian fish migrant in Slovenian waters (Lipej et al. 2008c).

Other important vectors of introduction such as mariculture, ballast waters and ballast sediments are unlikely to deliver new fish species to the area. The only other non-indigenous fish species known to inhabit the Slovenian coastal sea is the mosquito fish (*Gambusia hoolbroki*), which has been intentionally introduced to solve the problem of mosquitoes in the period between the two World Wars.

4.3 OTHER EVENTS

Recently, some unexpected fish species other than above mentioned were recorded in the Slovenian coastal sea. One of such events was related to the occurrence of a basking shark (*Cetorhinus maximus*) in the area. This shark species was considered rare according to some old sources (Brusina 1888). During the last decade, several records of this species have been reported for the Adriatic Sea with most of the data originating from the Northern Adriatic Sea (Lipej et Dulčić 2004). Some other rather rare or less known ocean-dwelling species have also been reported for the area, such as the common sunfish (*Mola mola*) and the slender sunfish (*Ranzania laevis*) (Lipej et al. 2007). The common sunfish could be related to the global sea warming (Dulčić *et al.* 2008b) as revealed by the analysis of its occurrence and the sea water temperature fluctuations. In 2007, a louvar (*Luvarus imperialis*) was also recorded in the Gulf of Trieste.

5. CONCLUSIONS

The marine biodiversity of the Mediterranean Sea is nowadays facing the structural changes in flora and fauna (sensu Bianchi 2007). Such changes were also recorded in the Adriatic Sea and in its northernmost part. Some neglected fish species were recorded for the very first time by performing new approaches and techniques in the area. Other fish species were related to certain processes in the Adriatic Sea, such as bioinvasion and meridionalisation. Despite the fact that the recent changes in marine biodiversity of the Slovenian coastal sea are not so dramatic than in other areas of the Mediterranean Sea, a regular monitoring of climate change induced modifications in biodiversity have to be established. With a regular and continuous monitoring of fish fauna in the Slovenian coastal sea, we would be able to answer on a plethora of questions related to the status of newcomers. Only in that way we are likely to get the opportunity to elucidate what impact such species may have on the environment.

6. ACKNOWLEDGMENTS

We would like to express our thanks to Milijan Šiško for his technical support. Special thanks are also due to Mr. Robert Turk for his immense trust in our work and support.

7. LITERATURE

1. Bianchi, C.N. (2007): Biodiversity issues for the forthcoming tropical Mediterranean Sea. Hydrobiologia 580: 7 – 21
2. Brusina, S. (1888): Morski psi Sredozemnoga i Crljenog mora (Sharks of the Adriatic and the Black Sea). Glasnik hrvatskoga naravoslovnoga družtva. III: 167-230
3. Costantini, M., M. Affronte (2003): Neonatal and juvenile sandbar sharks in the northern Adriatic Sea. Journal of Fish Biology 62: 740-743
4. Dulčić, J., L. Lipej (1997): New records of marine fishes from the Slovenian coastal waters = Nove najdbe morskih rib v slovenskih obalnih vodah. Falco 11(12): 35-40
5. Dulčić, J., B. Grbec, L. Lipej (1999): Information on the Adriatic ichthyofauna - effect of water warming? Acta Adriat. 40(2): 33-43
6. Dulčić, J., B. Marčeta, V. Žiža, A. Pallaoro, L. Lipej (2003a): Northern extension of the range of the vadigo *Campogramma glaycos* (Pisces: Carangidae) from the Adriatic Sea. J. Mar. Biol. Assoc. U.K. 83(4): 877-878
7. Dulčić, J., A. Pallaoro, L. Lipej (2003b): Lessepsian fish migrants reported in the eastern Adriatic Sea: an annotated list. Ann, Ser. hist. nat. 13(2): 137-144
8. Dulčić, J., L. Lipej, M. Orlando Bonaca, R. Jenko, B. Grbec, O. Guelorget, C. Capape' (2008a): The bull ray, *Pteromylaeus bovinus* (Myliobatidae), in the northern Adriatic Sea. Cybium (Paris) 32(2): 119-123
9. Dulčić, J., Beg Paklar, G. Grbec, M. Morović, F. Matić, L. Lipej (2008b): On the occurrence of ocean sunfish *Mola mola* and slender sunfish *Ranzania laevis* in the Adriatic Sea. J. Mar. Biol. Assoc. U.K. 87: 789-796
10. Francour, P., C.F. Boudouresque, J.G. Harmelin, M.L. Harmelin-Vivien, J.P. Quignard (1994): Are the Mediterranean waters becoming warmer? Information from biological indicators. Mar. Pollut. Bull. 9: 523-526
11. Harmelin, J.G. (1987): Structure et variabilité de l'ichtyofaune d'une zone rocheuse protégée en Méditeranée (Parc national de Port-Croos, France). P.S.Z.N.I.: Marine Ecology 8(3): 263-284
12. Harmelin-Vivien, M.L., P. Francour (1992): Trawling or Visual Censuses? Methodological Bias in the Assessment of Fish Populations in Seagrass Beds. P.S.Z.N.I: Marine Ecology 13(1): 41-51
13. Leiner, S., M. Povž, M. Mrakovčić (1995): Freshwater fish in Istrian peninsula. Annales, Ser. hist. nat. 7: 215-222
14. Lipej, L., M. Spoto, J. Dulčić (1996): *Plectorhinchus mediterraneus* from off north east Italy and Slovenia - the first records of fish of the family Haemulidae from the Adriatic Sea. J. Fish Biol. 48: 804-805
15. Lipej, L., T. Makovec, A. Soldo, V. Žiža (2000): Records of the Sandbar shark *Carcharhinus plumbeus*, (Nardo, 1827) in the Gulf of Trieste (Northern Adriatic). Annales, Ser. hist. nat. 10(2): 199-206

16. Lipej, L., J. Dulčić (2004): The current status of the Adriatic fish biodiversity. In: Griffiths H.I. et al. (eds.): Balkan Biodiversity. Kluwer Academic Publishers. Dordrecht, Boston, London. 291-306
17. Lipej, L., M. Orlando Bonaca, M. Richter (2005): New contributions to the marine coastal fish fauna of Slovenia. Ann, Ser. hist. nat. 15(2): 165-172
18. Lipej, L., Ž. Dobrajc, C. Castellarin, R. Odorico, J. Dulčić (2007): New records of some rare and less-known fishes in the Gulf of Trieste (Northern Adriatic). Ann, Ser. hist. nat. 17(2): 171-176
19. Lipej, L., B. Mavrič, J. Dulčić (2008a): Size of the bull ray, *Pteromylaeus bovinus* (Geoffroy Saint-Hilaire, 1817), from the northern Adriatic. J. appl. ichthyol. (in press)
20. Lipej, L., B. Mavrič, Ž. Dobrajc, C. Capape' (2008b): On the occurrence of the sandbar shark, *Carcharhinus plumbeus* (Chondrichthyes: Carcharhinidae) off the Slovenian coast (Northern Adriatic). Acta Adriatica. (in press)
21. Lipej, L., B. Mavrič, J. Dulčić (2008c): The largescaled terapon *Terapon theraps*: an Indo-Pacific fish new to the Mediterranean Sea. Journal of Fish Biology 73: 1819-1822
22. Mavrič, B., R. Jenko, T. Makovec, L. Lipej (2004): On the occurrence of the pelagic stingray *Dasyatis violacea* (Bonaparte, 1832) in the Gulf of Trieste (northern Adriatic). Annales Ser. Hist. Nat. 14(2): 185-190
23. Mavruk, S., D. Avsar (2008): Non-native fishes in the Mediterranean from the Red Sea, by way of the Suez Canal. Rev. Fish Biol. Fisheries 18: 251-262
24. Piron, M., E. Balasso, D. Poloniato, R. Odorico (2007): First record of *Coris julis* in the Miramare natural marine reserve. Ann, Ser. hist. nat. 17(2): 165-170
25. Sabates, A., P. Martin, J. Lloret, V. Raya (2006): Sea warming and fish distribution: the case of the small pelagic fish *Sardinella aurita*, in the western Mediterranean. Global Change Biology 12: 2209-2219
26. Stebbing, A.R.D., S.M.T. Turk, A. Wheeler, K. R. Clarke (2002): Immigration of southern fish species to south-west England linked to warming of the North Atlantic (1960-2001). J. Mar. Biol. Ass. U.K. 82: 177-180

Lovrenc LIPEJ, Borut MAVRIČ, Martina ORLANDO BONACA
Morska biološka postaja, Nacionalni inštitut za biologijo
Fornače 41
SI- 6330 Piran, Slovenija
lipej@mbss.org, orlando@mbss.org

ENVIRONMENTAL IMPACTS OF THE PORT OF KOPER

VPLIVI LUKE KOPER NA OKOLJE

Franka CEPAK, Boris MARZI

Keywords: port, environmental impacts, total particulate matter deposition, PM10, waste water, sea water protection, quality of sediments, noise level, dust emission concentration, VOC emission concentrations, wastes, flora, fauna
Ključne besede: luka, okoljski vplivi, celotna količina odloženih suspendiranih delcev, PM10, odpadne vode, zaščita morske vode, kakovost usedlin, raven hrupa, emisijska koncentracija prahu, emisijska koncentracija VOC, odpadki, flora, favna

ABSTRACT

This paper provides an insight into the extent and degree of the environmental impacts of the Port of Koper. For this purpose, the following indicators were selected: maritime throughput, imission concentration of PM10, total particulate matter deposition, emission concentrations of dust and emission concentration of volatile organic compounds (i.e. gasoline, jet fuel and o-xylene), noise levels, shares of waste collected separately, environmental load unit for waste water, quality of sediments. The selected environmental indicators are presented over a period of time and compared to some normative references. The first stage of the marine flora and fauna research in the Port's basins is presented.

IZVLEČEK

Pričujoči članek poskuša osvetliti obseg in stopnjo vplivov delovanja Luke Koper na okolje. V ta namen so bili uporabljeni naslednji kazalniki: tovorni promet, imisijske koncentracije suspendiranih delcev PM10, celotna količina odloženih suspendiranih delcev, imisijske koncentracije prahu in hlapljivih organskih zmesi (npr. bencin, gorivo za reaktivne motorje, o-ksilen), raven hrupa, deleži ločeno zbranih odpadkov, enota obremenitve okolja za odpadne vode, kakovost usedlin. Izbrani okoljski kazalniki, ki zajemajo daljše časovno obdobje, so primerjani z nekaterimi normativnimi referencami. Predstavljena je prva faza raziskav o morski flori in favni v luških bazenih.

1. INTRODUCTION

The Obalno-Kraška (Coastal-Karst) region is one of the smallest regions in Slovenia in terms of its size and among the most developed in terms of its economic conditions. The Port of Koper is a public limited company, whose activity leaves an impact on the development of the Obalno-Kraška region, giving it a positive and dynamic economic pulse. The expansion of the port, in economic and physical terms, nowadays has to take into account its impacts on the nearby urban contexts. These impacts affect the environment and the local community. The challenge is now to balance the economic, environmental and social issues. The concept of sustainable development has become one of the basic challenges in the field of maritime transport, including port activities. The Port of Koper strives to achieve and demonstrate a proper attitude towards the environment. Preservation of the environment and a system for dealing with the environment in the narrower and broader area influenced by the Port of Koper are becoming increasingly important components of the comprehensive quality system. Thus, monitoring and controlling environmental impacts is turning into one of the company's regular activities.

Many human activities are aggravating the environment, and port activities with its daily operations are no exception in this respect. Waterborne commerce is increasing rapidly and presenting ports with challenges that could not have even been imagined two decades ago. At the same time, lifestyle changes have made the cruise industry the fastest growing segment of the travel industry. To accommodate increases in trade volume, increases in the size of cargo and cruise ships, new security requirements in ports are investing in infrastructure improvements.

1.1 BAY OF KOPER

The Bay of Koper has been considered a sensitive area, since it is endangered by industrial and domestic land based activities and pollution sources along the coast and its watershed as well as by polluted waters of the Gulf of Trieste. A wide variety of economic activities are running in and along the Bay of Koper. Most of its coastline is built-up and urbanized. The central port of Slovenia, the Port of Koper, is located in the Bay. Activities in the port are increasing every year, and currently around 15 million tons of cargo are handled per year. The area is also industrially developed. Metal manufacturing, production of chemicals and food industry are the main branches of industry situated in this area. Tourism and recreation also exerts certain pressure on the environment and is particularly extensive in summer months. Municipal wastewaters are an important source of pollution in the Bay. They are primary treated and discharged in the estuary of the Rižana river, i.e. in Basin II of the Port of Koper. Around 122 tons of TN and 17 tons of TP are annually discharged into to the sea from the Koper wastewater treatment plant (Gosar et Muri 2005). River effluents are additional significant source of pollution. The Rižana and Badaševica rivers supply the sea with nutrients and other harmful pollutants from the coastal area and the watershed. Nevertheless, the Bay of Koper can be also endangered by polluted waters, entering the Bay from other parts of the Gulf of Trieste. Some areas on the Italian coast are highly industrialized and urbanized and, consequently, polluted. In addition, effluents of the Soča river are discharged into the Gulf and their impact can also be seen in the Slovenian part of the Gulf. All these factors can thus enhance the deterioration of the waters and the coastline of the Bay of Koper.

1.2 THE PORT OF KOPER PROFILE

The Port of Koper is a public limited company, situated in the Bay of Koper with a surface area of around 17 km^2. It provides port and logistics services and is a quickly developing port and logistics group, one of the most important in the Northern Adriatic region. It represents a stronger link in the logistics chain connecting Central and Eastern Europe as well as the

Far East. In 2007, the development impetus was enhanced by exceptional growth in container and general cargo throughput, by providing one of the largest distribution centres for vehicles, by setting up inland terminals, by expanding the range of additional services, by efficient technological processes, by new modern equipment and information solutions, and by a socially accountable approach (Figure 1).

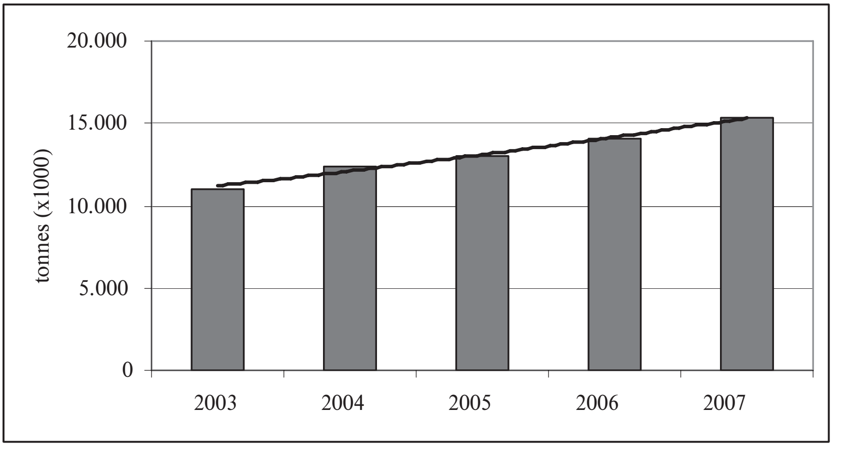


Figure 1: Increasing maritime throughput in Port of Koper
Slika 1: Rastoči tovorni promet v Luki Koper

The port lies on 255 hectares of land area where:

- 30 hectares are destined for indoor warehouses,
- 95 hectares for outdoor warehouses, and
- 26 ship moorings on 3.134 metres of shore alongside 173 hectares of sea area.

The Port of Koper manages 12 specialised terminals with modern equipment for various types of cargo (Table 1).

Table 1: List of The Port's specialised terminals and their potential effect on the environment
Tabela 1: Seznam terminalov Luke Koper in njihov potencialni vpliv na okolje

Terminals	**Potential effect on environment**
Container and Ro-Ro	Noise
Car Terminal	Noise
General Cargo Terminal	Noise
Fruit Terminal	Air
Timber Terminal	Noise
Terminal for Minerals	Air
Terminal for Cereals and Fodder	Air
Alumina Terminal	Air
European Energy Terminal	Air
Liquid Cargoes Terminal	Water, Air
Livestock Terminal	Water
Passenger terminal	Noise

The port procedures and operation are focused on the prevention of conditions that could endanger the environment or the people's health and safety. The Port of Koper is the only port in the Northern Adriatic to operate according to ISO 9001 standards - Quality management system, ISO 14001 - Environmental management system and OHSAS 18001 - Occupational health and safety management system. The established environment management system is systematic and well-planned, integrated into the business system of the port, and is supported and carried out by all employees. The next step is to implement an Eco-Environmental Management and Audit Scheme - EMAS (Regulation (EC) No. 761/2001..., OJ EC L 114(44) 2001).

The organisation strives to achieve and demonstrate a suitable attitude towards the environment. This means continuously controlling the impacts of the Port's activities, products and services on the environment. Preservation of the environment and a system for dealing with the environment in the narrower and broader area influenced by the Port of Koper are becoming increasingly important components of the comprehensive quality system.

The port is developing new methods and models for efficient environmental protection and management. Some of the environmental considerations that the port involves are: management of estuaries, all forms of pollution at ports, managing ecology and habitat, management of chemicals in or near water environments, oil discharge prevention and response, dredging and sediment removal including its disposal, management of the port, management of waste from vessels, loading and unloading of ships, management of ballast water, safety of ships and the people living around harbours, security of goods.

The responsible attitude towards natural and living environment is reflected in consistent implementation of the environmental policy, raising the awareness of the employees as regards preventive actions and rational use of energy sources and investments in environmental programmes.

2. ENVIRONMENTAL IMPACT OF THE PORT OF KOPER

2.1 AIR QUALITY

2.1.1 Particulate matter (PM10) imission levels

In 1987, EPA replaced the earlier total suspended particulate (TSP) air quality standard with a PM10 standard (BS EN 12341). The new standard focuses on smaller particles that are likely responsible for adverse health effects due to their ability to reach the lower regions of the respiratory tract. EPA's health-based national air quality standard for PM10 is 40 $\mu g/m^3$ (measured as an annual mean) and 150 $\mu g/m^3$ (measured as a daily concentration) (Council Directive 1999/30/EC..., OJ EC L 163(41) 1999). The main sources of primary PM10 are road transport, stationary coal combustion and industrial processes, including bulk handling, construction, etc. (Agencija RS za okolje / The Environment Agency 2007).

Major concerns for human health from exposure to PM10 include: effects on breathing and respiratory systems, allergic reactions, damage to lung tissue, cancer (Eržen et al. 2003).

Since 2003, the Primorska Institute of Natural Sciences and Technology has been conducting continuous measurements of PM10 in the immediate area of the source of imission - the bulk cargo disposal site in the port (Figure 2). The average measured PM10 concentrations are shown in Table 2. The legally prescribed limit (40 μg/m^3) has never been exceeded. The Port of Koper has set itself the task to halve this value by 2010, as required by the European and Slovenian legislation. This goal will be achieved by preventive measures and activities aimed at reducing dust particles in the atmosphere. The port has already implemented techniques such as the use of equipment that minimises the height of drop and speed of descent and free fall height, e.g. using height adjustable cascade tubes, the use of water sprays for moistening the heap surface (coal yard) by a sprinkler system, the use of enclosed conveyors with well designed, robust extraction and filtration equipment, the use of large volume silos, regularly cleaning of roads, the use of 11 m high windshield round the coal yard. Future approaches and techniques regarding the further reduction of dust emissions are the complete covering of the coal open storage, the development of a diffusion model of dust emission from the port, the use of alternative power systems (e.g. shore side power supply for ships, hybrid technology, biodiesel) and to further optimize the bulk cargo handling systems.

Two more sampling stations will monitor the concentration of PM10 at port border sites in 2009.

Figure 2: The continuous PM10 particulate monitoring station (TEOM 1400A) in the Port of Koper
Slika 2: Stalna postaja za spremljanje suspendiranih delcev (TEOM 1400A) v Luki Koper

Table 2: Average annual concentration of PM10
Tabela 2: Povprečna letna koncentracija PM10

Measuring period	**Concentration (μg/m^3)**
April 2003 – April 2004	32.0
April 2004 – April 2005	33.0
April 2005 – April 2006	25.1
April 2006 – April 2007	35.0
April 2007– April 2008	32.5
Permitted annual average concentration	40.0
Target annual average concentration in 2010	20.0

2.1.2 Total particulate matter deposition

Dust is generally understood to be an aerosol of solid particles, mechanically produced, with individual particle diameters of 0.1 μm upwards and can be a problem in almost any industry, from bakeries to building sites. The term dust particulate matter refers to particulate matter, which has fallen out of suspension within the atmosphere. It is no longer legally prescribed that such dust imissions have to be measured, but the maximum annual recommended imission level of particles of 200 mg.m^{-2}.day^{-1} is considered (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit 2002). The sampling is performed over a thirty day period of time using a Bergerhoff deposit dust gauge sampler (VDI 2119-2).

The sampling design for this study was not statistically based; rather, sites were chosen to provide data on dust flux at studied sites and to answer specific questions about the relations of port activities to the total dust deposition-imission regarding to the distance from source, climate influence, wind direction, etc.

A total number of 20 sampling points were selected (Figure 3). These 20 monitoring sites were distributed as follows:

- Points 11, 12, 13 for studying particulate matter flux,
- Points 14, 15 were chosen where complaints about dust deposition were often expressed,
- Point 16 as urban background,
- Points 17, 19, 20 as urban site,
- Point 18 as rural background,
- Points 1a,1b,1c-8 inside the port area.

In the studied period, the limit (200 mg.m^{-2}.day^{-1}) was not exceeded, except at the measuring site in the approximate vicinity of the pier extension (Points 4 and 6) or owing to other intensive building activities (Point 5, Figure 4). At sampling point 18 (rural background), an average concentration of 71 mg.m^{-2}.day^{-1} was calculated. The concentrations of total particulate matter deposition in the surrounding area (also rural background) and at other port sampling locations range from 57 mg.m^{-2}.day^{-1} to 120 mg.m^{-2}.day^{-1} (except for points 4, 5 and 6) and thus do not exceeded the recommended level of 200 mg.m^{-2}.day^{-1}. The results showed that the total particulate matter concentration is influenced by local emissions, the areas affected by natural dust re-suspension, desert dust transport, low rainfall rates favouring dust accumulation, long-range transport of pollutants, by sea-spray at coast sites, contribution from the local traffic, the urban background contribution and that from the port activities (Poljšak et al. 2007, Jereb et al. 2008).

Further study is being conducted to quantify the real influence of port activities regarding the total particulate matter deposition in the surrounding urban area.

Figure 3: Geographical location of the measurement of particulate matter deposition (source: http://maps.google.com/; sampling points were added)

Slika 3: Lokacije meritev suspendiranih delcev (vir: http://maps.google.com/; z dodanimi vzorčišči)

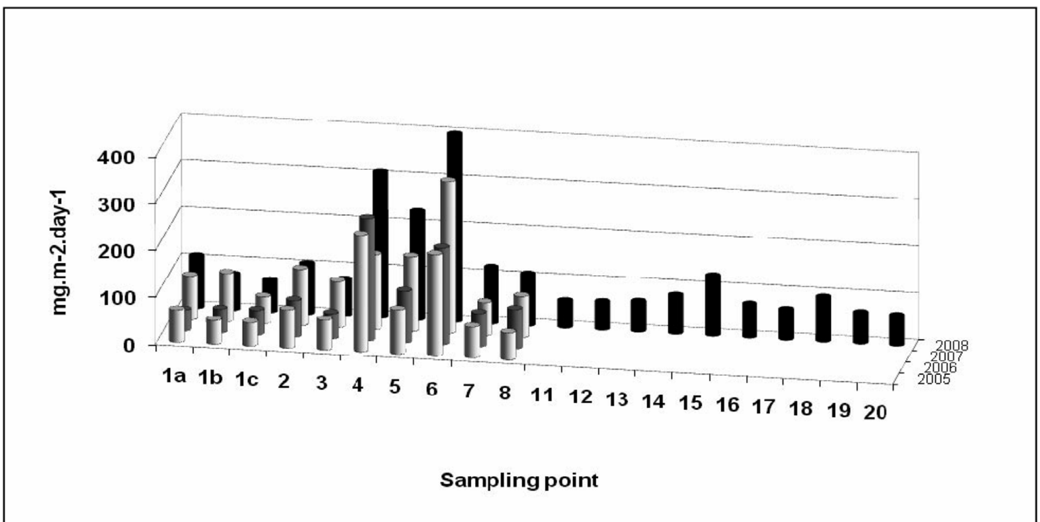


Figure 4: Annual particulate matter deposition at different sites

Slika 4: Letna količina odloženih suspendiranih snovi na posameznih vzorčiščih

2.1.3 Volatile organics and dust emissions levels

Because of the activities at the Port´s Liquid Cargo Terminal, European Energy Terminal, Alumina Terminal and Dry Bulk Cargoes Terminal, volatile organic compounds (gasoline, jet fuel, o-xylene) and dust are emitted. A regular monitoring network, measuring emissions of various pollutants from relevant sources, was set up and is regulated by the Environment Agency of the Republic of Slovenia (Council Directive 96/61/EC..., OJ EC L 257 1996).

In the Port of Koper, emissions levels of selected pollutants are measured every year by the competent authority since 2003. At each terminal, up to 10 sampling points were selected with regard to the possibility of emissions from cargo handling and storage.

The legally prescribed values for dust emission are defined in view of the total dust mass flow, i.e. 50 mg/m^3 or 150 mg/m^3 (Uredba o emisiji snovi v zrak, Ur.l. RS 31/07, 10/08). The results of measurements are summarised in Figure 5. The concentration of dust was too high only in 2004 at a single measuring point.

The total amount of emitted volatile organic compounds is presented in Figure 7. The total emitted amount of VOC is calculated from the measured mass flow at the specific source multiplied by the annual number of the operating hours. Maximum allowed losses are limited to 0.01% or 0.005% in view of the national legislation for fuel storage and handling (Uredba o emisiji hlapnih organskih spojin v zrak, Ur.l. RS 11/99). These values, however, were never exceeded (Figure 8).

Nevertheless, the Port employs several activities and preventive measures to reduce total air pollution. At Liquid Cargo Terminal, best available techniques for the storage of liquids and liquefied gases are practiced (European Commission 2006). The built tanks are equipped with floating, flexible or fixed covers, vapour recuperation systems are implemented, proper tank colours are used reducing unnecessary solar heating, regular inspections and maintenance are performed, instrumentation and automation systems to detect leakage are used, etc.

Although the total cargo load is increasing, the total measured emissions into air are decreasing (Figures 6, 8).

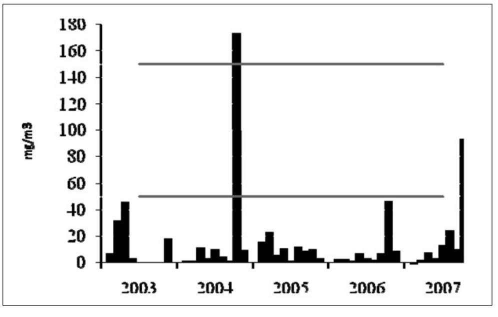


Figure 5: Emission concentrations of dust from different sampling points at European Energy Terminal, Alumina Terminal and Dry Bulk Cargoes Terminal
Slika 5: Emisijske koncentracije prahu na vzorčiščih različnih terminalov

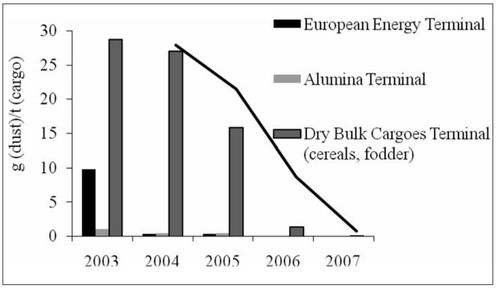


Figure 6: Annual emission levels of dust calculated in view of the total loaded cargo at different terminals
Slika 6: Letne emisijske ravni prahu glede na skupni tovor na različnih terminalih

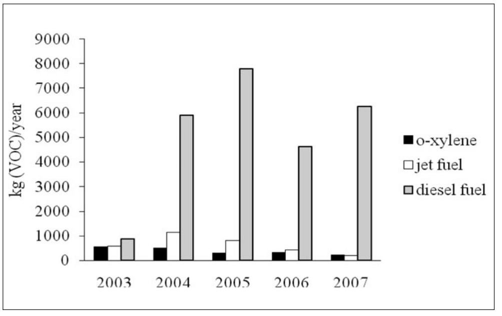


Figure 7: Emission concentrations of volatile organic compounds (VOC) at Liquid Cargo Terminal
Slika 7: Emisijske koncentracije hlapljivih organskih zmesi (VOC) na terminalu za tekoče tovore

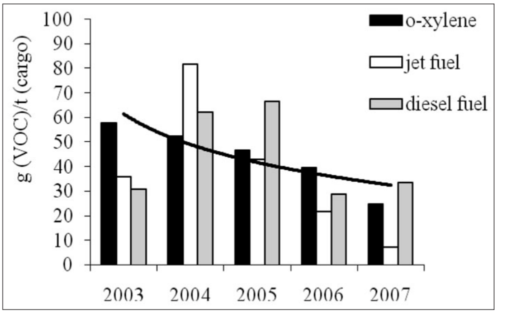


Figure 8: Emission levels of volatile organic compounds (VOC) calculated in view of the total loaded cargo at Liquid Cargo Terminal
Slika 8: Emisijske ravni hlapljivih organskih snovi (VOC), izračunane glede na skupni tovor na terminalu za tekoče tovore

2.2 NOISE LEVELS

The principal noise sources are ships, straddle carriers, cranes, forklifts, refrigerated containers, trucks and trains, and log handling equipment such as log grabbers, etc. The measurements of noise levels in the natural and living environment have been carried out since 1998 at three port border sites: near the town centre of Koper and at border points towards Ankaran and Bertoki (Directive 2002/49/EC..., OJ EU L 189(12) 2002). In 2007, three measuring devices were installed for continuous noise measurements (Figure 9). The measurements are performed by the competent institute. The average annual values do not exceed legally prescribed limits calculated regarding the distance of the measuring device to the nearest residential houses (Uredba o mejnih vrednostih..., Ur.l. RS 105/05). The results of average annual measurements are summarized in Table 4. Nevertheless, the Port has already taken certain measures to reduce noise, e.g. some noisy operations have been moved away from residential boundary, operational procedures were optimised to minimise the noise from loading, night operation hours have been limited, traffic speed in the Port has been limited, etc. The Port is also developing strategic noise mapping that will be used as a source of information and as base for action plans for further reduction of noise levels, identification of problems and situations that need to be improved, reduction of sound transmission, a tool for noise prediction, etc.

The Port usually has no direct influence on sound sources, such as ships at berth (engine noise), but is working on the possibility of installing the shore-side electrical power supply for ships, as already implemented for tugboat. In order to further reduce noise as well as gas emissions from trucks, the port entrance gate has been moved away from the residential area.

Table 4: Comparison of average noise levels in different port location areas
Tabela 4: Primerjava povprečnih ravni hrupa na različnih luških lokacijah

Measuring point	**Toward the town centre of Koper**		**Toward the settlement of Bertoki**		**Toward the settlement of Ankaran**	
	Daily noise level (L_d)	***Night noise level (L_n)***	***Daily noise level (L_d)***	***Night noise level (L_n)***	***Daily noise level (L_d)***	***Night noise level (L_n)***
2000	62	54	56	49	55	49
2001	63	55	60	54	60	57
2002	62	56	56	46	56	49
2003	61	57	51	46	57	46
2004	64	60	60	53	58	54
2005	62	50	59	55	57	52
2006	62	53	58	52	53	47
2007	62	58	60	56	55	51
Calculated legally prescribed limit	62	58	71	61	65	55

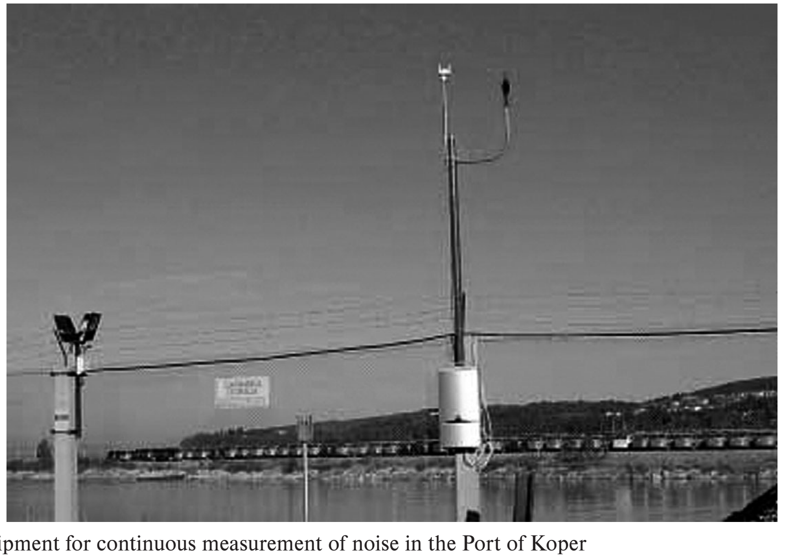


Figure 9: Equipment for continuous measurement of noise in the Port of Koper
Slika 9: Naprave za stalno merjenje hrupa v Luki Koper

2.3. WASTE MANAGEMENT SYSTEM

In order to avoid and minimize the potential effects of generated wastes, the Port of Koper has developed and implemented port waste management plans according to the national regulations (Uredba o obremenjevanju tal..., Ur.l. RS 34/08, Pravilnik o prevzemu ladijskih odpadkov, Ur.l. RS 66/05) and provided adequate reception facilities for oil, chemical and garbage wastes, and to remove, as far as practicable, any disincentives to landing waste in the port. As part of this process, the Port encouraged the responsible management of waste, including minimization and recycling, at the point of generation on ships, reception in ports, transportation and disposal, and ensured that the Port employees and users dispose of garbage and other wastes responsibly in facilities provided and report on any spills or large pieces of floating garbage to the Port authority.

The Port of Koper performs the mandatory public utility service of collecting solid and liquid waste from vessels in the Port area. The environmental awareness of the employees is also reflected in the separate collection and recycling of waste. At the Port, up to 70% of all waste is collected separately and then handed over for recycling. Figure 10 represents the Port's average shares of waste collected separately.

The Port of Koper has its own plant for managing wastes. In the Port area, a composting system consisting of an aerobic decomposition of biodegradable organic matter (food, mostly vegetables or manure) is also operating. The decomposition is performed primarily by facultative and obligate aerobic bacteria, yeasts and fungi, helped in the cooler initial and ending phases by a number of larger organisms. The produced compost is used as a fertilizer.

The Port has an ambitious idea to become an energetic self sufficient port. This can be achieved by the re-use of its internal resources, namely port generated wastes and municipal solid wastes from the nearby local communities.

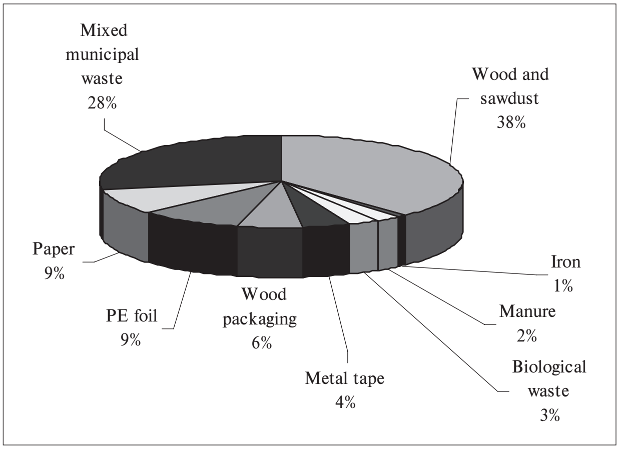


Figure 10: The average shares of waste collected separately in the Port
Slika 10: Povprečni deleži odpadkov, ločeno zbranih v Luki

2.4 WASTE WATER QUALITY

Slovenia has many sources of pollution at the coast and its watershed. Liquid pollutants as well as air pollutants are emitted from these sources. A regular monitoring network, measuring emissions of various pollutants (as directed by the law) from these of these sources was set up and is regulated by the Environment Agency of the Republic of Slovenia (Uredba o emisiji snovi in toplote..., Ur.l. RS 47/05, 45/07, Pravilnik o prvih meritvah..., Ur.l. RS 74/07).

The Port of Koper has some outflows of industrial waste waters and they are monitored by the competent authority. At the Liquid Cargo Terminal, a modern biological and chemical treatment system is operating. A total number of 32 separator systems are also used. They treat oil-contaminated rainwater (run-off) from impervious areas, e.g. car parks, roads and hall yard areas, covering 28 hectares of the Port area.

The majority of waste water produced in the Port is municipal waste water (Figure 11). A part of the municipal waste water is treated in small port wastewater treatment systems with up to 50 population equivalent. The total number of such treatment systems reaches the number of 40. The main part of the Port's originating municipal waste water is treated in the Koper central municipal waste water purification system. Figure 11 shows the environmental load unit (LU) that is calculated from the average measured chemical oxygen demand regarding the total amount of waste water (Uredba o okoljski dajatvi..., Ur.l. RS 123/04, 142/04, 68/05, 77/06, 71/07, 85/08).

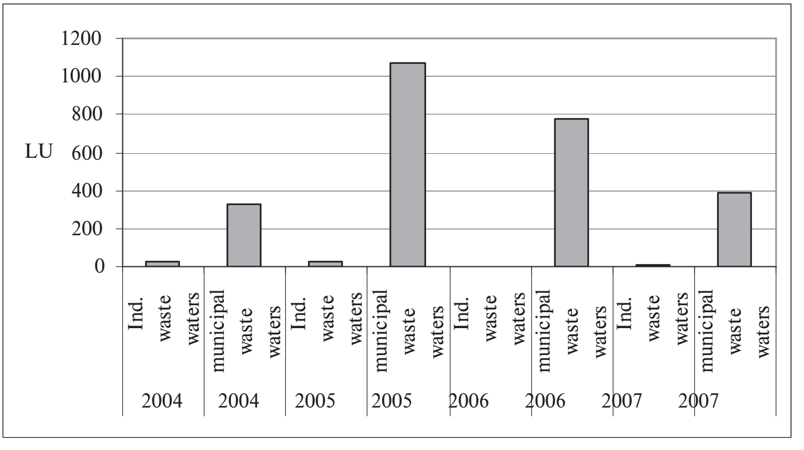


Figure 11: In the Port of Koper, the municipal waste water represents the main source of waste water
Slika 11: V Luki Koper so občinske odpadne vode glavni vir odpadnih voda

2.5 SEA WATER QUALITY

2.5.1 Sea water protection

Services related to the prevention and elimination of the consequences of sea pollution are carried out on the basis of the contract concluded between the Republic of Slovenia and the Port of Koper (Uredba o upravljanju koprskega tovornega pristanišča..., Ur.l. RS 71/08). The Port of Koper has opened its Sea Protection Department and formulated the plan known as Action and informing plan in the event of hazardous substance spills at sea. The Sea Protection Department has acquired two ecological intervention vessels to be used in the event of sea pollution, fitted with all the equipment necessary for remediation of small-scale pollution designed for patrolling and quick interventions in extraordinary events at sea (Figure 12). The Port has established, prepared, implemented and practiced oil spill contingency plans in order to provide guidance and direction to those responding to oil or chemical spills and to set in motion all the necessary actions to stop or minimize the pollution and to reduce its effects on the environment.

In 2007, the Sea Protection Department systematically began to register the number of interventions and to analyse the causes (Table 5).

Table 5: The statistical data of the Sea Protection Department - Port of Koper
Tabela 5: Statistični podatki o delovanju luškega Oddelka za varovanje morja

Year	**Total number of registered events at sea**	**Number of required interventions at sea**	**Number of non-required interventions at sea**
2007	51	39	12
2008	53	43	10

Interventions by the Sea Protection Department is required when material (branches) is brought down the Rižana or Badaševica rivers, when illegal oil spills from ships are observed, when bulk cargo is accidentally released into the sea, etc. The efficiency of the intervention is measured either visually (e.g. removing floating material) or quantitatively (chemical analyses, e.g. oil spill). The main factor influencing the efficiency of the intervention at sea is the response time. All the interventions in the years 2007 and 2008 were effectively performed, and all of them were carried out in port basins. A study of seawater current pattern in port basins is being conducted for a better prediction of spill movements.

Figure 12: One of the Port's ecological boats
Slika 12: Eden izmed luških ekoloških čolnov

2.5.2 Flora in fauna in selected parts in the Port's basins

Degradation of marine waters has been observed in the inner parts of Koper and Piran Bays. Inputs of organic matter and nutrients from insufficiently treated municipal and industrial wastewaters, as well as effluents of the Rižana, Badaševica, Dragonja and Drnica rivers are issues of the highest concern and have locally deteriorated marine waters along the Slovenian coast (Gosar et Muri 2005).

Several underwater investigations of flora and fauna have taken place within port basins in recent years (Štirn et Richter 2007, 2008). The collection of data has been carried out primarily by SCUBA diving, on linear transects inside the Port's water belt. The field work has been recorded with a photo-camera. The study has not included the assessment of fish diversity.

In the tidal zone or deeper, the following organisms have been found: *Fucus virsoides, Ulva rigida, Crassostrea gigas, Mytilus galloprovincialis, Balanus and Chthamalus species, Actinia equine, Anemonia sulcata, Eriphia spiniforms.* The concrete port underwater columns constitute a habitat suitable for many species such as: *Pleraphysilla spinifera, Dysidea fragilis, Eudendrium cf. rameum, Sabella spallanzani, Schizobrachiella sanguine, Phallusia fumigate, Polycarpa pomaria, Maia squinando.* At the bottom, Cymodocea nodosa, Pinna nobilis and Ubogebia species have also been found. The above organisms also inhabit the shallow Slovenian Sea (Lipej et al. 2000), but further study will have to be performed for a complete inventory of the flora and fauna in the Port's basins.

2.6 CHEMICAL DATA AND QUALITY CLASSIFICATION OF SEDIMENT SAMPLES

In 1998 and 1999, some sediment samples were taken and analysed from the Port's basins No. II and III. The concentration ranges of microelements from different sampling points in the Northern Adriatic region are summarised in Table 6. Microelements values are comparable to those from the inner part of Koper Bay, thus suggesting that the quality of sediments in port basins has not been altered by the Port's activities though the years.

Some organisations have set numerical guidelines involving processing of any information relating to a particular contaminant into two separate datasets, those that produce biological effects and those that do not (Table 7). The comparison of the results with some references regarding the quality of marine sediments has indicated that the quality of port sediments is not problematic regarding those values (Sediment quality guidelines http://www.mincos.gov.au...).

At the national level, the quality of sediments is evaluated in view of the legislation for depositing dredged material on shore since they are taken on land for alternative use, such as land reclamation, restoring mudflats or construction purposes. In this case, sediments are being regarded as waste material (Uredba o ravnanju z odpadki, Ur.l. RS 34/08).

Table 6: Comparison of concentration ranges of microelements from different sediment samples
Tabela 6: Primerjava koncentracij mikroelementov v različnih območjih na podlagi vzorcev usedlin

	Pb *($mgkg^{-1}$)*	**Cr** *($mgkg^{-1}$)*	**Hg** *($mgkg^{-1}$)*	**Ni** *($mgkg^{-1}$)*	**Zn** *($mgkg^{-1}$)*	**Cu** *($mgkg^{-1}$)*
Bay of Koper (Ogorelec et al., 1987)	32-77	64-209	0.06-0.28	60-145	12-95	25-42
Gulf of Trieste (Faganeli et al., 1991, Donazzolo et al., 1981)	10-65	15-183	0.1-3.0	12-230	20-410	25-45
Basins in Port of Koper (Ožbolt et al. 1998, Šömen-Joksič et al., 1999)	10-19	23-52	0.06-0.3	60-91	22-103	15-33

Table 7: The comparison of the quality of sediments (microelements) from the Port of Koper with some quality guidelines
Tabela 7: Primerjava kakovosti usedlin (mikroelementov) v Luki Koper z nekaterimi smernicami o njihovi kakovosti

Micro-element	***Unit***	**AZNECC**		**USEPA/ NOAA**		**CCME**		**SLO**	**Concentration range of microelements-different sediment samples from Port of Koper**
		ISOQ-L	ISOQ-H	ERL	ERM	ISOQ	PEL		
As	*$mgkg^{-1}$*	20	70	8.2	70	7.24	41.6	30	1-2
Cu	*$mgkg^{-1}$*	65	270	34	270	18.7	108	60	15-33
Zn	*$mgkg^{-1}$*	200	410	150	410	124	271	300	22-103
Cd	*$mgkg^{-1}$*	1.5	10	1.2	9.6	0.7	4.2	1,1	0.1-0.3
Cr	*$mgkg^{-1}$*	80	370	81	370	52.3	160	90	23-52
Pb	*$mgkg^{-1}$*	50	220	46.7	218	30.2	112	100	10-19
Hg	*$mgkg^{-1}$*	0.15	1	0.15	0.71	0.13	0.7	0,7	0.06-0.3

AZNECC: Australian and New Zealand Guidelines for Fresh and Marine Water Quality, Australian and New Zealand Environment and Conservation Council
USEPA: US Environmental Protection Agency; National Sediment Inventory, Appendix D- Screening Values for Chemicals Evaluated
NOAA: National Oceanic and Atmospheric Administration, Sediment Quality Guidelines Developed for the National Status and Trends Program
CCME: Canadian Council of Ministers of the Environment, Summary of Existing Canadian Environmental Quality Guidelines, ISQG- Interim Sediment Quality Guideline and PEL- Probable Effect Level
SLO: Uredba o obremenjevanju tal z vnašanjem odpadkov. Ur.l. RS 34/08.

3. CONCLUSIONS

In the present article, an overview of the environmental influence of the Port of Koper is presented, based on data collected over the last few years and on comparison to some normative references. As indicated in the article, the potential Port's effects embrace a wide range of environmental issues that has to be taken into account, such as water pollution, emissions of dust and volatile organic compounds, noise, contamination of bottom sediment, marine ecology, waste discharges, oil leakage and spillage, and so forth. The Port has introduced an extensive monitoring program to constantly monitor its influence and its effectiveness in performing preventive actions towards reducing its impacts.

The indicators referring to the air quality (PM10, particulate matter deposition, volatile organic compounds) show accordance with the legislation normative reference values. The average PM10 concentration has been gradually reduced (about 7%) in the last two years, thus indicating that the overall preventive measures and activities performed by the Port are effective.

In the study of the total dust particulate matter deposition, higher concentrations of total dust have been observed only at sampling points near the approximate vicinity of the pier extension owing to the intensive building activities. The concentrations of total particulate matter deposition in the surrounding area and in other port areas range from 57 to 120 $mg.m^{-2}.day^{-1}$ and thus do not exceed the recommended level of 200 $mg.m^{-2}.day^{-1}$. At the sampling point classified as rural background, an average annual concentration of 71 $mg.m^{-2}.day^{-1}$ was measured. The losses of volatile organic compounds, due to handling and storage, have never exceeded the limit of 0.01% or 0.005%.

The Port continues to monitor noise levels at three permanent listening stations. Through its noise management system it attempts to be in compliance with the legislation and to further reduce the annoying degree of unwanted sound, e.g. some noisy operations have been moved away from residential boundary, operational procedures were optimised, night operation hours have been limited, traffic speed in the port has been limited, port entrance gate has been moved away from the residential area.

The result of the ports effective waste management system is the high share (70%) of separately collected waste. Furthermore, the Port is going to re-use its internal resources (wastes) for the purpose of producing green energy.

The municipal waste water represents the main source of waste water in the Port. Many purification systems are used to treat port waste waters. The Port has managed to halve the environmental load unit in the last three years.

The quality of port sediments is comparable to those from other parts in Koper Bay. Because of its quality, the dredged sediments can be re-used for land reclamation, restoring mudflats or construction purposes.

The results of environmental indicators and their trends indicate a positive approach towards reducing port environmental influence and will be further used as a diagnostic tool.

4. SUMMARY

Environmental indicators are powerful tools that serve many purposes, useful as tools for performance evaluation, public information, estimation of the environmental influence, reporting on progress towards sustainable development.

The article presents a dynamic set of environmental indicators on priority issues for which the Port of Koper maintains monitoring programs. The main goal of this article was to provide an insight into the extent and degree of the environmental impacts of the Port of Koper. For this purpose, the following indicators were selected: maritime throughput, imission concentration of PM10, total particulate matter deposition, emission concentrations of dust, and emission concentration of volatile organic compounds (i.e. gasoline, jet fuel and o-xylene), noise levels, shares of waste collected separately, environmental load unit for waste water, quality of sediments. The selected environmental indicators were presented over a period of time and compared to some normative references. All the environmental measurements were performed by competent authorities using standardized methods and equipment.

The indicators referring to the air quality (PM10, particulate matter deposition, volatile organic compounds) show accordance with the legislation normative reference values. The average PM10 concentration has been gradually reduced (about 7%) in the last two years, thus indicating that the overall preventive measures and activities performed by the Port are effective. The concentrations of total particulate matter deposition in the surrounding area and in other port areas range from 57 mg.m-2.day-1 to 120 mg.m-2.day-1 and thus do not exceed the target level of 200 mg.m-2.day-1. The losses of volatile organic compounds, due to handling and storage, have never exceeded the limit of 0.01% or 0.005%.

Through the noise management system, the port attempt to be in compliance with the legislation and to further reduce annoying degree of unwanted sound. The port average daily noise levels range from 55 dB to 62 dB, while the average night noise levels range from 51 dB to 58 dB.

The result of the Port's effective waste management system is the high share (70%) of separately collected waste. Furthermore, the Port is going to re-use its internal resources (wastes) with the intention to produce green energy.

The municipal waste water constitutes the main source of waste water in the Port. Many purification systems are used to treat port waste waters. The Port has managed to halve the environmental load unit in the last three years.

The quality of port sediments is comparable to those from other parts in Koper Bay. Because of its quality, the dredged sediments can be re-used for land reclamation, restoring mudflats or construction purposes.

The results of environmental indicators and their trends indicate a positive approach towards reducing port environmental influence and will be further used as a diagnostic tool.

POVZETEK

Okoljski kazalniki so učinkovito in priročno orodje za ugotavljanje stanja na marsikaterem področju, na primer za ocenjevanje funkcionalnosti, pri javnem obveščanju, za ocenjevanje okoljskih vplivov, pri poročanju o napredku trajnostnega razvoja, etc.

V pričujočem članku je predstavljena dinamična skupina okoljskih kazalnikov glede prednostnih nalog, za katere v Luki Koper opravljajo programe monitoringa.

Glavni namen članka je osvetliti obseg in stopnjo vplivov delovanja Luke Koper na okolje. V ta namen so bili uporabljeni naslednji kazalniki: tovorni promet, imisijske koncentracije

suspendiranih delcev PM10, celotna količina odloženih suspendiranih delcev, imisijske koncentracije prahu in hlapljivih organskih zmesi (npr. bencin, gorivo za reaktivne motorje, o-ksilen), raven hrupa, deleži ločeno zbranih odpadkov, enota obremenitve okolja za odpadne vode, kakovost usedlin. Izbrani okoljski kazalniki, ki zajemajo daljše časovno obdobje, so primerjani z nekaterimi normativnimi referencami. Vse okoljske meritve so opravile pristojne službe z uporabo standardnih metod in opreme.

Kazalniki kakovosti zraka (PM10, odloženi suspendirani delci, hlapljive organske zmesi) kažejo na skladnost z normativnimi referenčnimi vrednostmi zakonodaje. Povprečna koncentracija PM10 se je postopoma zmanjšala v zadnjih dveh letih (za približno 7 %), kar govori v prid dejstvu, da so skupni preventivni ukrepi in dejavnosti, ki jih opravljajo v Luki Koper, učinkoviti. Koncentracije vseh suspendiranih delcev, odloženih v obdajajoče okolje in v druga luška območja, se gibljejo med 57 mg.m-2.dan-1 in 120 mg.m-2.dan-1 in zatorej ne presegajo ciljne ravni 200 mg.m-2.dan-1. Izgube hlapljivih organskih zmesi, kot posledica pretovarjanja in skladiščenja, niso nikoli presegle meje 0,01 % ali 0,005 %.

Luka Koper si s svojim sistemom za nadzor hrupa prizadeva ravnati v skladu z zakonodajo in hkrati skuša še nadalje zmanjšati raven motečega in neželenega hrupa. Povprečne dnevne ravni hrupa Luke Koper se gibljejo med 55 dB in 62 dB, povprečne nočne ravni pa med 51 dB in 58 dB.

Posledica luškega učinkovitega upravljanja z odpadki je visoki delež (70 %) ločeno zbranih odpadkov. Poleg tega v Luki načrtujejo reciklažo svojih notranjih virov (odpadkov) z namenom, da se vpelje proizvodnja zelene energije.

Občinske odpadne vode so glavni vir odpadnih voda v Luki. V rabi so mnogi sistemi za čiščenje luških odpadnih voda, in tudi to je razlog, da je v zadnjih treh letih Luki uspelo zmanjšati enoto okoljskega obremenjevanja kar za polovico.

Stanje usedlin v luki je primerljivo s tistim v drugih delih Koprskega zaliva. In prav zaradi njihove kakovosti se lahko te usedline uporabijo za osuševanje zemljišč, obnavljanje polojev ali pa v gradbene namene.

Rezultati okoljskih kazalnikov in njihovi trendi kažejo na pozitiven pristop k zmanjševanju vplivov Luke Koper na okolje in bodo še naprej uporabljani kot primerno diagnostično orodje.

5. SPECIAL THANKS

Special thank for underwater investigations are due to Marjan Rihter and prof. Emeritus Jože Štirn.

6. LITERATURE

1. Agencija RS za okolje (2007): Poročilo pilotnega projekta: Opredelitev virov delcev PM10 v Sloveniji. ARSO. Ljubljana. 44 pp.
2. BS EN 12341. Air quality. Determination of the PM10 fraction of suspended particulate matter. Reference method and field test procedure to demonstrate reference equivalence of measurement methods. 1999. 18 pp.
3. Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (2002): Erste Allgemeine Verwaltungsvorschrift zum Bundes-Immissionsschutzgesetz. Technische Anleitung zur Reinhaltung der Luft. Vom 24. Juli 2002.
4. Council Directive 1999/30/EC of 22 April 1999 relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air. Official Journal of the European Communities L 163(41), 29/6/1999.
5. Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control. Official Journal of the European Communities L 257, 10/10/1996.
6. Directive 2002/49/EC of the European Parliament and of the Council of 25 June 2002 relating to the Assessment and Management of Environmental Noise. Official Journal of the European Communities L 189(12), 18/7/2002.
7. Donazzolo, R., O. Heike Merlin, L. Menegazzo Vitturil, A. Orio, B. Pavoni, G. Perin, S. Rabitti (1981): Heavy metal contamination in surface sediments from the Gulf of Venice, Italy. Mar. Pollut. Bull. 12: 417-425
8. Eržen, I., T. Cegnar, D. Podkrajšek, N. Furlan, M. Juričič, N. Konec Juričič, M. Lovrečič, A. Uršič, V. Zadnik, L. Zaletel Kragelj (2003): Proučevanje vpliva okolja na pojav določenih bolezni in povečano stopnjo umrljivosti prebivalcev na območju dela Mestne občine Koper. Zaključno poročilo. Mestna občina Koper. 46 pp.
9. European Commission (2006): Integrated Pollution Prevention and Control. Reference Document on Best Available Techniques on Emissions from Storage. 432 pp.
10. Faganeli, J., R. Planinc, J. Pezdič, B. Smodiš, P. Stegnar, B. Ogorelec (1991): Marine geology of the Gulf of Trieste (northen Adriatic): Geochemical aspects. Marine geology 99 (1-2): 93-108.
11. Gosar, L., G. Muri (2005): National action plan (NAP) for Slovenia: for the protection of the Mediterranean Sea against pollution from land-based sources. University of Ljubljana, Faculty of Civil and Geodetic Engineering, National Institute of Biology. Ljubljana. 68 pp.
12. Jereb, G., B. Poljšak, F. Cepak, B. Marzi, A. Katz Sidney (2008): Correlation between vertical and horizontal particulate matter deposition. In: European aerosol conference 2008. 24-29 August 2008. Thessaloniki, Greece.
13. Lipej, L., M. Orlando, T. Makovec (2000): Pestrost življenja piranske Punte: naravna dediščina. Nacionalni inštitut za biologijo, Morska biološka postaja. Piran. 16 pp.
14. Ogorelec, B., M. Mišič, J. Faganeli, P. Stegnar, B. Vrišer, A. Vukovič (1987): Recentni sediment Koprskega zaliva. Geologija 30: 87-121
15. Ožbolt, A., M. Colarič, F. Poljšak, H. Čotar, J. Župan, G. Hempt, O. Novel, K. Vatič (1998): Ocena stanja obremenjenosti okolja na področju bodočega živinskega terminala Luke Koper. Zavod za zdravstveno varstvo Koper. Koper. 33 pp.
16. Poljšak, B., G. Jereb, B. Marzi, F. Cepak, G. Dražić (2007): Characteristics of particulate matter deposition from Port of Koper. V: European Aerosol Conference 2007. September 9-14, 2007. Salzburg, Austria.
17. Pravilnik o prevzemu ladijskih odpadkov. Ur.l. RS 66/05.
18. Pravilnik o prvih meritvah in obratovalnem monitoringu odpadnih vod ter o pogojih za njegovo izvajanje. Ur.l. RS 74/07.

19. Regulation (EC) No. 761/2001 of the European parliament and of the council of 19 March 2001 allowing voluntary participation by organisations in a Community eco-management and audit scheme (EMAS). Official Journal of the European Communities L 114(44), 24/4/2001.
20. Sediment quality guidelines. http://www.mincos.gov.au/__data/assets/pdf_file/0003/316137/gfmwq-guidelines-vol2-8-4.pdf (2. jun. 2008)
21. Šömen-Joksič, A., Z. Kralj, F. Poljšak, A. Koželj, B. Kahne Juriševič, R. Fikon , J. Župan (1999): Preiskava morskih sedimentov v Luki Koper. Zavod za zdravstveno varstvo Koper. Koper. 6 pp.
22. Štirn, J., M. Richter (2007): Vpliv delovanja Luke Koper na pojave onesnaženja in druge probleme okolja v koprskem zalivu ter predlog strategije in ukrepov za njegovo varstvo: Poročilo – faza III. Luka Koper. 15 pp.
23. Štirn, J., M. Richter (2008): Vpliv delovanja Luke Koper na pojave onesnaženja in druge probleme okolja v koprskem zalivu ter predlog strategije in ukrepov za njegovo varstvo: Poročilo – faza IV. Luka Koper. 35 pp.
24. Uredba o emisiji hlapnih organskih spojin v zrak iz naprav za skladiščenje in pretakanje motornega bencina. Ur.l. RS 11/99.
25. Uredba o emisiji snovi in toplote pri odvajanju odpadnih vod v vode in javno kanalizacijo. Ur.l. RS 47/05, 45/07.
26. Uredba o emisiji snovi v zrak iz nepremičnih virov onesnaževanja. Ur.l. RS 31/07, 10/08.
27. Uredba o mejnih vrednostih kazalcev hrupa v okolju. Ur.l. RS 105/05.
28. Uredba o obremenjevanju tal z vnašanjem odpadkov. Ur.l. RS 34/2008.
29. Uredba o okoljski dajatvi za onesnaževanje okolja zaradi odvajanja odpadnih voda. Ur.l. RS 123/04, 142/04, 68/05, 77/06, 71/07, 85/08.
30. Uredba o ravnanju z odpadki. Ur.l. RS 34/08.
31. Uredba o upravljanju koprskega tovornega pristanišča, opravljanju pristaniške dejavnosti, podelitvi koncesije za upravljanje, vodenje, razvoj in redno vzdrževanje pristaniške infrastrukture v tem pristanišču. Ur.l. RS 71/08.
32. VDI 2119-2. Measuring of particulate precipitations - Determination of the dust precipitation with collecting pots made of glass (Bergerhoff method) or plastic. 1996. 12 pp.

Franka CEPAK, Boris MARZI
Port of Koper
Vojkovo nabrežje 38
SI- 6501 Koper, Slovenia
franka.cepak@luka-kp.si

IMPACT OF ARTIFICIAL LIGHT ON BEHAVIOURAL PATTERNS OF COASTAL FISHES OF CONSERVATION INTEREST

VPLIV UMETNE SVETLOBE NA VEDENJSKE VZORCE OBALNIH RIB NARAVOVARSTVENEGA POMENA

Mara MARCHESAN, Maurizio SPOTO and Enrico A. FERRERO

Keywords: vision, visual behaviour, artificial illumination, conservation, marine protected area
Ključne besede: vidni vedenjski vzorci, umetno osvetljevanje, naravovarstvo, morska zaščitena območja

ABSTRACT

The effects of artificial light of variable intensity and wavelength were investigated on aggregation, phototaxis and photokinesis in the blue damselfish *Chromis chromis* L., the brown meagre *Sciaena umbra* L., the peacock wrasse *Symphodus tinca* L. and the white seabream *Diplodus sargus* L. Overall, the brown meagre was the most affected by the presence of artificial light. The other three species did not react conspicuously to light exposure. The results fit into the ecological classification of species according to their visual behaviour patterns towards artificial light, and show that the rationalisation of artificial light emissions in the underwater environment would help to improve the quality of management and the effectiveness of conservation policies in coastal and marine protected areas.

IZVLEČEK

Avtorji članka so preučevali vplive umetne svetlobe različnih intenzitet in valovnih dolžin na agregacijo, fototakso in fotokinezo pri črniku *Chromis chromis* L., konju *Sciaena umbra* L., pisani ustnači *Symphodus tinca* L. in šargu *Diplodus sargus* L. Izkazalo se je, da je za umetno svetlobo najbolj občutljiv konj, medtem ko pri preostalih treh vrstah ni bilo videti, da bi se odzivale nenavadno nanjo. Rezultati raziskave se ujemajo z ekološko klasifikacijo vrst glede na njihove vidne vedenjske vzorce med izpostavljenostjo umetni svetlobi in kažejo, da bi z racionalizacijo sevanja umetne svetlobe v podvodnem okolju izboljšali kakovost upravljanja in učinkovitost naravovarstvenih ukrepov v obalnih in morskih zaščitenih območjih.

1. INTRODUCTION

Most fish depend on photoreception in order to perform activities that are crucial for survival (e.g. Lythgoe, 1979). Behavioural patterns are often differentiated throughout the twenty-four hour cycle. The activities performed in different periods of the day may depend on each species' visual characteristics (Helfman, 1993). Activity rhythms, behavioural patterns and visual system of most species are therefore strictly correlated, and depend on both phylogenetic traits and ecological conditions of life. Species that have evolved in similar environments, or that have similar lifestyles, tend to show common traits in their visual adaptations (e.g. Land & Nilsson, 2002). A primary role in shaping visual system and behaviour of different groups of fish is played by their inter-specific trophic relations (Hobson et al., 1981; Pankhurst & Hilder, 1998). In each fish community, we can recognise strictly diurnal species (e.g. *Chromis chromis* L., *Symphodus tinca* L.), strictly nocturnal species (e.g. *Sciaena umbra* L., *Scorpaena porcus* L.) and species characterised by more flexible circadian behavioural patterns (e.g. *Diplodus sargus* L., *Sparus auratus* L.). Broadly speaking, diurnal species are well-adapted to the exposure of a wide range of light intensities throughout the whole visual spectrum (conventionally referred to the human range, but see Hawryshyn, 2003). This is usually associated to a low reactivity to light stimuli and to a good tolerance for high light intensities. On the other hand, nocturnal species can easily detect the presence of low-to-very-low light sources, and they are particularly sensitive to the shorter wavelengths of the visual spectrum (violet, blue, green-blue). The level of tolerance to light exposure is reduced, and they usually tend to move away from the light. The exposure to light stimuli, either natural or artificial, can therefore induce diverse and conspicuous reactions in fish (Ben-Yami, 1976). The type of response is often associated to each species' feeding habits. In most cases, fish that are attracted by strong lights have diurnal habits, and they are often planktivorous, detritivorous or grazers (Ben-Yami, 1976; Marchesan et al., 2003). Most other species tend to prefer medium-to-low lights and to keep at some distance from the light source (Ben-Yami, 1976; Kawamura, 1986; Beltestad & Misund, 1988). Such a distance is higher for strictly nocturnal species, whereas it is shorter for crepuscular species that show peaks of activity during the twilight periods. In most cases, such species are characterised by carnivorous habits (Ben-Yami, 1976; Marchesan et al., 2003).

Coastal fish communities are among the most sensitive to human disturbance, as many anthropic activities are concentrated along the coast, for instance small scale fishing with lights, coastline traffic and public illumination, lighthouses and harbour lights, light and sound performances in tourist areas. Hence, the evaluation of the impact of human activities on coastal fishes of conservation interest is of the utmost importance for the effective management of marine protected areas. It is apparent that such areas should be free from 'photopollution' (Verheijen, 1985; Witherington, 1997), but this does not mean that all activities implying the use of light should be avoided, as long as they are calibrated on the level of tolerance of the most sensitive species.

In this study, the behavioural effects of artificial light were investigated in four fish species of conservation interest: the blue damselfish *C. chromis* L., the brown meagre *S. umbra* L., the peacock wrasse *S. tinca* L. and the white seabream *D. sargus* L. The aim of the study was to determine how levels of aggregation, phototaxis and photokinesis of the experimental fish were affected by lights of variable intensity and wavelength. Such investigations were performed in order to define the specific level of disturbance associated to the emission of artificial light, and thus to determine the light levels that could be tolerated by the fish community living inside a marine reserve.

2. MATERIALS AND METHODS

All observations were carried out at the Department of Biology of the University of Trieste between October 2002 and November 2003. The experimental fish were obtained from wild caught stocks kept at the Aquarium of Piran (Slovenia). For each species, groups of 10 adults of medium size were tested.

All experiments were carried out in a grey fibreglass tank (L x W x H: 320 x 40 x 60 cm). A transparent glass window (W x H: 30 x 50 cm), uncovered only during the experiments, was present at one of the short sides of the rectangular tank. The tank was divided into 5 sections, the closest to the light source was called E, the farthest A.

The tank was filled with approximately 700 l artificial seawater and fitted with closed circuit filtering and water re-circulating system. Water temperature was maintained in the 18-22°C range, salinity in the 30-34 ‰ range. Before being tested, fish were left in the experimental tank for at least one week to acclimate, and were subjected to a 12 L:12 D photoperiod (Light from 06:00 to 18:00; Dark from 18:00 to 06:00). Ambient illumination at water-level was about 20 $\mu Es^{-1}m^{-2}$ in light conditions, provided by Philips type 94 fluorescent tubes matching the solar spectrum, and $8x10^{-3}$ $\mu Es^{-1}m^{-2}$ in dark conditions.

Both before and during the experiments, fish were fed every two or three day's ad libitum on chopped *Atherina* sp. At the end of the tests, the fish were either released in the open sea or used for other investigations.

The experimental light beam was provided by a Strand Harmony 22 illuminator equipped with a 1000 W halogen lamp. The illuminator was placed in front of the glass window, at one meter distance. The diffused light beam was regulated in order to exactly fit the window.

Light intensity was varied with a rheostat in discrete steps. Eight levels of irradiance were tested: (1) 0.2 $\mu Es^{-1}m^{-2}$, (2) 4 $\mu Es^{-1}m^{-2}$, (3) 10 $\mu Es^{-1}m^{-2}$, (4) 20 $\mu Es^{-1}m^{-2}$, (5) 30$\mu Es^{-1}m^{-2}$, (6) 41$\mu Es^{-1}m^{-2}$, (7) 53$\mu Es^{-1}m^{-2}$, (8) 68$\mu Es^{-1}m^{-2}$. The intensity was always kept well within the fish photopic vision and tolerance limits. It spans the range from crepuscular to full day light in coastal waters (Clarke & Denton, 1962; Ali, 1971).

Light colour was varied throughout the visual spectrum by placing LEE Filters monochrome gelatine sheets in front of the lamp. Six colours were tested: (1) violet (peak at approx. 410 nm), (2) blue (peak at approx. 460nm), (3) green (peak at approx. 525nm), (4) yellow (peak at approx. 580nm), (5) orange (peak at approx. 600nm), (6) red (peak at approx. 650nm). For all colours, irradiance was regulated at a standard of 4 $\mu Es^{-1}m^{-2}$, as this was the maximum intensity that could be reached by the colour with highest absorbance (blue filter) and still within the range of colour vision.

Light irradiance measurements were made with a Li-Cor radiometer equipped with a LI-192SA PAR (photosynthetically active radiation) underwater quantum sensor, sensitive to $0.5x10^{-3}$ $\mu E\ s^{-1}\ m^{-2}$. The sensor was placed in mid-water, at 30 cm distance from the glass window. A light gradient was present along the tank, and light intensity was attenuated of about 70% at 300 cm distance from the glass window.

Two sets of experiments were carried out, following the protocols described hereby.

First set of experiments: reactions to light stimuli of variable intensity. For each species, two experiments were performed. Three replicate trials were conducted for each experiment.

In the first experiment (LH), light intensity was progressively increased from the lowest (1) to the highest (8) level over a time span of 4 hours. In the second experiment (HL), light intensity was progressively decreased from the highest to the lowest level, again over a span of 4 hours.

Each light condition was kept for 30 minutes to allow habituation of the fish. Recordings were carried out during the first 20 minutes of exposure to each illumination level. All experimental sessions started at 18:00 and ended at 22:00. For each species, a total of 960 minutes of videotapes were analysed.

Second set of experiments: reactions to light stimuli of variable wavelength. Again, two experiments were performed for each species. Three replicate trials were conducted for each experiment.

In the first experiment (SL), light colour was progressively shifted from the shorter (violet) to the longer (red) wavelengths of the visual spectrum, testing 6 colours over a span of 3 hours. In the second experiment (LS), light colour was progressively shifted from the longer to the shorter wavelengths of the visual spectrum, again testing 6 colours over a span of 3 hours.

Each light condition was kept for 30 minutes to allow habituation of the fish. Recordings were carried out during the first 20 minutes of exposure to each level of illumination. All experimental sessions started at 18:00 and ended at 21:00. For each species, a total of 840 minutes of videotapes were analysed.

Behavioural patterns were analysed from remote video-recorded sessions. All recordings were performed with a SONY SSC-DC50AP colour video-camera with minimum sensitivity of 1 lux. Videotapes were preliminary observed at 9X speed, to obtain a first qualitative description of each session. Then a temporal sequence of 21 frames, randomly chosen within 1 minute intervals throughout the session, was analysed in detail.

The following parameters were considered: (1) mean nearest neighbour distance (MNND), as a proportion of fish total length, to determine the level of aggregation of the group of fish, (2) mean percentage of fish in the area closest to (E) and farther from (A) the light source, to define the degree of attraction to or repulsion from light, (3) mean percentage of fish still, to determine fish activity levels and thus degree of inhibition.

Statistical analysis was performed using the statistical package Statistica 5.1. Only non-parametric statistics were used. Mean values were given ± one standard deviation. Significance was set at probability $P=0.05$.

3. RESULTS

Reactions to light stimuli of variable intensity

The blue damselfish *C. chromis* L. was moderately affected by changes in light intensity, and it was especially attracted by strong lights. Individuals maintained a positive phototaxis even when light intensity was experimentally decreased. In all cases, the level of aggregation was rather low, and a high percentage of fish tended to keep still.

During both experiments, there were no significant differences in the degree of aggregation of the group of fish at different light intensities (Fig. 1a, HL & LH, Kruskal-Wallis test, d.f.=7, NS). Fish showed a higher aggregation with an increasing light intensity only at low illumination levels (HL vs LH, levels 1-3, Mann-Whitney U test, n=3, P<0.01). When light intensity was progressively increased, fish tended to keep close to the light source when the illumination was low (level 1-3) and to move away from it when it became stronger, whereas the differences in the phototactic reactions between illumination levels were less pronounced,

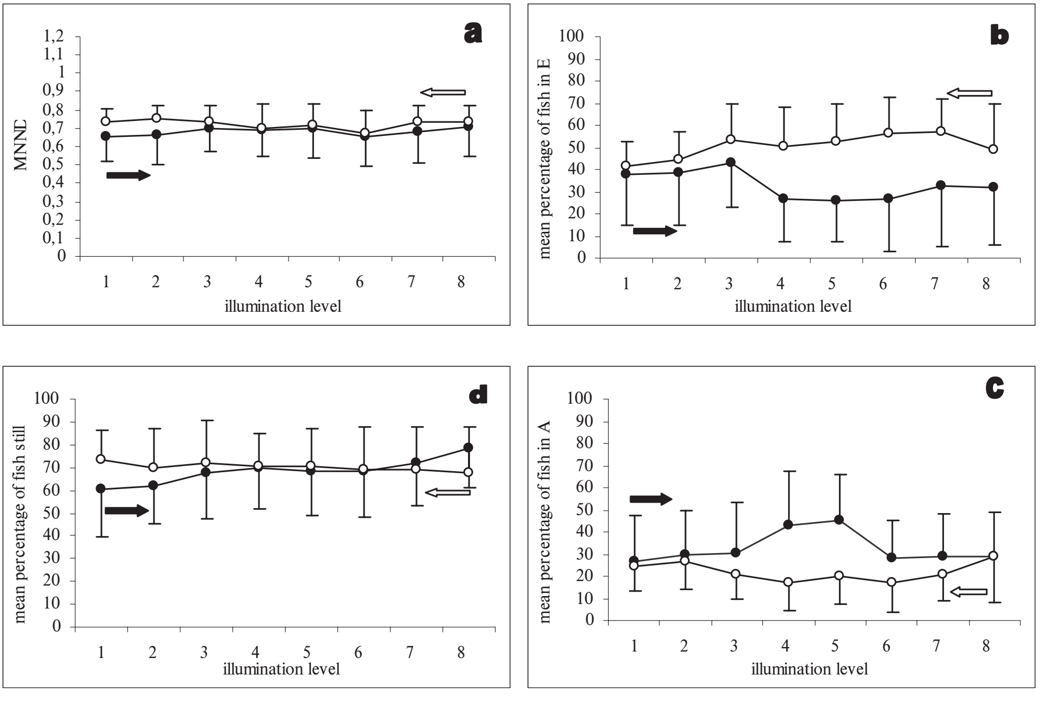


Figure 1: Blue Damselfish *C. chromis* L.
Effects of light intensity variations on the following parameters: (a) mean nearest neighbour distance (MNND), (b) mean percentage of fish in the area closest to the light source (E), (c) mean percentage of fish in the area farther from the light source (A), (d) mean percentage of fish still. Filled circles and arrows indicate experiment LH: illumination progressively increased from the Lowest (1) to the Highest (8) level. Open circles and arrows indicate experiment HL: illumination progressively decreased from the Highest (8) to the Lowest (1) level. Values given as means (n=3), bars ± one standard deviation. Levels of irradiance tested: (1) 0.2 µEs-1m-2, (2) 4 µEs-1m-2, (3) 10 µEs-1m-2, (4) 20 µEs-1m-2, (5) 30µEs-1m-2, (6) 41µEs-1m-2, (7) 53µEs-1m-2, (8) 68µEs-1m-2.
Slika 1: Črnik C. chromis L.
Vplivi svetlobe različnih intenzitet na naslednje parametre: (a) srednja oddaljenost do najbližjih sosedov (MNND), (b) srednji odstotek rib v območju, najbližjem svetlobnemu viru (E), (c) srednji odstotek rib v območju, najbolj oddaljenem od svetlobnega vira (A), (d) srednji odstotek mirujočih rib. Polni krogci in puščice ponazarjajo eksperiment LH: svetloba se je postopoma povečevala od L (najšibkejše - 1) do H (najmočnejše - 8). Prazni krogci in puščice ponazarjajo eksperiment HL: svetloba se je postopoma zmanjševala od H (najmočnejše - 8) do L (najšibkejše - 1). Vrednosti, prikazane kot srednje (n=3), stolpci ± standardni odklon. Ravni testiranega izžarevanja: (1) 0.2 µEs-1m-2, (2) 4 µEs-1m-2, (3) 10 µEs-1m-2, (4) 20 µEs-1m-2, (5) 30µEs-1m-2, (6) 41µEs-1m-2, (7) 53µEs-1m-2, (8) 68µEs-1m-2.

although still significant, with a decreasing light intensity (Fig. 1b,c, LH and HL, Kruskal-Wallis test, d.f.=7, P<0.01). Fish were significantly more attracted to light when the illumination was strong at first and then progressively diminished (HL vs LH, Mann-Whitney U test, n=3, P<0.01). Switching from low to high illumination levels, fish tended to be moderately active at first, and to become stiller as the experiment progressed (Fig. 1d, LH, Kruskal-Wallis test, d.f.=7, P<0.01). No variations in the level of photokinesis were registered when light intensity was progressively decreased (Fig. 1d, HL, Kruskal-Wallis test, d.f.=7, NS). Fish activity was significantly more inhibited by a progressive increase in light intensity (HL vs LH, Mann-Whitney U test, n=3, P<0.01).

The brown meagre *S. umbra* L. was strongly reactive to the presence of an illuminated field during both experiments, independent of the light intensity. Overall, fish tended to aggregate as far as possible from the light source, and to keep still in such a position. However, it is interesting to note that during the low-to-high illumination experiment, fish showed an increase in the aggregation and inhibition levels, and a higher negative phototaxis, when light intensity was varied from crepuscular to diurnal levels (lev. 1-2 to 3-4).

The group of fish was characterised by high MNNDs during both experiments. In particular, fish showed a pronounced aggregation when they were exposed to strong lights at the beginning of the experiment, and when light intensity varied from crepuscular to diurnal values (Fig. 2a, HL and LH, Kruskal-Wallis test, d.f.=7, P<0.01). Overall, the presence of strong illumination followed by a decrease in light intensity induced higher aggregation of the fish group (HL vs LH, Mann-Whitney U test, n=3, P<0.01). At all light levels, fish were dramatically repulsed by the presence of a light source (Fig. 2b, c, HL and LH, Kruskal-Wallis test, d.f.=7, P<0.01). Overall, the level of negative phototaxis was higher during the high-to-low illumination experiment (HL vs LH, Mann-Whitney U test, n=3, P<0.01). All fish tended to keep still throughout the high-to-low experiment (Fig. 2d, HL, Kruskal-Wallis test, d.f.=3, NS). When light was progressively increased, fish showed a peak in their inhibition levels in the central part of the experiment (levels 3-5) (Fig. 2d, LH, Kruskal-Wallis test, d.f.=7, P<0.01). Overall, the degree of inhibition was, however, higher when light intensity was progressively decreased (HL vs LH, Mann-Whitney U test, n=3, P<0.01).

The peacock wrasse *S. tinca* L. was only slightly affected by changes in light intensity. During both experiments, fish tended to show moderate aggregation and to keep still in the proximity of the light source.

During both experiments, the group of fish showed a slight tendency to increase the aggregation as the experiment went on (Fig. 3a, LH and HL, Kruskal-Wallis test, d.f.=7, P<0.01). Overall, the group was more cohered when light intensity was progressively increased (LH vs HL, Mann-Whitney U test, n=3, P<0.01). Fish were strongly attracted to light during both experiments, and the differences among light levels did not show any specific trend, although still significant (Fig. 3b,c, LH and HL, Kruskal-Wallis test, d.f.=7, P<0.01). However, fish were more attracted to light during the low-to-high experiment (LH vs HL, Mann-Whitney U test, n=3, P<0.01). Levels of inhibition were high during both experiments, and both within and between experiment differences were not pronounced (Fig. 3d, LH and HL, Kruskal-Wallis test, d.f.=7, P<0.05; LH vs HL, Mann-Whitney U test, n=3, P<0.05).

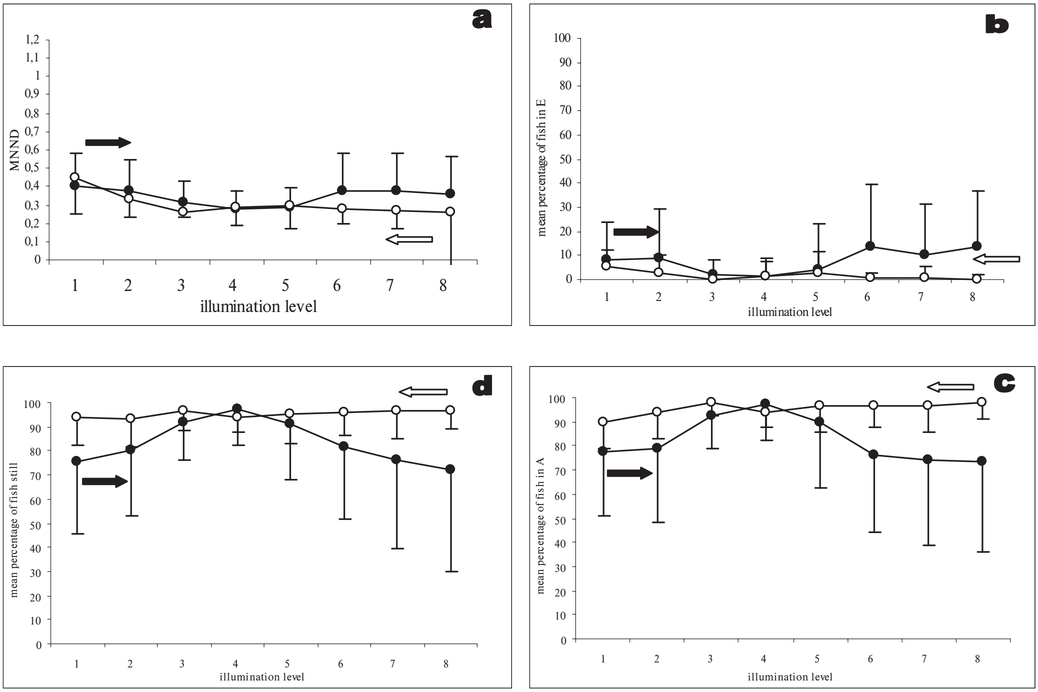


Figure 2: Brown Meagre *S. umbra* L.
Effects of light intensity variations on the following parameters: (a) mean nearest neighbour distance (MNND), (b) mean percentage of fish in the area closest to the light source (E), (c) mean percentage of fish in the area farther from the light source (A), (d) mean percentage of fish still. Filled circles and arrows indicate experiment LH: illumination progressively increased from the Lowest (1) to the Highest (8) level. Open circles and arrows indicate experiment HL: illumination progressively decreased from the Highest (8) to the Lowest (1) level. Values given as means (n=3), bars ± one standard deviation. Levels of irradiance tested: (1) 0.2 µEs-1m-2, (2) 4 µEs-1m-2, (3) 10 µEs-1m-2, (4) 20 µEs-1m-2, (5) 30µEs-1m-2, (6) 41µEs-1m-2, (7) 53µEs-1m-2, (8) 68µEs-1m-2.
Slika 2: Konj S. umbra L.
Vplivi svetlobe različnih intenzitet na naslednje parametre: (a) srednja oddaljenost do najbližjih sosedov (MNND), (b) srednji odstotek rib v območju, najbližjem svetlobnemu viru (E), (c) srednji odstotek rib v območju, najbolj oddaljenem od svetlobnega vira (A), (d) srednji odstotek mirujočih rib. Polni krogci in puščice ponazarjajo eksperiment LH: svetloba se je postopoma povečevala od L (najšibkejše - 1) do H (najmočnejše - 8). Prazni krogci in puščice ponazarjajo eksperiment HL: svetloba se je postopoma zmanjševala od H (najmočnejše - 8) do L (najšibkejše - 1). Vrednosti, prikazane kot srednje (n=3), stolpci ± standardni odklon. Ravni testiranega izžarevanja:: (1) 0.2 µEs-1m-2, (2) 4 µEs-1m-2, (3) 10 µEs-1m-2, (4) 20 µEs-1m-2, (5) 30µEs-1m-2, (6) 41µEs-1m-2, (7) 53µEs-1m-2, (8) 68µEs-1m-2.

The white seabream *D. sargus* L. was influenced by changes in light intensity during both experiments, although the reactions were not always pronounced. Overall, fish tended to show moderate aggregation, and to keep active at some distance from the light source.

Levels of aggregation were higher when fish were exposed to low lights at the beginning of the experiment, whereas no specific trends were recognisable during the high-to-low experiment, although the variations were still significant (Fig. 4a, LH and HL, Kruskal-Wallis test, d.f.=7, $P<0.01$). Comparing the two experiments, group cohesion was higher when fish experienced low illumination conditions first (LH vs HL, Mann-Whitney U test, n=3, $P<0.01$). Fish tended to be progressively more attracted to the illuminated area as light intensity increased (Fig.

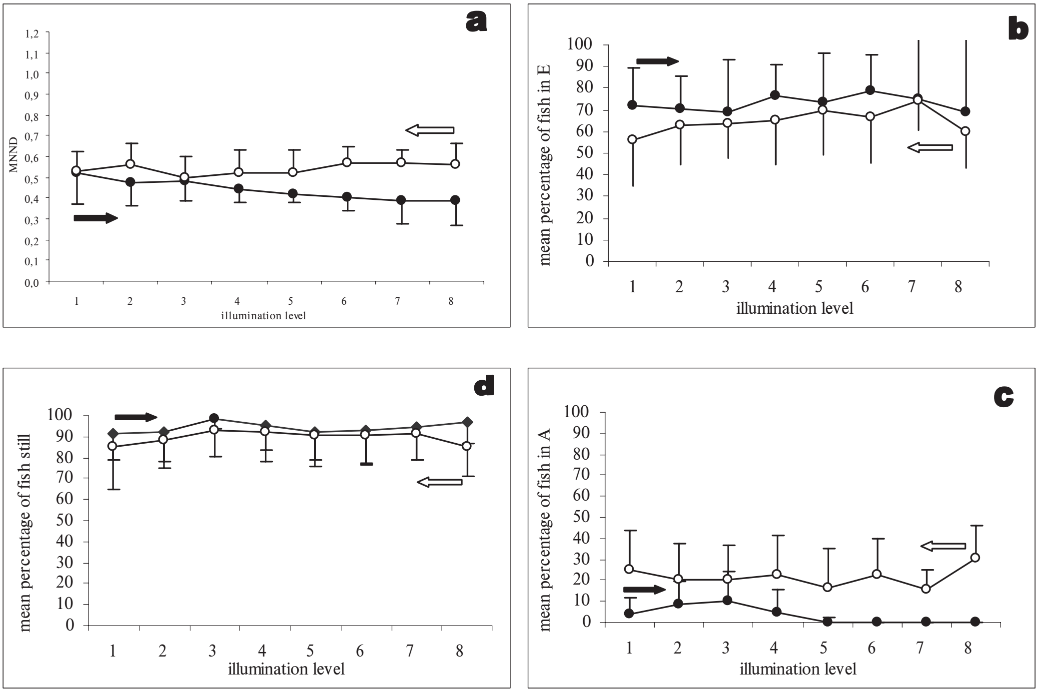


Figure 3: Peacock Wrasse *S. tinca* L.
Effects of light intensity variations on the following parameters: (a) mean nearest neighbour distance (MNND), (b) mean percentage of fish in the area closest to the light source (E), (c) mean percentage of fish in the area farther from the light source (A), (d) mean percentage of fish still. Filled circles and arrows indicate experiment LH: illumination progressively increased from the Lowest (1) to the Highest (8) level. Open circles and arrows indicate experiment HL: illumination progressively decreased from the Highest (8) to the Lowest (1) level. Values given as means (n=3), bars ± one standard deviation. Levels of irradiance tested: (1) 0.2 µEs-1m-2, (2) 4 µEs-1m-2, (3) 10 µEs-1m-2, (4) 20 µEs-1m-2, (5) 30µEs-1m-2, (6) 41µEs-1m-2, (7) 53µEs-1m-2, (8) 68µEs-1m-2.
Slika 3: Pisana ustnača S. tinca L.
Vplivi svetlobe različnih intenzitet na naslednje parametre: (a) srednja oddaljenost do najbližjih sosedov (MNND), (b) srednji odstotek rib v območju, najbližjem svetlobnemu viru (E), (c) srednji odstotek rib v območju, najbolj oddaljenem od svetlobnega vira (A), (d) srednji odstotek mirujočih rib. Polni krogci in puščice ponazarjajo eksperiment LH: svetloba se je postopoma povečevala od L (najšibkejše - 1) do H (najmočnejše - 8). Prazni krogci in puščice ponazarjajo eksperiment HL: svetloba se je postopoma zmanjševala od H (najmočnejše - 8) do L (najšibkejše - 1). Vrednosti, prikazane kot srednje (n=3), stolpci ± standardni odklon. Ravni testiranega izžarevanja:: (1) 0.2 µEs-1m-2, (2) 4 µEs-1m-2, (3) 10 µEs-1m-2, (4) 20 µEs-1m-2, (5) 30µEs-1m-2, (6) 41µEs-1m-2, (7) 53µEs-1m-2, (8) 68µEs-1m-2.

4b,c, LH, Kruskal-Wallis test, d.f.=7, P<0.01), whereas differences were less pronounced with a decreasing light intensity (Fig. 4b,c, HL, Kruskal-Wallis test, d.f.=7, P<0.05). However, comparing the two experiments, it is apparent that fish were more attracted to light when the illumination was strong at first and then progressively decreased (HL vs LH, Mann-Whitney U test, n=3, P<0.01). The level of inhibition was low in all cases, and tended to further decrease throughout both experiments (Fig. 4d, LH and HL, Kruskal-Wallis test, d.f.=7, P<0.01). At high illumination levels, fish were progressively more active if they had been exposed to low light intensity first (LH vs HL, Mann-Whitney U test, n=3, P<0.01).

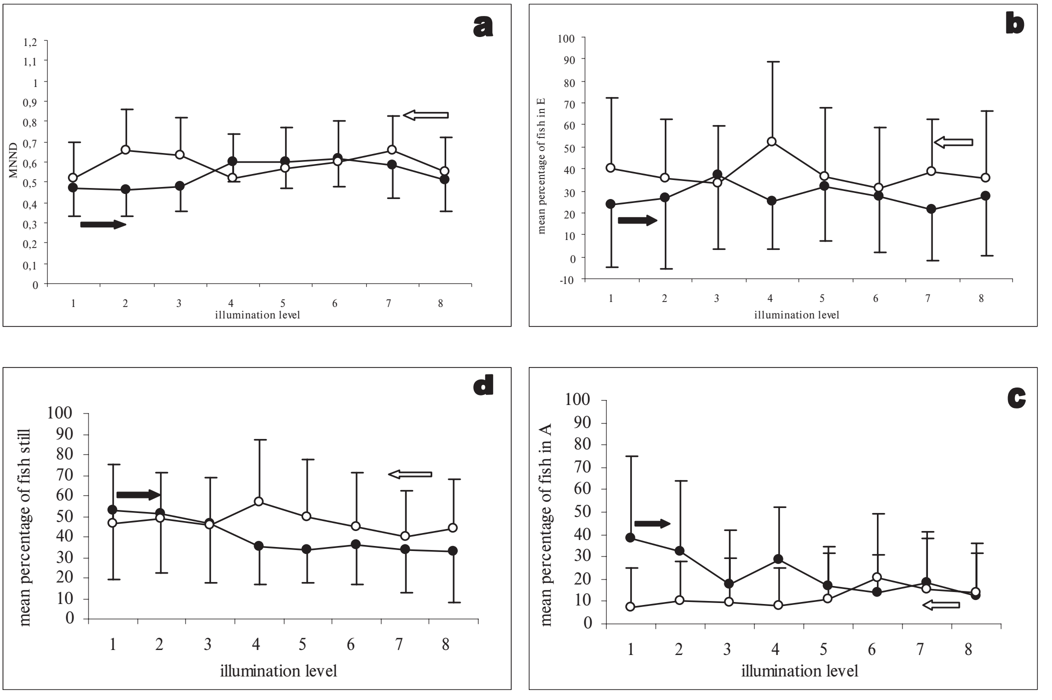


Figure 4: White seabream *D. sargus* L.
Effects of light intensity variations on the following parameters: (a) mean nearest neighbour distance (MNND), (b) mean percentage of fish in the area closest to the light source (E), (c) mean percentage of fish in the area farther from the light source (A), (d) mean percentage of fish still. Filled circles and arrows indicate experiment LH: illumination progressively increased from the Lowest (1) to the Highest (8) level. Open circles and arrows indicate experiment HL: illumination progressively decreased from the Highest (8) to the Lowest (1) level. Values given as means (n=3), bars ± one standard deviation. Levels of irradiance tested: (1) 0.2 $\mu Es^{-1}m^{-2}$, (2) 4 $\mu Es^{-1}m^{-2}$, (3) 10 $\mu Es^{-1}m^{-2}$, (4) 20 $\mu Es^{-1}m^{-2}$, (5) 30$\mu Es^{-1}m^{-2}$, (6) 41$\mu Es^{-1}m^{-2}$, (7) 53$\mu Es^{-1}m^{-2}$, (8) 68$\mu Es^{-1}m^{-2}$.
Slika 4: Šarg D. sargus L.
Vplivi svetlobe različnih intenzitet na naslednje parametre: (a) srednja oddaljenost do najbližjih sosedov (MNND), (b) srednji odstotek rib v območju, najbližjem svetlobnemu viru (E), (c) srednji odstotek rib v območju, najbolj oddaljenem od svetlobnega vira (A), (d) srednji odstotek mirujočih rib. Polni krogci in puščice ponazarjajo eksperiment LH: svetloba se je postopoma povečevala od L (najšibkejše - 1) do H (najmočnejše - 8). Prazni krogci in puščice ponazarjajo eksperiment HL: svetloba se je postopoma zmanjševala od H (najmočnejše - 8) do L (najšibkejše - 1). Vrednosti, prikazane kot srednje (n=3), stolpci ± standardni odklon. Ravni testiranega izžarevanja:: (1) 0.2 $\mu Es^{-1}m^{-2}$, (2) 4 $\mu Es^{-1}m^{-2}$, (3) 10 $\mu Es^{-1}m^{-2}$, (4) 20 $\mu Es^{-1}m^{-2}$, (5) 30$\mu Es^{-1}m^{-2}$, (6) 41$\mu Es^{-1}m^{-2}$, (7) 53$\mu Es^{-1}m^{-2}$, (8) 68$\mu Es^{-1}m^{-2}$.

Reactions to light stimuli of variable wavelength

The blue damselfish *C. chromis* L. was not particularly affected by the exposure to monochromatic lights of different wavelength, independent of the order of presentation. In general, the aggregation was low, the level of inhibition medium-to-high, and the attraction to the light source moderate.

There were no significant variations in the degree of aggregation either shifting light colour from violet to red or back (Fig. 5a, SL and LS, Kruskal-Wallis test, d.f.=7, P=NS). Similarly, there were no differences between the level of aggregation shown by the group of fish during the two experiments (SL vs LS, Mann-Whitney U test, n=3, P=NS). During the violet-to-red experiment, fish tended to be progressively less attracted to the light source as the test went on (Fig. 5b,c, SL, Kruskal-Wallis test, d.f.=7, P<0.01). The exposure to red light induced a repulsive reaction also during the red-to-violet experiment, but the level of attraction was medium and constant throughout the rest of the test (Fig. 5b,c, LS, Kruskal-Wallis test, d.f.=7, P<0.01). Overall, fish were slightly more attracted to light when the colour was shifted from red to violet (Fig. 5b,c, SL vs LS, Mann-Whitney U test, n=3, P<0.01). A high percentage of fish was still

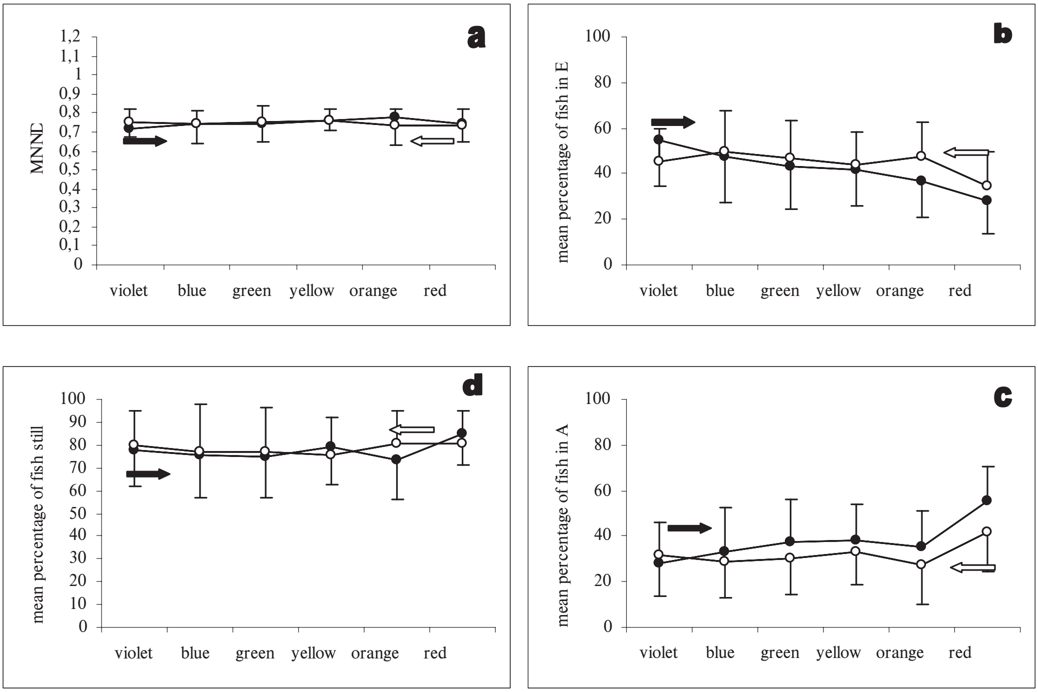


Figure 5: Blue Damselfish *C. chromis* L.

Effects of light colour variations on the following parameters: (a) mean nearest neighbour distance (MNND), (b) mean percentage of fish in the area closest to the light source (E), (c) mean percentage of fish in the area farther from the light source (A), (d) mean percentage of fish still. Filled circles and arrows indicate experiment SL: light colour progressively shifted from the Shorter (violet) to the Longer (red) wavelengths of the visual spectrum. Open circles and arrows indicate experiment LS: light colour progressively shifted from the Longer (red) to the Shorter (violet) wavelengths of the visual spectrum. Values given as means (n=3), bars ± one standard deviation. Colours tested: (1) violet (peak at approx. 410 nm), (2) blue (peak at approx. 460nm), (3) green (peak at approx. 525nm), (4) yellow (peak at approx. 580nm), (5) orange (peak at approx. 600nm), (6) red (peak at approx. 650nm).

Slika 5: Črnik C. chromis L.

Vplivi svetlobe različnih intenzitet na naslednje parametre: (a) srednja oddaljenost do najbližjega soseda (MNND), (b) srednji odstotek rib v območju, najbližjem svetlobnemu viru (E), (c) srednji odstotek rib v območju, najbolj oddaljenem od svetlobnega vira (A), (d) srednji odstotek mirujočih rib. Polni krogci in puščice ponazarjajo eksperiment SL: svetla svetloba se je postopoma premikala od S (krajših – vijoličnih) do L (daljših – rdečih) valovnih dolžin vidnega spektra. Prazni krogci in puščice ponazarjajo eksperiment LS: svetla svetloba se je postopoma premikala od L (daljših – rdečih) do S (krajših-vijoličnih) valovnih dolžin vidnega spektra. Vrednosti, prikazane kot srednje (n=3), stolpci ± standardni odklon. Testirane barve: (1) vijolična (višek pri pribl. 410 nm), (2) modra (višek pri pribl. 460nm), (3) zelena (višek pri pribl. 525nm), (4) rumena (višek pri pribl. 580nm), (5) oranžna (višek pri pribl. 600nm), (6) rdeča (višek pri pribl. 650nm).

in all cases and during both experiments (Fig. 5d, LS, Kruskal-Wallis test, d.f.=7, P=NS; SL, Kruskal-Wallis test, d.f.=7, P<0.05; SL vs LS, Mann-Whitney U test, n=3, P=NS).

The brown meagre *S. umbra* L. was conspicuously influenced by monochromatic lights that induced overall a negative reaction. Fish tended to be especially repulsed by the shorter-wavelength colours (violet, blue and to a lesser extent green).

During both experiments, the cohesion was high in presence of violet, blue and green lights, whereas the MNND slightly increased with the other colours (Fig. 6a, SL and LS, Kruskal-Wallis test, d.f.=7, P<0.01). In general, fish were more aggregated when they were

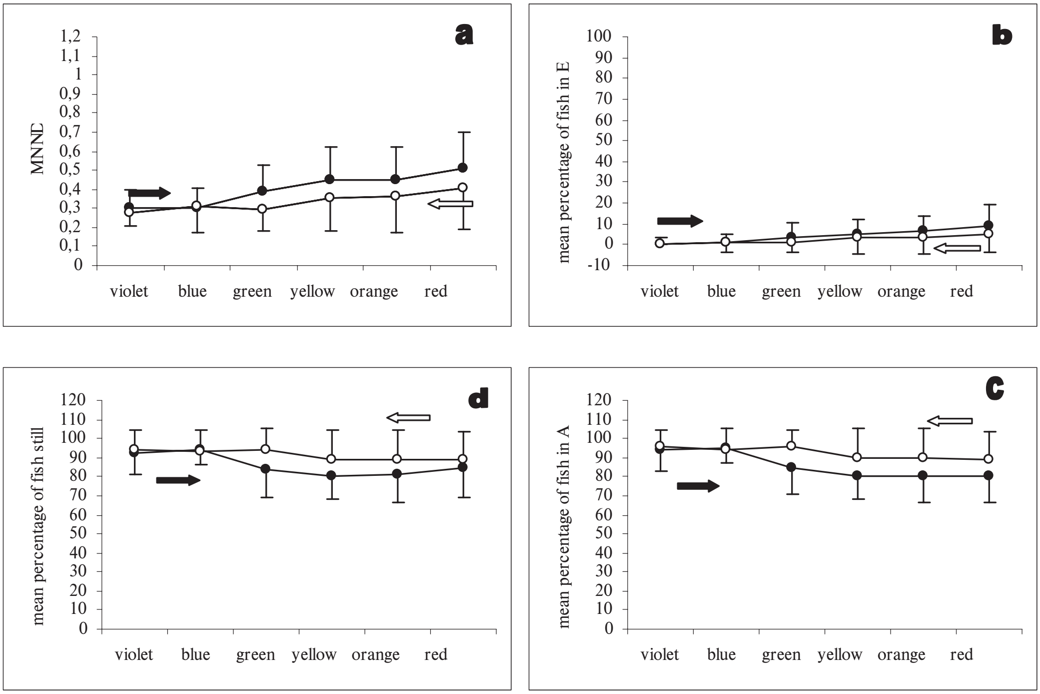


Figure 6: Brown Meagre *S. umbra* L.
Effects of light colour variations on the following parameters: (a) mean nearest neighbour distance (MNND), (b) mean percentage of fish in the area closest to the light source (E), (c) mean percentage of fish in the area farther from the light source (A), (d) mean percentage of fish still. Filled circles and arrows indicate experiment SL: light colour progressively shifted from the Shorter (violet) to the Longer (red) wavelengths of the visual spectrum. Open circles and arrows indicate experiment LS: light colour progressively shifted from the Longer (red) to the Shorter (violet) wavelengths of the visual spectrum. Values given as means (n=3), bars ± one standard deviation. Colours tested: (1) violet (peak at approx. 410 nm), (2) blue (peak at approx. 460nm), (3) green (peak at approx. 525nm), (4) yellow (peak at approx. 580nm), (5) orange (peak at approx. 600nm), (6) red (peak at approx. 650nm).
Slika 6: Konj S. umbra L.
Vplivi svetlobe različnih intenzitet na naslednje parametre: (a) srednja oddaljenost do najbližjih sosedov (MNND), (b) srednji odstotek rib v območju, najbližjem svetlobnemu viru (E), (c) srednji odstotek rib v območju, najbolj oddaljenem od svetlobnega vira (A), (d) srednji odstotek mirujočih rib. Polni krogci in puščice ponazarjajo eksperiment SL: svetla svetloba se je postopoma premikala od S (krajših – vijoličnih) do L (daljših – rdečih) valovnih dolžin vidnega spektra. Prazni krogci in puščice ponazarjajo eksperiment LS: svetla svetloba se je postopoma premikala od L (daljših – rdečih) do S (krajših-vijoličnih) valovnih dolžin vidnega spektra. Vrednosti, prikazane kot srednje (n=3), stolpci ± standardni odklon. Testirane barve: (1) vijolična (višek pri pribl. 410 nm), (2) modra (višek pri pribl. 460nm), (3) zelena (višek pri pribl. 525nm), (4) rumena (višek pri pribl. 580nm), (5) oranžna (višek pri pribl. 600nm), (6) rdeča (višek pri pribl. 650nm).

exposed to red light (diurnal wavelengths) first (SL vs LS, Mann-Whitney U test, n=3, P<0.01). Violet and blue lights projected at the beginning of the experiment induced a particularly strong repulsion (Fig. 6b,c, SL, Kruskal-Wallis test, d.f.=7, P<0.01). During the second experiment, all colours appeared to evoke a constant and strong negative reaction (Fig. 6b,c, LS, Kruskal-Wallis test, d.f.=7, P<0.05). Long-to-medium-wavelength colours were significantly more repulsive when presented at the beginning of the experiment (SL vs

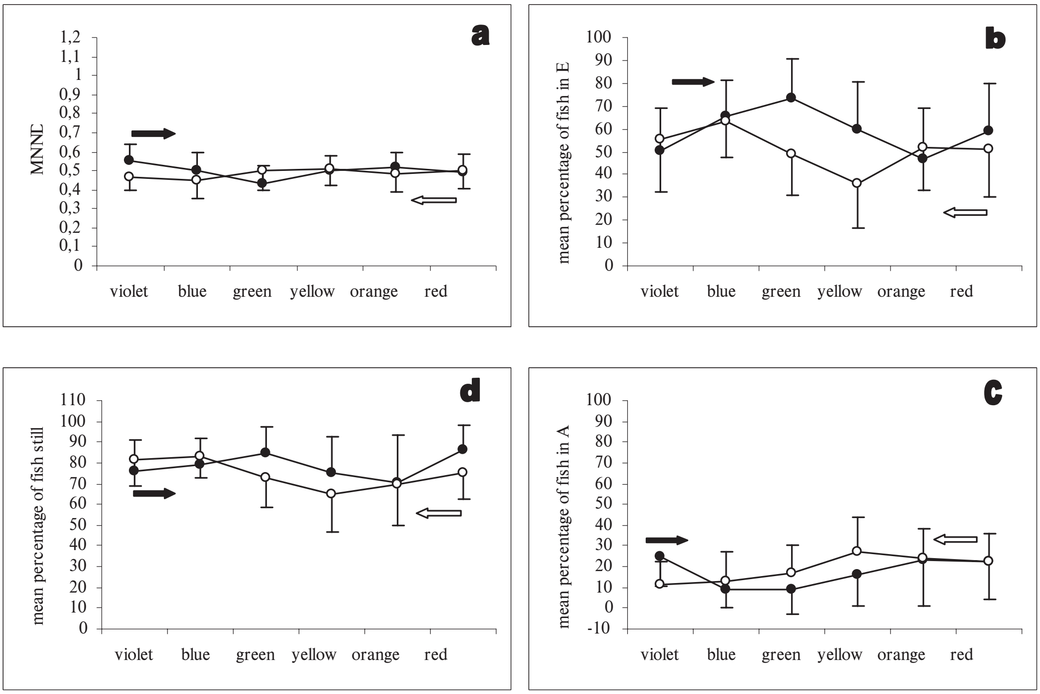


Figure 7: Peacock Wrasse *S. tinca* L.

Effects of light colour variations on the following parameters: (a) mean nearest neighbour distance (MNND), (b) mean percentage of fish in the area closest to the light source (E), (c) mean percentage of fish in the area farther from the light source (A), (d) mean percentage of fish still. Filled circles and arrows indicate experiment SL: light colour progressively shifted from the Shorter (violet) to the Longer (red) wavelengths of the visual spectrum. Open circles and arrows indicate experiment LS: light colour progressively shifted from the Longer (red) to the Shorter (violet) wavelengths of the visual spectrum. Values given as means (n=3), bars ± one standard deviation. Colours tested: (1) violet (peak at approx. 410 nm), (2) blue (peak at approx. 460nm), (3) green (peak at approx. 525nm), (4) yellow (peak at approx. 580nm), (5) orange (peak at approx. 600nm), (6) red (peak at approx. 650nm).

Slika 7: Pisana ustnača S. tinca L.

Vplivi svetlobe različnih intenzitet na naslednje parametre: (a) srednja oddaljenost do najbližjih sosedov (MNND), (b) srednji odstotek rib v območju, najbližjem svetlobnemu viru (E), (c) srednji odstotek rib v območju, najbolj oddaljenem od svetlobnega vira (A), (d) srednji odstotek mirujočih rib. Polni krogci in puščice ponazarjajo eksperiment SL: svetla svetloba se je postopoma premikala od S (krajših – vijoličnih) do L (daljših – rdečih) valovnih dolžin vidnega spektra. Prazni krogci in puščice ponazarjajo eksperiment LS: svetla svetloba se je postopoma premikala od L (daljših – rdečih) do S (krajših-vijoličnih) valovnih dolžin vidnega spektra. Vrednosti, prikazane kot srednje (n=3), stolpci ± standardni odklon. Testirane barve: (1) vijolična (višek pri pribl. 410 nm), (2) modra (višek pri pribl. 460nm), (3) zelena (višek pri pribl. 525nm), (4) rumena (višek pri pribl. 580nm), (5) oranžna (višek pri pribl. 600nm), (6) rdeča (višek pri pribl. 650nm).

LS, Mann-Whitney U test, n=3, P<0.01). The level of inhibition was high throughout both experiments, although there were differences among colours in the violet-to-red test (Fig. 6d, SL, Kruskal-Wallis test, d.f.=7, P<0.01; LS, Kruskal-Wallis test, d.f.=7, P=NS). Fish tended to keep slightly stiller when longer-wavelength lights were presented first (SL vs LS, Mann-Whitney U test, n=3, P<0.01).

Overall, the peacock wrasse *S. tinca* L. was not particularly affected by monochromatic lights. Level of aggregation, attraction and inhibition were set on medium values and both within-and-between-experiment differences were either not pronounced or did not show a specific trend.

Both experiments had only a slight effect on levels of aggregation (Fig. 7a, SL, Kruskal-Wallis test, d.f.=7, P<0.01; LS, Kruskal-Wallis test, d.f.=7, P<0.05). Differences between experiments were not marked either (SL vs LS, Mann-Whitney U test, n=3, P=NS). Shifting colour from violet to red, fish were progressively more attracted at first (violet to green), then they tended to move farther from the light source (green to orange) and to get closer to it again in presence of red light (Fig. 7b,c, SL, Kruskal-Wallis test, d.f.=7, P<0.01). An inverse trend was detected during the red to violet experiment (Fig. 7b,c, LS, Kruskal-Wallis test, d.f.=7, P<0.01). The differences between the two experiments were significant, especially due to the higher attractive effect of green and yellow lights presented after the shorter-wavelength ones (SL vs LS, Mann-Whitney U test, n=3, P<0.01). The degree of inhibition was always medium-to-high, and the fluctuations were similar to those pointed out for the level of attraction (Fig. 7d, SL and LS, Kruskal-Wallis test, d.f.=7, P<0.01; SL vs LS, Mann-Whitney U test, n=3, P<0.01).

The white seabream *D. sargus* L. was characterised by low levels of aggregation and inhibition in presence of coloured lights, and it did not show any conspicuous phototactic response.

Levels of aggregation are low in all cases, although fish show a slightly higher cohesion in presence of short-to-medium wavelength lights (Fig. 8a, SL and LS, Kruskal-Wallis test, d.f.=7, P<0.01). There are no differences between the two experiments (SL vs LS, Mann-Whitney U test, n=3, P=NS). Fish were not particularly attracted by monochromatic lights, and there were not significant differences between colours either within and between experiments (Fig. 8b,c, SL and LS, Kruskal-Wallis test, d.f.=7, P=NS; LS vs SL, Mann-Whitney U test, n=3, P=NS). The level of inhibition was in general low, and the differences between colours were not significant when the colour was shifted from violet to red (Fig. 8d, SL, Kruskal-Wallis test, d.f.=7, P=NS). During the second experiment, inhibition was slightly higher in presence of yellow, green and blue lights (Fig. 8d, LS, Kruskal-Wallis test, d.f.=7, P<0.01). Between-experiment variations in the level of inhibition were not significant (LS vs SL, Mann-Whitney U test, n=3, P=NS).

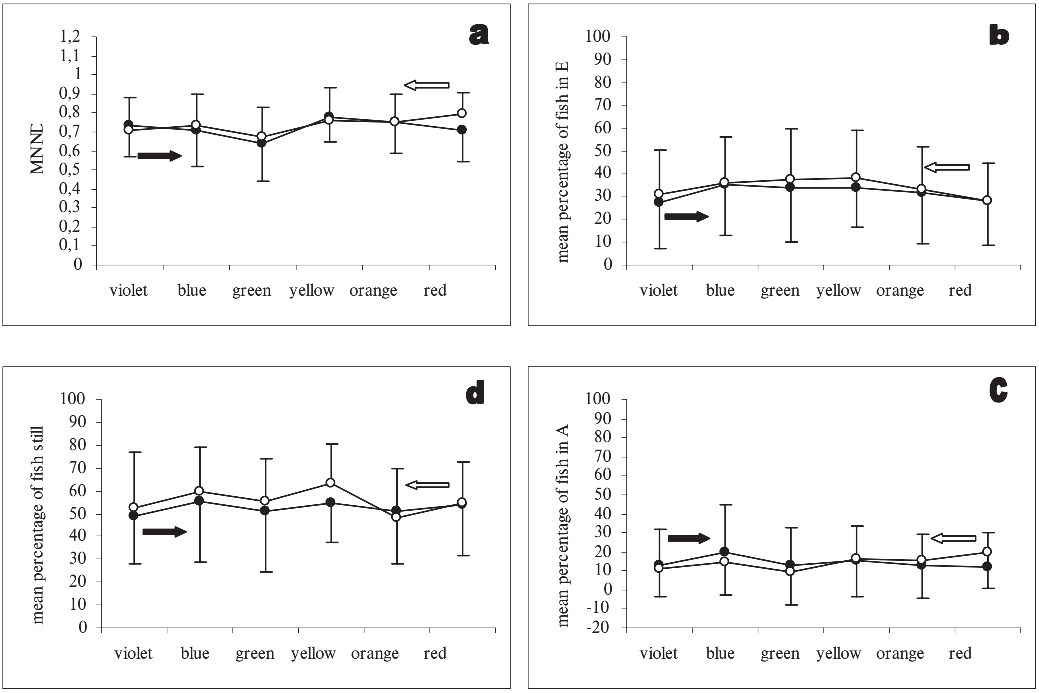


Figure 8: White seabream *D. sargus* L.
Effects of light colour variations on the following parameters: (a) mean nearest neighbour distance (MNND), (b) mean percentage of fish in the area closest to the light source (E), (c) mean percentage of fish in the area farther from the light source (A), (d) mean percentage of fish still. Filled circles and arrows indicate experiment SL: light colour progressively shifted from the Shorter (violet) to the Longer (red) wavelengths of the visual spectrum. Open circles and arrows indicate experiment LS: light colour progressively shifted from the Longer (red) to the Shorter (violet) wavelengths of the visual spectrum. Values given as means (n=3), bars ± one standard deviation. Colours tested: (1) violet (peak at approx. 410 nm), (2) blue (peak at approx. 460nm), (3) green (peak at approx. 525nm), (4) yellow (peak at approx. 580nm), (5) orange (peak at approx. 600nm), (6) red (peak at approx. 650nm).
Slika 8: Šarg D. sargus L.
Vplivi svetlobe različnih intenzitet na naslednje parametre: (a) srednja oddaljenost do najbližjih sosedov (MNND), (b) srednji odstotek rib v območju, najbližjem svetlobnemu viru (E), (c) srednji odstotek rib v območju, najbolj oddaljenem od svetlobnega vira (A), (d) srednji odstotek mirujočih rib. Polni krogci in puščice ponazarjajo eksperiment SL: svetla svetloba se je postopoma premikala od S (krajših – vijoličnih) do L (daljših – rdečih) valovnih dolžin vidnega spektra. Prazni krogci in puščice ponazarjajo eksperiment LS: svetla svetloba se je postopoma premikala od L (daljših – rdečih) do S (krajših-vijoličnih) valovnih dolžin vidnega spektra. Vrednosti, prikazane kot srednje (n=3), stolpci ± standardni odklon. Testirane barve: (1) vijolična (višek pri pribl. 410 nm), (2) modra (višek pri pribl. 460nm), (3) zelena (višek pri pribl. 525nm), (4) rumena (višek pri pribl. 580nm), (5) oranžna (višek pri pribl. 600nm), (6) rdeča (višek pri pribl. 650nm).

4. DISCUSSION

4.1 DEGREE OF REACTIVITY TO LIGHTS OF VARIABLE INTENSITY

Exposure to artificial lights of variable intensity had an effect on all species, although each of them reacted in a distinctive way. Behavioural responses were affected both by absolute illumination levels and by mode of intensity variation.

During both experiments, the brown meagre *S. umbra* L. was the most reactive to the presence of light. It was in all cases strongly disturbed by the presence of an illuminated field, in front of which it showed marked repulsion. The response was particularly pronounced when fish were exposed to high intensities first. On the contrary, the exposure to low-intensity lights at the beginning of the experiment induced a negative response at first (moving from crepuscular to diurnal conditions), but this was followed by a slight habituation to the increasing illumination levels.

The other three species were less influenced by light intensity variations. The peacock wrasse *S. tinca* L. showed the highest levels of aggregation and inhibition, together with a strong tendency to remain in proximity of the light source. However, the reactivity to variations in light conditions was not pronounced.

Blue damselfish *C. chromis* L. were in all cases rather dispersed along the tank and tended to keep still, probably due to their territorial habits. Phototactic reactions were not particularly marked, although fish tended to be attracted by strong lights, and to remain close to the light source even if the intensity was progressively decreased.

The white seabream *D. sargus* L. was the less influenced by variations in light intensity conditions. The group of fish tended to keep aggregated and moderately active throughout both experiments, and it was only slightly attracted by the presence of light. Positive phototactic reactions were more pronounced when light intensity was progressively decreased.

4.2 DEGREE OF REACTIVITY TO MONOCHROMATIC LIGHTS OF VARIABLE WAVELENGTH

Monochromatic lights of variable wavelength induced an effect on all species, although the reactions were different among them. Behavioural responses were affected both by quality and order of presentation of colours.

The brown meagre *S. umbra* L. showed the most dramatic reactions also when exposed to monochromatic lights. Repulsive reactions reached a peak with shorter-wavelength colours, such as violet, blue, and to a lesser extent green. Such colours induced a marked aggregation of the group of fish in the farthest and darkest corner of the tank, where they kept totally still. The behavioural response conforms to the narrow peak of absorbance 500-504 nm reported for the A1 visual pigment of members of the same family (Ali & Anctil, 1976).

The peacock wrasse *S. tinca* L. was less reactive to monochromatic stimuli. Aggregation and attraction to light were moderate, inhibition was medium-to-high. The only conspicuous differences between the two experiments were detected in the central bands of the visual spectrum. Indeed, fish were significantly more attracted by green and yellow lights when these were emitted after the shorter-wavelength ones, simulating the shift from crepuscular (prevalence of shorter wavelengths) to daylight (prevalence of longer wavelengths) conditions. Wider peaks of absorption and both A1 (484-527 nm) and A2 (510-513) visual pigments are reported for members of the same family (Ali & Anctil, 1976). Electrophysiological recordings of compound action potentials from retinal ganglion cells of *Thalassoma duperrey* Quoy & Gaimard evidence at least two sensitivity peaks for the on response at lambda (max) = 460 and 550 nm (Barry & Hawryshyn, 1999).

Similarly, the blue damselfish *C. chromis* L. was only slightly influenced by variations in light colours. Overall, the order of presentation of the different monochromatic lights did not affect markedly the behavioural responses of the group of fish. Aggregation was in all cases low and inhibition high, probably due to the territorial habits of the species. Phototactic responses were moderately positive independent of the colour, with the exception of red lights that induced a repulsive reaction. The family Pomacentridae is diurnal, planktivore and lives in visually complex habitats. A reported A1 visual pigment peak absorption of 491-497 nm along with the presence of A2 (Ali & Anctil, 1976) and a UV visual capability (Marshall & Vorobyev, 2003) accord with a broad range of spectral sensitivities and adaptation to an illuminated environment. Chromatic action spectra based on juvenile feeding behaviour response peak around lambda (max) 500 nm but shift to longer wavelengths occur during ontogeny (Job & Shand, 2001).

Among the four species, the white seabream *D. sargus* L. (A1 max 493-518 nm for the Sparidae: Ali & Anctil, 1976) showed the lowest reactions also in presence of monochromatic lights. Fish tended to keep moderately aggregated and active in all cases, and did not show any differential attraction to coloured lights that always induced a modest positive reaction.

4.3 ECOLOGICAL CHARACTERISATION OF VISUAL BEHAVIOUR AND OF PHOTOSENSITIVITY

Although some common evolutionary trends can be recognised in the adaptations to the underwater environment (e.g. Lythgoe, 1979), the visual behaviour of fish can vary conspicuously among species (Ben-Yami, 1976; Marchesan et al., 2003). Indeed, the visual behaviour of a species depends on both its biological features (e.g. morpho-physiology of the eye and visual system) and the ecological conditions of life (e.g. habitat, social structure, feeding habits) (Hobson et al., 1981; Helfman, 1993; Pankhurst & Hilder, 1998). Species characterised by different ecological requirements are therefore expected to show differences in their structural and behavioural adaptations to the presence of light, both in natural and artificial conditions. Conversely, we expect to draw an ecological classification of fish according to their behavioural reactions to light, as already suggested by Ben-Yami (1976).

In the present study, a very pronounced differentiation in the behavioural responses to light can be recognised between the brown meagre *S. umbra* L. and the other three species analysed. Indeed, the brown meagre is a strictly nocturnal species, thus adapted to very low light conditions and to the presence of a restricted band of wavelengths in the environment (mostly in the violet-blue range of the visual spectrum). This explains the strong sensitivity to both white and monochromatic lights, even at low intensities. Interestingly, the negative responses are particularly pronounced with violet and blue lights. This suggests that the brown meagre's eye and visual system – as supported by retina structure and visual pigment absorption peak (Ali & Anctil, 1976) – is finely tuned on such shorter wavelengths, in order to better move in a nocturnal environment. Indeed, such colours may be detected as very brilliant even at extremely low illumination levels, and for this reason they may have induced a repulsive reaction during the experiments described above.

The brown meagre *S. umbra* L. is a typical predator species, and its habits can be compared to those of tunas that live in deep sea (Ben-Yami, 1976). Repulsion for illuminated fields, associated to nocturnal and predatory habits, is reported also for other Sciaenidae living in coral reefs (Hobson, 1973). Furthermore, a preference for very low artificial light conditions has been highlighted in a number of predatory species, such as *Trachurus japonicus* Temminck & Schlegel and *Scomber japonicus* Houttuyn (Imamura & Takeuchi, 1960).

The other three species analysed show more similar responses to the presence of light. Overall, they are not particularly reactive to the exposure to different light conditions. However, a certain degree of differentiation can be recognized. The blue damselfish *C. chromis* L. is in an antithetic position compared to the brown meagre's one. Indeed, the blue damselfish is a strictly diurnal species, and it is therefore well adapted to strong light conditions and to the whole range of the visual spectrum, including UV. This explains why fish show a good tolerance to lights of variable intensity and wavelength throughout this study, maintaining their territorial habits independent of the illumination conditions. Interestingly, fish tend to perform some vertical movements when the light is progressively increased (pers. obs.), suggesting the presence of crepuscular vertical migrations in such a species, as described for other Pomacentridae (Hobson, 1973; Hobson et al., 1981).

The peacock wrasse *S. tinca* L. has also shown a good tolerance to differential light conditions throughout the study. This species, however, appears to be slightly more reactive to the presence of light of variable intensity and wavelength. In general, it is moderately attracted to white lights independent of their intensity, and to monochromatic lights in the central band of the visual spectrum (green-yellow). This is in accordance with its diurnal and crepuscular habits, and with its preferential habitats, as it can be found in vegetated coastal environments, where the underwater illumination is mainly centred in the green-yellow band of the spectrum.

The visual behaviour of blue damselfish and peacock wrasse can be compared to that of Pacific and Atlantic sauries (*Cololabis saira* Brevoort and *Scomberesox saurus* Walbaum) that show positive phototaxis and good tolerance to a wide variety of light intensities and colours (Ben-Yami, 1976). Blue damselfish, peacock wrasses and sauries are all diurnal species that live in coastal waters, characterised by high illumination most of the time, and that feed on plankton (blue damselfish, sauries) and on benthic preys (blue damselfish, peacock wrasse). Similar feeding habits and responses to light are highlighted also in coral reef Pomacentridae and Labridae (Hobson, 1973).

Among the three species, the white seabream *D. sargus* L. is the less influenced by light conditions, and it remains active even at low light intensities and with all type of monochromatic lights. This suggests that such a species is well adapted to a wider range of light intensities and colours. Indeed, the white seabream is active both during the day and at twilight, and to a certain extent it keeps feeding independent of the light conditions.

Although the white seabream *D. sargus* L. is not a typical predator, its visual behaviour is very similar to that of predatory fish such as *Scomber japonicus* Houttuyn, Carangidae and Thunidae (Ben-Yami, 1976). All these species are not particularly affected by the presence of light and they tend to keep active all the time, even if they often show a preference for medium-to-low light conditions. Considering the feeding habits of the white seabream, however, some similarities can be found with these predators. The white seabream is carnivorous, characterised by flexible circadian rhythms and it is active even at twilight (Sala & Ballesteros, 1997). A similar flexibility of circadian habits and feeding behaviour has been reported for *Gadus morhua* L. (Løkkeborg & Fernö, 1999).

5. SUMMARY

This study highlights that the behavioural reactions to lights of different intensity and wavelength can vary conspicuously among species, according to their visual traits and lifestyles. When conservation measures must be taken in order to avoid or at least attenuate underwater 'photopollution' inside marine protected areas (Witherington, 1997), the behaviour of the most photosensitive species should be taken into account. Species that would be strongly impacted by the presence of illuminated fields should be regarded as the limiting factor for the definition of the maximum level of illumination that could be tolerated without causing any disturbance on the fish community living inside a protected area.

POVZETEK

Pričujoča študija kaže, kako nenavadne so lahko vedenjske reakcije rib na svetlobo različne intenzitete in valovnih dolžin glede na vidne značilnosti in življenjski slog teh ribjih vrst. Kadar smo prisiljeni sprejeti naravovarstvene ukrepe, da bi se izognili ali pa vsaj omilili podvodno "svetlobno onesnaževanje" v zaščitenih morskih območjih (Witherington, 1997), moramo upoštevati vedenje vrste, ki je najbolj občutljiva za svetlobo. Vrste, ki jih osvetljena vodna polja najbolj prizadenejo, je treba jemati kot omejujoči dejavnik pri določanju največje dovoljene osvetljenosti, ki jo je še mogoče dopuščati, ne da bi s tem vznemirjali ribje skupnosti, živeče v zaščitenih morskih območjih.

6. ACKNOWLEDGEMENTS

We thank Valter Žiža working at the Aquarium of Piran for kind provision of fish, and the whole staff at Miramare Marine Reserve for cooperation and logistical support.

7. LITERATURE

1. Ali, M. A. (1971): Les reponses retinomotrices: caractères et mechanismes. Vision Research 11:1225-1288.
2. Ali, M. A., M. Anctil (1976): Retinas of fishes. An Atlas. Berlin: Springer Verlag.
3. Barry, K. L., C. W. Hawryshyn (1999): Spectral sensitivity of the Hawaiian saddle wrasse, *Thalassoma duperrey*, and implications for visually mediated behaviour on coral reefs. Environmental Biology of Fishes 56:429-442.
4. Beltestad, A. K., O. A. Misund (1988): Attraction of Norwegian spring-spawning herring to underwater light. In Proceedings of World Symposium on fishing gear and fishing vessel design. The Marine Institute St. John's, Newfoundland.190-192pp.
5. Ben-Yami, M. (1976): Fishing with light. FAO of the United Nations. Fishing News Books, Oxford.
6. Clarke, G. L., E. J. Denton (1962) : Light and animal life. In Hill, M.N. (ed.): The Sea: Ideas and Observations. Interscience Publishers, New York. 456-468 pp.
7. Hawryshyn, C. G. (2003): Mechanisms of ultraviolet polarization vision in fishes. In Collin, S.P. & Marshall, N.J. (ed.): Sensory processing in aquatic environment. Springer Verlag, New York. 252-265 pp.
8. Helfman, G. S. (1993): Fish behaviour by day, night and twilight. In Pitcher, T.J. (ed.): Behaviour of Teleost fishes 2nd edition. Chapman & Hall, London. 479-512 pp.
9. Hobson, E. S. (1973): Diel feeding migrations in tropical reef fishes. Helgoländer wiss. Meeresunters 24:361-370.
10. Hobson, E. S., W. N. McFarland, J. R. Chess (1981): Crepuscular and nocturnal activities of Californian nearshore fishes, with consideration of their scotopic visual pigments and the photic environment. Fishery Bulletin 79:1-30.
11. Imamura, Y., S. Takeuchi (1960): Study on the disposition of fish towards light (no. 6). Compare with the disposition of *Engraulis japonicus*, *Decapterus muroadsi*, *Trachurous japonicus* and *Scomber japonicus*. Journal of Tokio University Fisheries 46:149-155.
12. Job, S. D., J. Shand (2001): Spectral sensitivity of larval and juvenile coral reef fishes: implications for feeding in a variable light environment. Marine Ecology Progress Series 214:267-277.
13. Kawamura, G. (1986): Vision and behaviour of fish in the vicinity of fish lamp. Proceedings of International Conference for Development and Management of Tropical Living Aquatic Resources. Serdang, Malaysia, 2-5 Aug. 1983. 197-204.pp
14. Land, M. F., D. E. Nilsson (2002): Animal Eyes. Oxford University Press, Oxford.
15. Løkkeborg, S., A. Fernö (1999): Diel activity pattern and food search behaviour in cod, *Gadus morhua*. Environmental Biology of Fishes 54:345-353.
16. Lythgoe, J. N. (1979): The ecology of vision. Clarendon Press, Oxford.
17. Marchesan, M., M. Spoto, L.Verginella, E. A. Ferrero (2003): Behavioural effects of artificial light on fish species of commercial interest. Fisheries Research 73:171-185.
18. Marshall, N. J., M. Vorobyev (2003): The design of color signals and color vision in fishes. In: Collin, S.P. & N.J., Marshall (ed.): Sensory processing in aquatic environment. Springer Verlag, New York. 194-222 pp.
19. Pankhurst, P. M., P. E. Hilder (1998): Effect of light intensity on feeding of striped trumpeter *Latris lineata* larvae. Marine and Freshwater Research 49:363-368.
20. Sala, E., E. Ballesteros (1997): Partitioning of space and food resources by three fish genus *Diplodus* (Sparidae) in a Mediterranean rocky infralittoral ecosystem. Marine Ecology Progress Series 152:273-283.
21. Verheijen, F. J. (1985): Photopollution: artificial light optic spatial control systems fail to cope with. Incidents, causations, remedies. Experimental Biology 44:1-18.

22. Witherington, B. E. (1997): The problem of photopollution for sea turtles and other nocturnal animals. In : Clemmons, J.R & R., Bucholz (ed.): Behavioral approaches to conservation in the wild Cambridge. Cambridge University Press, Cambridge.

Mara MARCHESAN, Enrico A. FERRERO
University of Trieste, Department of Life Sciences
via Giorgieri 7
I-34127 Trieste, Italy
marmarchesan@gmail.com

Maurizio SPOTO
WWF Marine Natural Reserve of Miramare
viale Miramare 349
I-34100 Trieste, Italy

POLLUTION OF THE SLOVENIAN COAST WITH SOLID WASTES

ONESNAŽEVANJE SLOVENSKE OBALE S TRDIMI ODPADKI

Andreja PALATINUS

Key words: coast, solid wastes, plastic, Slovenia, pollution
Ključne besede: obala, trdi odpadki, plastika, Slovenija, onesnaževanje

ABSTRACT

Evaluation of quantity, quality and sources of solid wastes at three different localities on the Slovenian coast was carried out between May and September 2007. On 1,350 m of the coast, 16,414 pieces of litter were collected. Most common were plastic wastes and cigarette butts.

IZVLEČEK

Med majem in septembrom 2007 smo na treh lokacijah na slovenski obali ocenjevali količino, tipe in vire trdih odpadkov. Na 1350 metrih vzdolž morja smo našli 16.414 odpadkov. Najpogostejši med njimi so bili plastični izdelki in cigaretni ogorki.

1. INTRODUCTION

The term marine debris defines any manufactured or processed solid waste material that enters the marine environment from any source (Coe et Rogers 1997). This pollution is caused by humans and is scattered all over the marine environment.

For centuries, the ocean was viewed as a boundless reservoir with unlimited capacity to assimilate wastes. Now everyday wastes constitute a marine pollution problem of global proportions, clearly showing that man has the capacity to affect the ocean.

Slovenia is a European country with 46.7 kilometres long shore in the Mediterranean Sea. Port industry, intensive tourism and the biggest net migration in the country (Primorska region) present a great threat to marine life by being exposed to various marine debris.

The only scientific study of pollution of the Slovenian coast with marine debris so far was conducted in 2007. Here I describe its methods and results.

2. METHODS

According to Dixon et Dixon (1981), three different approaches are being used to investigate the composition, quantity and distribution of debris in marine environment. These include quantification of solid wastes generated aboard ships and pleasure craft, observation on or collections of surface floating litter at sea and beach survey.

Our investigation was implemented by beach survey for the following reasons:

- shoreline can be surveyed more easily and accurately than water masses,
- litter tends to accumulate on beaches, therefore statistically viable samples can be collected at any given time.

In 2005, the Ministry of the Environment in Israel launched a long-term program entitled "Clean Coast" (Alkalay et al. 2007). The cause was an unsuccessful way of cleaning Israeli beaches as practiced prior to 2005. Clean Coast Index (CCI) measures the actual cleanliness of the beach in an objective and easy way precluding bias by the assessor (Alkalay et al. 2007). Considering that plastics constitute, by far, the majority of litter on the beaches (also in Israel – 90% of all debris items), only plastic particles larger than 2 cm in size to calculate CCI were conducted in Israel.

On the Slovenian coast, the CCI method was adapted to get information regarding the level of cleanliness on some unauthorized beaches in Slovenia. One unit of our conduct had the same surface – 150 m^2, like the ones in Israel. We collected all anthropogenic debris larger than 2 cm, not just plastic, and used plastic to calculate the index.

Calculation of CCI:

$$\frac{Z}{n \times \text{segment length} \times \text{coast width}} = \text{No. of plastic debris} / m^2 \qquad (1)$$

Z – No. of plastic debris in transect in total
n – No. of segments in one transect (n=3)
segment length [m] = 50 m

Three beaches in Slovenia (Debeli rtič, Mesečev zaliv, Fiesa-Piran) were morphologically defined as three locations, each characterized by same coastal conditions (sandy/gravelled, narrow/wide, open/bordered by cliffs, etc.) (Figure 1). They were sampled on five different occasions in May, June, July, August and September 2007.

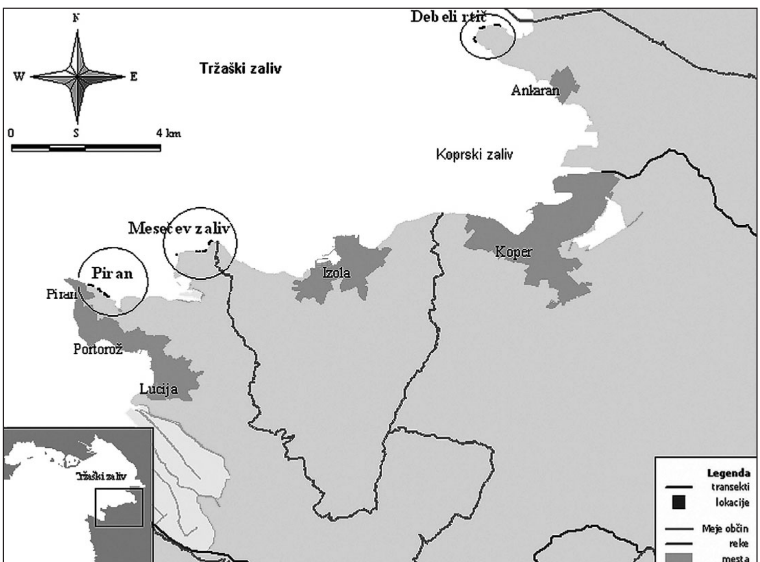


Figure 1: Map of the Slovenian coast with studied areas (circled)
Slika 1: Zemljevid slovenske obale s preučevanimi (obkroženimi) območji

Each location was divided into three transects regularly distributed on each location (from east to west) from 0.5 m below and above water's edge at the high tide line, to the border of the coast, represented by any obstacle – cliff, vegetation, path, fence. Each transect was further divided into three segments (each 50 m long) with two parallel spaces (one from the 0.5 m line above the line of the high tide to the first natural obstacle toward the land, other 0.5 m below and above the line of the high tide).

The exact measurement location point was defined with GPS system. The average area of each segment was 150 m^2 (Figure 2).

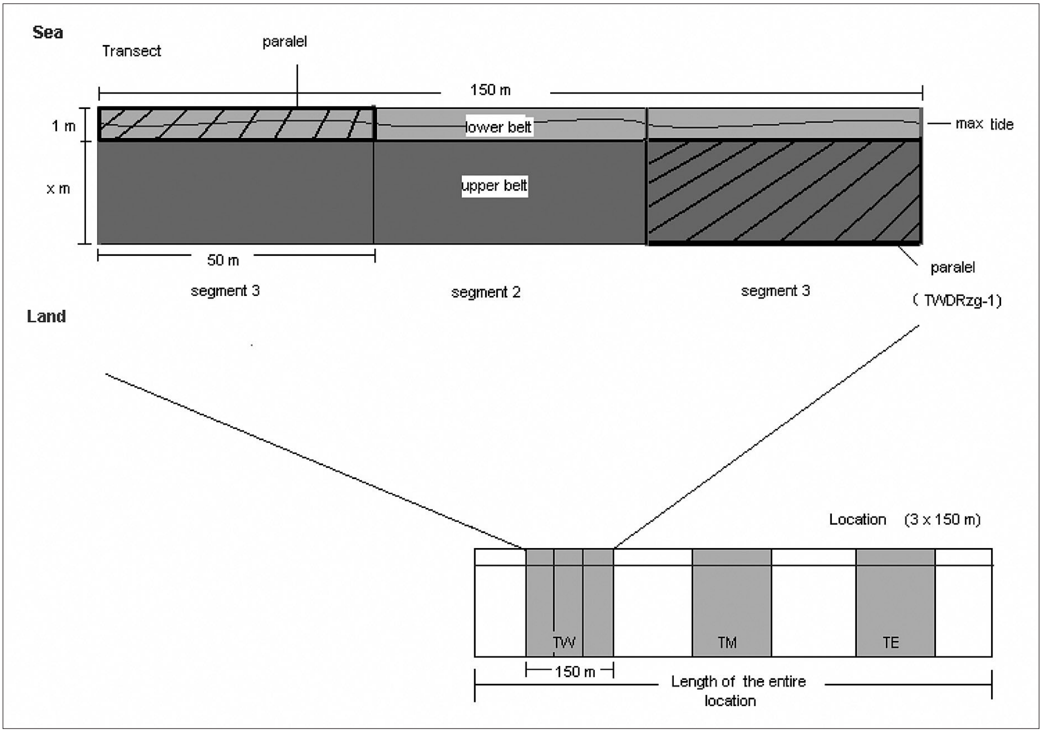


Figure 2: Presentation of transects, segments, belts and parallels
Slika 2: Predstavitev transektov, segmentov in paralel

All anthropogenic debris was collected along transects extending parallel to the water line. Each parallel was collected into its own, pre-marked bag. We collected debris forth and back (Figure 3) with the help of 4 employees of national service for protection of coastal seas (Javna vodnogospodarska služba za varstvo obalnega morja - SVOM).

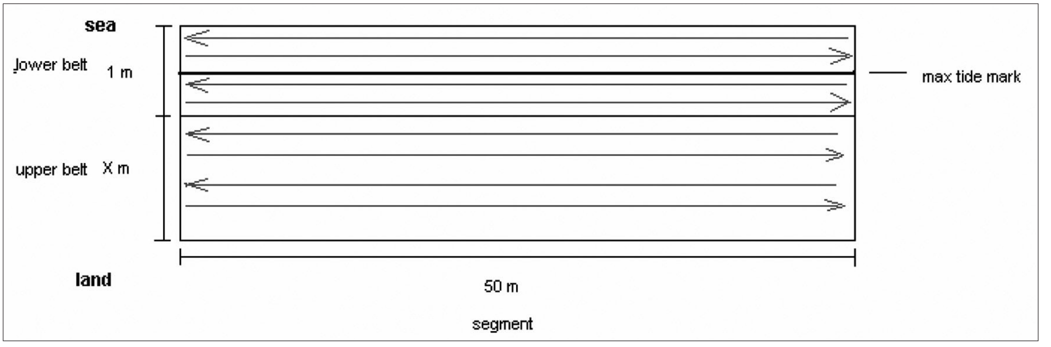


Figure 3: Collecting debris forth and back
Slika 3: Zbiranje odpadkov sem in tja

The locations of Piran and Mesečev zaliv do undergo regular cleaning by local authority, all locations are cleaned regularly (once a month) by SVOM. In April 2007, SVOM conducted initial beach cleanup at each survey site to clean the beach of all debris that had accumulated over an unknown period of time.

The collected debris was laboratory analyzed. We cleaned, dried, and divided them into categories regarding material (plastic, glass, metal, paper, Styrofoam, toxic wastes[1], fabric, composites). We counted and weighed every category separately for every parallel (Figure 2). In the end we discarded the debris.

3. RESULTS

A total of 16,414 solid waste items of different material weighing 76,079 g were recovered from the 1,350 m of sampled beaches. The most abundant were cigarette butts (2,823 pieces). In terms of numbers of items per m^2, plastic debris predominated with 64% (Table 1).

Table 1: Number and relative abundance of debris
Tabela 1: Število in relativna gostota odpadkov

Material	**Abundance**	
	No. of pieces	%
Plastic	10,552	64
Cigarette buts	2,823	17
Glass	1,513	9
Metal	524	3
Composites	435	3
Paper	336	2
Fabric	182	1
Toxic wastes	49	<1
Total	**16,414**	**100**

[1] Toxic wastes include toxic wastes according to the national legislation Pravilnik o ravnanju z odpadki, Ur.l. RS 84/98

The most polluted location was Piran (Figure 4), owing primarily to the discarded cotton buds that were very abundant on this location (altogether 1,742 pieces).

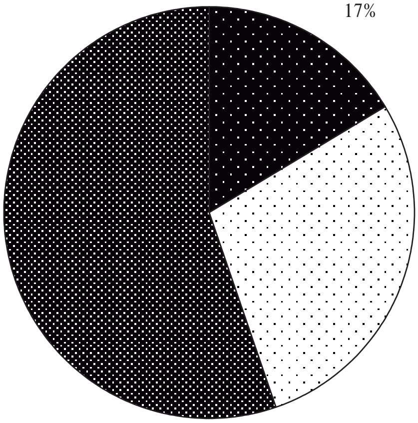


Figure 4: Abundance of marine debris on various locations
Slika 4: Gostota naplavljenih odpadkov na različnih lokacijah

The most polluted month was May (Figure 5). We concluded that this must be the consequence of inefficient initial beaches clean up carried out in April.

43% of all debris originate from land-based sources according to our research (Table 2).

Table 2: Abundance of marine debris
Tabela 2: Gostota naplavljenih odpadkov

	Number of all debris collected	**Partial Sum**	**%**	**Partial %**
Marine sources				
Styrofoam	2,225		13.5	
Shellfish farming nets	632		4	
Polyurethane foam	308		2	
Big plastic bags	237		1	
Ropes	54		<1	
Cloths	26		<1	
Plastic containers-cleaning	11		<1	
Gloves	6		<1	
Light bulbs	4		<1	
Containers for oil, gas	3		<1	
Personal hygiene	2		<1	
Fishing nets	2		<1	
Buckets	2		<1	
Carpets	1		<1	
Sum		3,513		21

	Number of all debris collected	Partial Sum	%	Partial %
Land sources				
Cigarette butts	2,823		17	
Cotton buds	1,742		11	
Glass	1,513		9	
Food and drink containers	855		5	
Cigarette boxes	73		<1	
Beach requisites	46		<1	
Balloons	35		<1	
Syringes	10		<1	
Remainder	4		<1	
Condoms	1		<1	
Sum		7,102		43
Undefined				
Bags	2,489		15	
Plastic	2,184		13	
Containers	1,005		6	
Undefined	121		<1	
Sum		5,799		35
Total sum		**16,414**		**≈100**

The index was calculated from the formula (1) for every transect (Table 3). In comparison with the Israeli results, Slovenia has much higher index values. While in Israel the values hardly exceed the figure 5, one of the indexes in Slovenia reached even the value of 143.8!

Table 3: CCI values for transects (with lowest and highest values in bold)
Tabela 3: Vrednosti CCI za posamezne transekte

Transect \month	**May**	**June**	**July**	**August**	**September**
TEDR	10.95	14.29	-	8.49	8.64
MDR	6.76	10.53	-	5.67	3.89
TWDR	10.35	4.71	-	2.93	1.7
TEMZ	18.13	-	4.77	-	5.76
TMMZ	38.27	8.85	29.51	-	33.92
TWMZ	20.47	6.02	3.2	-	12.3
TEPI	**143.8**	24.72	20.19	30.21	22.61
TMPI	16.58	5.19	3.67	8.56	11.51
TWPI	-	4.32	3.62	6.22	35.53

4. DISCUSSION

According to the statistical analysis, there are differences in debris abundance between locations and transects but not months. This indicates that such analysis should also be made during winter months to assess possible differences between tourist and non-tourist seasons.

According to our positioning of locations, the most isolated among them, Debeli rtič, is least polluted. Piran and Mesečev zaliv locations are not statistically different in number of debris collected; although Piran was the most polluted site. The biggest reason for its pollution was high number of plastic buts (length 7 cm) found on beach, originating from households. Currents could bring the plastic buts to this beach, and they indeed caused high pollution rate for this beach.

High percentage of plastic debris (64%) collected on all locations is comparable with results obtained by scientists all over the world: Gabrielides (1991) (46-71%), Claereboudt (2004) (61%), Golik et Gertner (1992) (70,9%), Alkalay et al. (2007) (90%).

The most abundant items in numbers were cigarette filters (17% of all debris). Similar problem is encountered all over the world. U.S. Commission on Ocean Policy reported that litter associated with cigarette smoking was the second largest source of marine debris in the world (Reducing Marine Debris 2004).

Through Index (1) calculation, we compared the cleanliness of our beaches with the cleanliness of beaches in Israel in 2005. Our index results show that the Slovenian coast is more polluted with marine debris than the Israeli coast. According to Index, 49% of all our results fall into the categories "dirty" and "extremely dirty". The Index values are between 0 and 20, with values above 20 indicating extreme pollution.

According to the Index values, the Slovenian coast is jammed with plastic debris at some localities and we believe that owing to some extremely high results (Piran, May: 143.8), the Index calculation should be revised and adapted even further to Slovenian conditions.

The source of coastal litter is perhaps the most important issue of the litter problem as it has a direct bearing on the strategy, which should be employed to control it (Gabrielides 1991). We have established that the majority of debris were directly related to various beach activities. Cigarette filters, plastic bags, plastic and metal food and drink containers, cigarette boxes and picnic debris represented 45% percent of all debris collected, probably most of them coming from beach activities.

Some action should be taken to inform the public about this problem and cleaning should be more thorough and backed up with supported and organized volunteer actions.

5. SUMMARY

Our findings have confirmed that the problem of marine debris in Slovenia certainly exists and that despite the effort to regularly clean the beaches the latter remain heavily polluted with marine debris. *Most* of the *debris* is comprised of *plastic* materials – the problem underlined by other researchers around the globe as well.

Some action should be taken to inform the public about this problem, and cleaning should be more thorough and backed up with supported and organized volunteer actions. Special problems are cigarette butts, cotton buds and plastic bags.

The CCI index was considered an appropriate form to compare the pollution on the Israeli and Slovenian coasts. We still believe that the Index calculation should be revised in order to establish why our results are so much higher than in Israel.

We suggest that the future monitoring is longer and conducted during the winter as well. This would support the evidence of land-based sources of debris in the summer season from tourism. Taking action should be concentrated on the main and easily reachable source.

6. POVZETEK

Naši izsledki kažejo, da problem z naplavljenimi odpadki v Sloveniji vsekakor obstaja, vendar pa kljub naporom, da se plaže redno čistijo, naše obrežje še vedno ostaja močno onesnaženo z naplavljenimi odpadki vseh vrst. *Večina naplavin sestoji iz plastičnih izdelkov – problem, s katerim se ubadajo tudi drugod po svetu.*

V tem pogledu bi bila potrebna akcija za ozaveščanje javnosti, hkrati pa bi morali poskrbeti, da je čiščenje temeljitejše in podprto s prostovoljnimi akcijami. Poseben problem so cigaretni ogorki, vatirane paličice in plastične vrečke.

Indeks CCI se je zdel pravšnji za primerjavo onesnaženosti izraelske in slovenske obale, vendar še vedno menimo, da bi bilo indeks treba revidirati, če želimo ugotoviti, zakaj so naši rezultati neprimerno višji kot v Izraelu.

Predlagamo, da je monitoring v prihodnosti daljši in da se opravlja tudi v zimskih mesecih. S tem bi dokazali, da so s kopnega izvirajoči naplavljeni odpadki v poletni sezoni posledica turizma.

7. LITERATURE

1. Alkalay, R., G. Pasternak, A. Zask (2007): Clean Coast Index - a new approach for evaluation of the actual coast cleanliness. Ocean & Coastal Management 50(5-6): 352-362
2. Coe, J.M., D.B. Rogers (1997): Marine Debris: Sources, Impacts and Solutions. New York, Springers. New York. 432 pp.
3. Claereboudt, M.R. (2004): Shore litter along sandy beaches of the Gulf of Oman. Marine Pollution Bulletin 49: 770-777
4. Dixon, T.R., T.J. Dixon (1981) : Marine Litter Surveillance. Marine Pollution Bulletin 12: 289-295
5. Gabrielides G.P., A. Golik, L. Loizides, M.G. Marino, F. Bingel, M.V. Torregrossa (1991): Man-made Garbage Pollution on the Mediterranean Coastline. Marine Pollution Bulletin 23: 437-441
6. Golik, A., Y. Gertner (1990): Solid waste on the Israeli coast: composition, sources, and management. In: Shomura R.S., Godfrey M.L. (eds.): Proceedings of the Second International Conference on Marine Debris 1989. U.S. Department of Commerce. Washington D.C.: 369-378
7. Reducing Marine Debris. 2004. In: An Ocean Blueprint for the 21st Century. Final Report. U.S. Commission on Ocean Policy. Washington D.C.: 264 – 271 http://www.oceancommission.gov/documents/full_color_rpt/18_chapter18.pdf (3. mar. 2009)

Andreja PALATINUS
Ecological Non-governmental Environmental Organisation Eco Vitae
http://www.ecovitae.org
Pot v dolino 3c
SI-1261 Ljubljana-Dobrunje, Slovenia
andreja.palatinus@gmail.com

EVALUATION OF TRACE-METAL CONTAMINATION IN THE NORTHEASTERN ADRIATIC COASTAL WATERS USING THE SEAGRASS *POSIDONIA OCEANICA*

OCENITEV ONESNAŽENOSTI OBALNIH VODA SEVEROVZHODNEGA JADRANA S KOVINAMI OB POMOČI POZEJDONKE *POSIDONIA OCEANICA*

Maylis SALIVAS-DECAUX, C. ALGLAVE C., L. FERRAT, T. BAKRAN-PETRICIOLI, R. TURK, C. PERGENT-MARTINI, G. PERGENT

Keywords: Seagrass, pressures, *Posidonia oceanica*, metallic contamination, Adriatic Sea
Ključne besede: morska trava, posegi, *Posidonia oceanica*, onesnaženost s kovinami, Jadransko morje

ABSTRACT

Seagrasses appear relevant bioindicators of metallic contamination in coastal waters. *Posidonia oceanica* leaves were collected at six locations along the north and east coast of the Adriatic Sea selected on the basis of the presence of different types and levels of human-induced pressures. Concentration of seven trace-metals (Ag, As, Cd, Cu, Hg, Ni and Pb), as well as the Methyl-Mercury content, were determined. The level of contamination is low at the pristine site of Lavdara (Cu: 4.73 ± 0.01 µg/g; Hg: 0.054 ± 0.003 µg/g; Met-Hg: 0.015 ± 0.000 µg/g; Ni: 21.40 ± 0.63 µg/g; Pb: 0.90 ± 0.10 µg/g) and higher along the Slovenian coast (Cu: 11.83 ± 0.22 µg/g, Hg : 0.092 ± 0.004 µg/g ; Met-Hg: 0.027 ± 0.004 µg/g; Ni: 40.07 ± 2.08 µg/g, Pb: 1.50 ± 0.06 µg/g). Generally, Mercury and the associated trace metals contents are relatively high in *P. oceanica* collected in the Northern Adriatic region. This is due not only to the strong anthropogenic impact (ports of Trieste and Koper, former chloralkaline plant – PVC near Seget Donji) but also to the geological characteristics of the hinterland (former cinnabar ore in Slovenia). This preliminary study confirms the capability of *P. oceanica* to record trace metal in relation with human-induced pressures, as well as with geological background of the coast.

IZVLEČEK

Morske trave so se izkazale kot nadvse ustrezni bioindikatorji onesnaženosti s kovinami v obrežnih vodah. Na šestih lokacijah ob severni in vzhodni obali Jadranskega morja so avtorji nabrali liste pozejdonke *Posidonia oceanica*, in sicer glede na različne vrste in ravni človekovih posegov v tamkajšnje okolje. Ugotovljene so bile koncentracije sedmih kovin (Ag, As, Cd, Cu, Hg, Ni in Pb) in tudi metil živega srebra. Raven onesnaženosti je bila nizka na neokrnjeni lokaciji ob otoku Lavdara (Cu: 4,73 ± 0,01 µg/g; Hg: 0,054 ± 0,003 µg/g; Met-Hg: 0,015 ± 0,000 µg/g; Ni: 21,40 ± 0,63 µg/g; Pb: 0,90 ± 0,10 µg/g) in višja ob slovenski obali (Cu: 11,83 ± 0,22 µg/g, Hg : 0,092 ± 0,004 µg/g ; Met-Hg: 0,027 ± 0,004 µg/g; Ni: 40,07 ± 2,08 µg/g, Pb: 1,50 ± 0,06 µg/g). Na splošno je bila vsebnost živega srebra in z njim povezanimi kovinami razmeroma visoka v pozejdonki *P. oceanica*, ki so jo nabrali v območju severnega Jadrana, vendar pa razloga za takšno vsebnost ne gre iskati le v antropogenih vplivih (koprskega in tržaškega pristanišča in nekdanje tovarne PVC pri Segetu Donjem), marveč tudi v geoloških značilnostih zaledja (nekdanja proizvodnja cinobra v Sloveniji). Pričujoča študija potrjuje sposobnost pozejdonke *P. oceanica*, da beleži sledi kovin, povezanih z antropogenimi vplivi in geološkim zaledjem obale.

1. INTRODUCTION

In spite of its exceptional biodiversity (Galil 2007), the Mediterranean Sea is one of the most threatened seas in the world (PAM/Plan Bleu 2005). Indeed, the Mediterranean basin is subject to important human-induced pressures. Human activities along the coasts are responsible for the release of, among other things, contaminants (organic and inorganic). The Adriatic Sea, situated between the eastern coast of Italy and Croatia, is subject to both growing tourism pressure and industrial expansion. Study of trace-metals appears to be necessary to evaluate anthropogenic contamination of the coastal environment.

Seagrasses, and *Posidonia oceanica* (L.) Delile in particular, are important bioindicators of metallic contamination in coastal waters (Pergent-Martini and Pergent 2000). *P. oceanica* bioaccumulates and concentrates trace-metals in relation to their concentration in the water column (Lafabrie *et al*., 2007).

The aim of this study is to evaluate the metallic contamination (seven trace-metals Ag, As, Cd, Cu, Hg, Ni and Pb, as well as the Methyl-Mercury content) of *P. oceanica* leaves at different locations, selected on the basis of different types and levels of human-induced pressures, in the Northern and Eastern Adriatic.

2. MATERIAL AND METHODS

Samples of *P. oceanica* leaves were collected at six sites along the north and east coast of the Adriatic Sea (Figure 1). These sites are characterized by different types and levels of human activities.

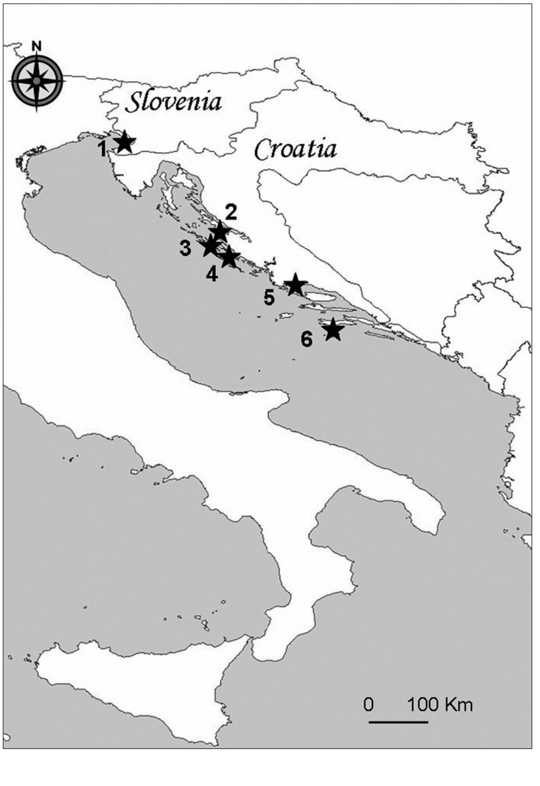


Figure 1: Location of studied sites in the Northern and Eastern Adriatic Sea (1: Izola (Izo); 2: Zadar (Zdr); 3: Brbinjšćica (Brb); 4: Lavdara (Lav); 5: Seget Donji (SgD); 6: Island Vlašnik (IsV))

Slika 1: Preučevane lokacije v severnem in vzhodnem Jadranu (1: Izola (Izo); 2: Zadar (Zdr); 3: Brbinjšćica (Brb); 4: Lavdara (Lav); 5: Seget Donji (SgD); 6: otok Vlašnik (IsV))

Izola (Izo) is located in the Northern Adriatic, in the Gulf of Trieste, along the Slovenian coast between Izola and Koper. This relic meadow grows in shallow water in the area of strong anthropogenic influence due mainly to the nearby port of Trieste. Moreover, cinnabar (red Mercury (II) sulphide) is naturally found in Slovenian hinterland and therefore in the coastal sediments due to mining exploitation. Zadar (Zdr) is located in the Mid Adriatic, in the vicinity of the main sewage outlet (city of 73,000 inhabitants), which also collects rain water run-off. Brbinjšćica (Brb) cove faces open Adriatic Sea. This location is exposed to low anthropogenic influence, since there are no human settlements in the vicinity. However, the cove is used during the summer as a mooring site for small local boats. Lavdara (Lav), an island in the Mid Adriatic, is located in one of the channels between two rows of islands, far from any human activities. Seget Donji (SgD), also in the Mid Adriatic, is situated near the city of Trogir, in an area with a huge human impact. This location is a few kilometres down-current from Kaštela Bay – one of the most polluted spots along the Croatian coast. The location of Vlašnik Island (IsV), in the Southern Adriatic, is oriented towards the open sea and exposed to high water movement. Despite being on the trajectory of a regular everyday ferry connection to Lastovo, this site can be considered as being under a low anthropogenic influence.

The two external leaves of *P. oceanica* (Adult 1 and Adult 2) were collected at 10 m depth, between May 15th and July 15th. Blades were cleaned (epiphytes scraped off), rinsed (ultrapure water) and either lyophilisied (Heto® FD4-85 freeze dryer, HetoHolten A/S) or dried at 30°C to constant weight, before they were reduced to powder. For Hg analyses, 50mg of each sample were weighed in a Teflon digestion vessel CEM® ACV of 100ml (CEM Corporation, USA). 5ml of 69% HNO3 (Normapur) and 1ml of H2O2 30% (Normapur) were added. The vessels were sealed and placed into CEM® MARS 5 chamber (20 minutes at 200°C and 20 minutes of cooling). The content of each vessel was poured into 25ml volumetric flasks and diluted to volume with ultrapure water and then transferred to 60ml polypropylene flasks. Mineralized samples were analysed with a cold vapour atomic absorption spectrometer (CV-AAS – Perkin Elmer®). The standard addition method was applied for calibration. Calibration standards were prepared from a mercury standard solution 1 000 $mg \cdot l^{-1}$. For Met-Hg, 50mg of each sample were heated for one hour at 95°C with 205 ml potassium hydroxide (10M). When it had cooled at room temperature, 5 ml NaCl (2%) were added. After centrifugation at 1000 g for 10 min, 34 ml of NaCl (2%) and 1ml of K2Cr2O7 (1%) were added to the supernatant. Concentrations of inorganic and organic Mercury in the sample were determined with the same laboratory apparatus, according to the adapted method of Riisgard and Hansen (1990) and Ferrat *et al*. (2002). Ag, As, Cd, Cu, Ni and Pb were analysed by atomic absorption spectrometry with quality assurance procedures at the Laboratory of Rouen/ ETSA (France). The analytic procedure was verified using certified reference materials (*Lagarosiphon major,* CRM 60; Community Bureau of Reference – Commission of the European Communities and TORT-2 Lobster Hepatopancreas Marine Reference Material for Trace Metals, National Research Council of Canada, Ottawa).

3. RESULTS

All mean concentrations of trace metals show significant difference between sites (KW, $p<0.05$ or $p<0.1$). The lowest value is every time significantly different from the highest value (Post Hoc Test, $p<0.05$ or $p<0.10$). Zadar and Izola seem to be the most contaminated sites (maximum values for Ag, Cu, Ni and Pb) and Lavdara the least (minimum values in Ag, Cd, and Cu).

Table 1: Metal concentrations ($\mu g \cdot g^{-1}$ dry wt.) in the blades of adult 1 and 2 leaves of *P. oceanica* (St.: station; mean ± SE; maximum values in bold and minimum values in italic; ** KW, $p<0.05$ and * KW, $p<0.1$)

*Tabela 1: Koncentracije kovin ($\mu g \cdot g^{-1}$ suha wt.) v bilkah pozejdonke P. oceanica (St.: postaja; srednja ± SE; maksimalne vrednosti v krepkem tisku, minimalne v poševnem; ** KW, p<0,05 in * KW, p<0,1)*

St.	Ag**	As**	Cd*	Cu**	Ni**	Pb*
Izo	0.13 ± 0.03	0.87 ± 0.03	2.1 ± 0.27	11.83 ± 0.22	**40.07 ± 2.08**	**1.50 ± 0.06**
Zdr	**0.83 ± 0.03**	0.40 ± 0.06	1.74 ± 0.11	**15.17 ± 0.32**	*18.40 ± 0.56*	**1.50 ± 0.15**
Brb	0.30 ± 0.00	**5.3 ± 0.35**	2.44 ± 0.09	7.43 ± 0.33	32.10 ± 0.70	1.23 ± 0.10
Lav	*0.10 ± 0.00*	1.77 ± 0.22	*1.41 ± 0.02*	*4.73 ± 0.09*	21.40 ± 0.62	0.90 ± 0.10
SgD	0.23 ± 0.03	*0.33 ± 0.03*	1.72 ± 0.03	10.57 ± 0.32	20.83 ± 1.37	1.33 ± 0.03
IsV	0.17 ± 0.03	0.67 ± 0.03	**2.75 ± 0.15**	6.20 ± 0.15	22.60 ± 3.51	*0.77 ± 0.15*

The Mercury content was measured at the six sites and Methyl-Mercury in Izola, Brbinjšćica and Lavdara (Table 2). Izola and Seget Donji present the highest values in the total Mercury content and exhibit statistical difference from Brbinjšćica (Post Hoc Test, $p<0.05$ and $p<0.10$). Methyl Mercury concentration in the Gulf of Trieste is twice as high as Lavdara's.

Table 2: Metal concentrations ($\mu g \cdot g^{-1}$ dry wt.) in the blades of adult 1 and 2 leaves of *P. oceanica* (St.: station; mean ± ES; maximum values in bold and minimum values in italic; **KW, $p<0.05$)

*Tabela 2: Koncentracije kovin ($\mu g \cdot g^{-1}$ suha wt.) v bilkah pozejdonke P. oceanica (St.: postaja; srednja ± ES; maksimalne vrednosti v krepkem tisku, minimalne v poševnem; ** KW, p<0,05)*

St.	Hg**	Met-Hg
Izo	**0.092 ± 0.004**	**0.027 ± 0.004**
Zdr	0.066 ± 0.008	
Brb	*0.041 ± 0.003*	0.017 ± 0.003
Lav	0.054 ± 0.003	*0.015 ± 0.000*
SgD	**0.094 ± 0.011**	
IsV	0.074 ± 0.008	

4. DISCUSSION AND CONCLUSION

According to the preliminary quality scale based on values recorded in the North Occidental Mediterranean Sea (Pergent, 2007; Romero *et al.* 2007), the level of contamination for each site can be evaluated (Table 3).

Table 3: Evaluation of the contamination using quality scale (from Pergent, 2007)
Tabela 3: Ocena onesnaženosti z uporabo lestvice kakovosti (po Pergentu, 2007)

	Very low contamination level	Low contamination level	Moderate contamination level	High contamination level	Very high contamination level
Ag	<0.29	0.29 – 045	0.45 – 0.61	0.61 – 0.77	>0.77
Cd	<1.92	1.92 – 2.52	2.52 – 3.16	3.16 – 3.98	>3.98
Hg	<0.035	0.035 – 0.053	0.053 – 0.067	0.067 – 0.092	>0.092
Ni	<18.10	18.10 – 23.32	23.32 – 31.58	31.58 – 55.05	>55.05
Pb	<1.31	1.31 – 1.83	1.83 – 2.42	2.42 – 3.54	>3.54

The level of contamination recorded at Lavdara is generally between "Low contamination" (Ni) and "Very low contamination" (Ag, Cd and Pb) for the five trace metals; it confirms the pristine character of this site. Moreover, this site presents the lowest values for Copper and Methyl-Mercury (Tables 1 and 2). Brbinjšćica is considered as a "Low contaminated" site for all metals, except for Mercury (moderate contamination).

The site of Izola exhibits "Very high contamination" in Mercury and "High contamination" in Nickel, additionally the values in Copper and Methyl-Mercury are also highest. The impacted site of Zadar presents "Very high contamination" in Silver and "High contamination" in Mercury.

From a general point of view, the Mercury content is relatively high - between "Very high contamination" and "High contamination" - at four of the sites in the researched area: Izola, Zadar, Seget Donji and Vlašnik.

In the Northern Adriatic (Izola), the results seem in line with the geological and geographical situation - presence of cinnabar in the marine sediments (Hylander and Meil 2003, Frančišković-

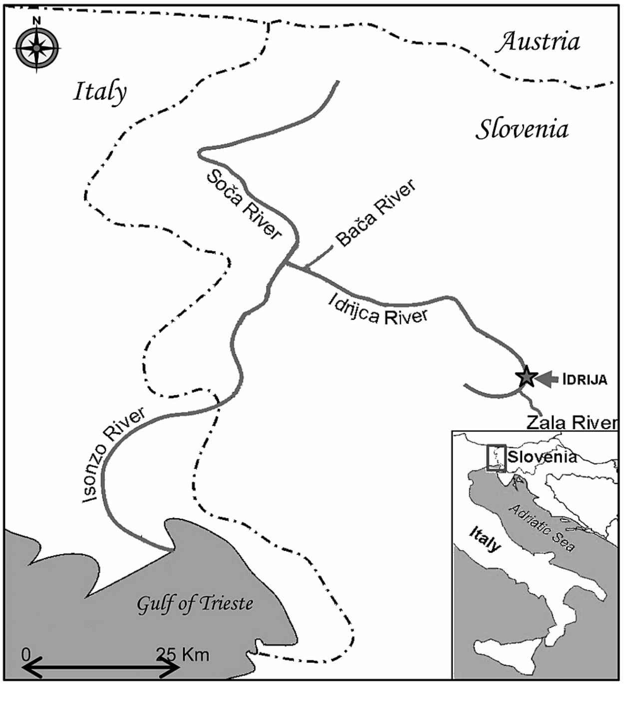


Figure 2: Rivers that flow from former Idrija Hg Mine into the Gulf of Trieste
Slika 2: Reke, ki tečejo iz območja nekdanjega idrijskega rudnika Hg v Tržaški zaliv

Bilinski *et al.*, 2005). Indeed, the city of Idrija, in Slovenian hinterland, was the second largest Mercury mine in the world. It has closed in the 1980's, but this area continues to deliver considerable quantities of Mercury to the river system and many kilometres downstream to the Northern Adriatic Sea (Figure 2, Hines *et al.*, 1999, Covelli *et al.*, 2001). Moreover, the high concentration in Nickel observed at the site of Izola could also be related to Mercury extraction (Covelli *et al.*, 2001, Frančišković-Bilinski *et al.*, 2005).

A general direction of the sea currents in the Adriatic Sea is northwards along its Eastern coast (Poulain, 2001). Although, at local level sea current patterns can be very complex, it is likely that *P. oceanica* meadow in Seget Donji is exposed to an incoming current through the passage between Trogir and Čiovo Island (Figure 3). This current would come from nearby Kaštela Bay – the "black spot" of pollution on the Croatian coast. Today considerable funds and effort are invested in the remediation of the area, but consequences of human activities are still present. Anthropogenic Mercury pollution of the sediments and water column is very high due to the chloralkaline plant (PVC), although it stopped production a decade ago (Kwokal *et al.* 2002, Mikac *et al.* 2006). This would explain the high levels of Mercury in *P. oceanica* leaves in Seget Donji.

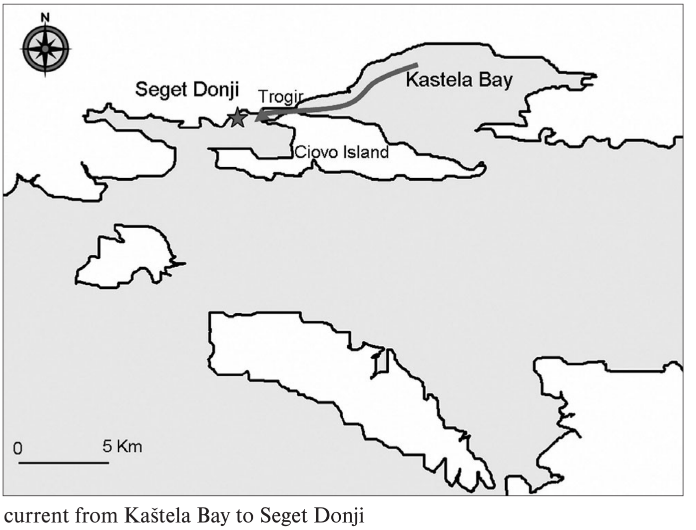


Figure 3: Incoming current from Kaštela Bay to Seget Donji
Slika 3: Morski tok, ki se vije iz Kaštelanskega zaliva proti Segetu Donjem

High Mercury contamination measured in *P. oceanica* at Vlašnik Island (Lastovo Archipelago Natural Park) requires further investigation. Although this area should be considered as not highly impacted by human activities, the nearby small port of Ubli on Lastovo Island – nowadays used for regular daily ferry traffic – was used for decades as a military base. If this could cause high mercury levels, remains to be elucidated.

This preliminary study along the north and east coast of the Adriatic Sea confirms the capability of *P. oceanica* to record trace metal in relation to human-induced pressures as well as to the geological background of the coast (Pergent-Martini *et al.* 1998, Lafabrie *et* *al*. 2007) and it highlights two aspects. Indeed, it is interesting to stress that even though immediate activities that yielded Mercury contamination (cinnabar ore in Slovenia, chloralkaline plant in Croatia) ceased to operate decades ago, Mercury is still present in biogeochemical cycling. Moreover, comparing with other sites in the Mediterranean Sea (Grauby *et al*. 1991), the Arsenic contamination values appear very high in the Northeastern Adriatic Sea.

5. SUMMARY

The aim of this study is to evaluate the metallic contamination (seven trace-metals Ag, As, Cd, Cu, Hg, Ni and Pb, as well as the Methyl-Mercury content) of *P. oceanica* leaves at different locations in the Northern and Eastern Adriatic. Samples were collected at six sites, characterised by different types and levels of human-induced pressures, along Slovenian and Croatian coast, from Izola to Vlašnik Island. Concentrations of total and organic Mercury were determined with cold vapour atomic absorption spectrometer (CV-AS – Perkin Elmer®), according to the adapted method of Ferrat *et al*., 2002 and Riisgard and Hansen, 1990. Ag, As, Cd, Cu, Ni and Pb were analysed by atomic absorption spectrometry with quality assurance procedures at the Laboratory of Rouen/ ETSA (France). The level of contamination is low at the pristine site of Lavdara (Ag: 0.10 ± 0.00 µg/g; Cu: 4.73 ± 0.01 µg/g; Hg: 0.054 ± 0.003 µg/g; Met-Hg: 0.015 ± 0.000 µg/g; Ni: 21.40 ± 0.63 µg/g; Pb: 0.90 ± 0.10 µg/g) and higher along the Slovenian coast (Cu: 11.83 ± 0.22 µg/g, Hg : 0.092 ± 0.004 µg/g ; Met-Hg: 0.027 ± 0.004 µg/g; Ni: 40.07 ± 2.08 µg/g, Pb: 1.50 ± 0.06 µg/g) and in Zadar (Ag: 0.83 ± 0.03 µg/g; Cu: 15.17 ± 0.32 µg/g; Hg: 0.066 ± 0.008 µg/g; Pb: 1.50 ± 0.15 µg/g). Generally, Mercury and the associated trace metals contents are relatively high in *P. oceanica* collected in the Northern Adriatic region. This is due not only to the strong anthropogenic impact (ports of Trieste and Koper) but also to the geological characteristics of the hinterland (former cinnabar ore in Slovenia). According to a preliminary quality scale based on values recorded in the North Occidental Mediterranean Sea, the level of contamination in Mercury for Seget Donji is also very high. Indeed, *P. oceanica* meadow at Seget Donji is exposed to an incoming current through the passage between Trogir and Čiovo Island. This current would come from nearby Kaštela Bay – the “black spot” of pollution on the Croatian coast. Anthropogenic Mercury pollution of the sediments and water column is very high due to the chloralkaline plant (PVC), although it stopped production a decade ago. This preliminary study confirms the capability of *P. oceanica* to record trace metal in relation with human-induced pressures, as well as with geological background of the coast.

POVZETEK

Namen pričujoče študije je bil oceniti kontaminacijo (s kovinami Ag, As, Cd, Cu, Hg, Ni in Pb in tudi vsebnost metil živega srebra) bilk pozejdonke *P. oceanica* na različnih krajih

v severnem in vzhodnem Jadranu. Primerki pozejdonke so bili nabrani na šestih lokacijah (značilnih po različnih tipih in ravneh človekovih posegov) vzdolž slovenske in hrvaške obale vse od Izole do otoka Vlašnik. Koncentracije celotnega in organskega živega srebra so bile ugotovljene s hladnim parnim atomskim absorpcijskim spektrometrom (CV-AS – Perkin Elmer®), in sicer po metodi Ferrat *et al*., 2002 in Riisgard in Hansen, 1990. Ag, As, Cd, Cu, Ni in Pb so bili analizirani z atomsko absorpcijsko spektrometrijo in s kakovostnimi postopki Laboratorija v Rouenu/ETSA, Francija).

Raven onesnaženosti je bila nizka na neokrnjeni lokaciji ob otočku Lavdara (Ag: 0,10 ± 0,00 µg/g; Cu: 4,73 ± 0,01 µg/g; Hg: 0,054 ± 0,003 µg/g; Met-Hg: 0,015 ± 0,000 µg/g; Ni: 21,40 ± 0,63 µg/g; Pb: 0,90 ± 0,10 µg/g) in višja ob slovenski obali (Cu: 11,83 ± 0,22 µg/g, Hg : 0,092 ± 0,004 µg/g ; Met-Hg: 0,027 ± 0,004 µg/g; Ni: 40,07 ± 2,08 µg/g, Pb: 1,50 ± 0,06 µg/g) in v Zadru (Ag: 0,83 ± 0,03 µg/g; Cu: 15.17 ± 0.32 µg/g; Hg: 0.066 ± 0.008 µg/g; Pb: 1.50 ± 0.15 µg/g). Na splošno je bila vsebnost živega srebra in z njim povezanimi kovinami razmeroma visoka v pozejdonki *P. Oceanica*, nabrani v območju severnega Jadrana, vendar pa razloga za takšno vsebnost ne gre iskati le v antropogenih vplivih (koprskega in tržaškega pristanišča in nekdanje tovarne PVC pri Segetu Donjem), marveč tudi v geoloških značilnostih zaledja (nekdanja proizvodnja cinobra v Sloveniji). Glede na preliminarno lestvico kakovosti, zabeleženo v severozahodnem Sredozemskem morju, je raven kontaminacije v živem srebru pri Segetu Donjem tudi zelo visoka. Vsekakor pa drži, da je travnik pozejdonke *P. oceanica* pri Segetu Donjem izpostavljen morskemu toku, ki priteka skozi preliv med Trogirjem in otokom Čiovo, in sicer iz Kaštelanskega zaliva, ki je znan kot "črna točka" onesnaževanja v obalnem hrvaškem morju. Antropogeno onesnaževanje usedlin in vodnega stolpca z živim srebrom je visoko zaradi tovarne PVC, pa čeprav je nehala obratovati že pred desetletjem. Pričujoča študija potrjuje sposobnost pozejdonke *P. oceanica*, da beleži sledi kovin, povezanih z antropogenimi vplivi in tudi z obalnim geološkim zaledjem.

6. ACKNOWLEDGEMENTS

This study was made thanks to the Piran Regional Unit of ZRSVN and University of Zagreb, scientific project No. 119-0362975-1226 of the Ministry of Science, Education and Sports of the Republic of Croatia (project coordinator T. Bakran-Petricioli).

7. LITERATURE

1. Covelli, L., J. Faganeli, M. Horvat, A. Brambati (2001): Mercury contamination of coastal sediments as the result of long-term cinnabar mining activity (Gulf of Trieste, northern Adriatic sea). Applied Geochemistry 16: 541-558
2. Ferrat, L., A. Bingert, M. Romeo, M. Gnassia-Barelli, C. Pergent-Martini (2002): Mercury uptake and enzymatic response of Posidonia oceanica after an experimental exposure to organic and inorganic forms. Environmental Toxicology and Chemistry 21(11): 2365-2371
3. Frančišković-Bilinski, S., H. Bilinski, D. Tibljaš, G. Rantitsch, (2005): Effects of Mercury mining regions from NW Dinarides on quality of stream sediments. Fresenius Environmental Bulletin 14(10): 913-927
4. Galil, B.S. (2007): Loss or gain? Invasive aliens and biodiversity in the Mediterranean Sea. Marine Pollution Bulletin 55: 314–322
5. Grauby, A., Augier, H., Lion, R., Charlent, O. (1991): Neutron Activation analysis of elemental composition in a marine phanerogam, *Posidonia oceanica* (L.) Delile: a biological indicator of pollution. Environmental and Experimental Botany 31(3): 255-265
6. Hines, M., M. Horvat, J. Faganeli, J.C. Bonzongo, T. Barkay, E. Major, K. Scott, E. Bailey, J. Warwick, W.B. Lyons (1999): Mercury Biogeochemistry in the Idrija River, Slovenia, from above the Mine into the Gulf of Trieste. Environmental Research 83(2): 129-139
7. Hylander, L., M. Meil (2003): 500 years of Mercury production: global annual inventory by region until 2000 and associated emissions. The Science of the Total Environment 304: 13–27
8. Kwokal, Ž., S. Frančišković-Bilinski, H. Bilinski, M. Branica (2002): A comparison of anthropogenic mercury pollution in Kaštela Bay (Croatia) with pristine estuaries in Öre (Sweden) and Krka (Croatia). Marine Pollution Bulletin 44: 1152–1169
9. Lafabrie, C., G. Pergent, R. Kantin, C. Pergent-Martini, J.L. Gonzalez (2007): Trace metals assessment in water, sediment, mussel and seagrass species – Validation of the use of *Posidonia oceanica* as a metal biomonitor. Chemosphere 68: 2033–2039
10. Mikac, N., V. Roje, N. Cukrov, D. Foucher (2006): Mercury in aquatic sediments and soils from Croatia. Archives of Industrial Hygiene and Toxicology (Arh Hig Rada Toksikol) 57(3): 325-332
12. PAM/Plan Bleu (2005): Méditerranée: les perspectives du Plan Bleu sur l'environnement et le développement. Guillaume Benoit, In : Benoit G., A. Comeau (eds.) : Editions de l'Aube. La Tour d'Aigues. 432 pp.
13. Pergent, G. (2007) : Protocole pour la mise en place d'une surveillance des herbiers de Posidonies. Programme « MedPosidonia » / CAR/ASP - Fondation d'entreprise TOTAL pour la Biodiversité et la Mer ; Mémorandum d'Accord N°21/2007/RAC/SPA/ MedPosidonia Nautilus-Okianos. 24 pp.
14. Pergent-Martini, C., V. Camuglio, G. Pergent (1998) : Impact des anciennes exploitations minières sur la contamination en métaux-traces du littoral corse. Rapp. Comm. int. mer Médit. 35: 572-573
15. Pergent-Martini, C., G. Pergent (2000): Marine phanerogams as a tool in the evaluation of marine trace-metal contamination: an example from the Mediterranean. International Journal of Environment and Pollution 13(1-6): 126-147
16. Poulain, P.M. (2001): Adriatic Sea surface circulation as derived from drifter data between 1990 and 1999. Journal of Marine Systems 29: 3–32
17. Riisgård, H.U., S. Hansen (1990): Biomagnification of Mercury in a marine grazing food chain: algal cells *Phaeodactylum tricornutum*, mussels *Mytilus edulis* and flounders *Platichtys flesus* studied by means of a stepwise-reduction CVAA-method. Marine Ecology Progress Series 62: 259-270

18. Romero, J., G. Pergent, M. Pérez, C. Pergent-Martini, T. Alcoverro, C. Lopez y Royo, B. Martínez-Crego, B. Mimault, A. Vich, T. García, N. Sanmartí (2007): Mise en cohérence, développement, harmonisation et validation de méthodes d'évaluation de la qualité du milieu littoral par le suivi de l'herbier de *Posidonia oceanica*. Final Report – Sub-project: Bioindicators. Programme INTERREG »Posidonia« : 1-59

Maylis SALIVAS-DECAUX, C. ALGLAVE, L. FERRAT, C. PERGENT-MARTINI and G. PERGENT
UMR CNRS 6134
University of Corsica
PB 52, 20250 Corte, France

T. BAKRAN-PETRICIOLI,
Division of Biology
Faculty of Science, University of Zagreb
Rooseveltov trg 6
HR-10000 Zagreb, Croatia

Robert TURK
Institute of the Republic of Slovenia
Piran Regional Unit
Tartinijev trg 12
SI- 6330 Piran, Slovenia

RISK ASSESSMENT OF POLLUTANTS ALONG FOOD CHAIN OF *CARETTA CARETTA*

OCENA TVEGANJA KOPIČENJA ONESNAŽEVALCEV V PREHRANJEVALNI VERIGI GLAVATE KARETE (*CARETTA CARETTA*)

Annalisa ZACCARONI, Flavio GUIDI, Marina SILVI, Giuseppe MONTANARI, Dino SCARAVELLI

Key words: heavy metals, loggerhead turtle, Northern Adriatic
Ključne besede: težke kovine, glavata kareta, severni Jadran

ABSTRACT

Several monitoring activities have been performed to assess the exposure and accumulation of different pollutants in the tissues of stranded and living loggerhead turtles, while little or no work has been carried out to define, which could be the contribution of food items to the heavy metal body burden of sea turtles. Understanding the contribution of diet of sea turtles to contaminant body burden is important for their conservation. The monitoring of contaminants in food items and the estimation of the amount of each pollutant that can be provided by each single item in sea turtles is important in the risk assessment of loggerheads' health related to environment pollution.
The present article reports on the evaluation of heavy metals in marine species representing a potential example of loggerhead sea turtle diet and on the assessment of the probable contribution of these species in heavy metal body burden of the turtles.
The obtained data confirm the reduced contamination by lead and mercury in the Adriatic Sea, while cadmium is generally present in concentrations within the range of toxic subchronic threshold defined for marine species. Thus it is possible to consider that a diet containing such levels can potentially induce some alteration also in higher organisms, sea turtles included. For arsenic As, mean concentrations are within the range of background levels, but the amounts detected are in the range of tissue concentration corresponding to adverse effects in aquatic organisms, so a potential toxic effect can be considered for the species studied, turtles included.

IZVLEČEK

Medtem ko je bilo z namenom, da se oceni kopičenje različnih onesnaževalcev v tkivih nasedlih mrtvih in živih glavatih karet in izpostavljenost teh morskih želv tem nevarnim snovem, opravljena že cela vrsta monitoringov, pa doslej ni bilo narejeno skoraj nič, da bi ugotovili, v kolikšni meri k obremenitvi organizmov glavatih karet s težkimi kovinami prispevajo posamezne vrste njihovega plena. Za varstvo teh živali je zatorej pomembno, da vemo, kakšen je prispevek prehrane glavatih karet k njihovemu zastrupljanju. Monitoring onesnaževalcev v posameznih vrstah plena in ugotavljanje njihove količine v vsakem izmed njih je pomemben za ocenjevanje, v kakšni meri je ogroženo zdravje glavatih karet zaradi onesnaževanje njihovega okolja.
Avtorji pričujočega članka so ugotavljali koncentracije težkih kovin v različnih morskih živalskih vrstah, s katerimi se hrani glavata kareta, in ocenjevali, v kolikšni meri lahko te vrste prispevajo k obremenitvi njenega organizma s težkimi kovinami.

Zbrani podatki potrjujejo, da je Jadransko morje manj onesnaženo s svincem in živim srebrom, medtem ko se kadmij na splošno pojavlja v koncentracijah znotraj meja toksičnega praga, določenega za morske živalske vrste. Tako je mogoče reči, da prehrana, ki vsebuje takšne ravni kovin, lahko povzroči določene spremembe tudi v višjih organizmih, vključno z morskimi želvami. Srednje koncentracije arzenika so sicer na ravni naravnega ozadja, vendar pa se zaznane količine gibljejo v razponu tkivne koncentracije s škodljivimi posledicami za morske organizme. Obstaja torej možnost toksičnega učinkovanja na preučevane morske vrste, vključno z želvami.

1. INTRODUCTION

Loggerhead turtle (*Caretta caretta*) is the most common sea turtle species inhabiting the Adriatic Sea. Several monitoring activities have been performed to assess the exposure and accumulation of different pollutants in the tissues of stranded and living loggerhead turtles, while little or no work has been carried out to define, which could be the contribution of food items to the heavy metal body burden of sea turtles.

Understanding the contribution of diet of sea turtles to contaminant body burden is important for their conservation. The monitoring of contaminants in food items and estimation of the amount of each pollutant, which can be provided by each single item to sea turtles, is important in the risk assessment of loggerheads' health related to environment pollution.

Among others, heavy metals represent a great risk for marine organisms, as they can persist in the environment for long period, can accumulate in sediments and living organisms and can experience biomagnifications along the food chain, even if the amplitude of the biomagnification process is not as great as for organic pollutants.

The present work reports on the evaluation of heavy metals in marine species, representing a potential example of loggerhead sea turtle diet, and on the assessment of the probable contribution of these species to the heavy metal body burden of the turtles.

2. METHODS

Sampling was performed with the aid of oceanographic boat "Daphne II" of Agenzia Prevenzione e Ambiente (ARPA) of the Emilia Romagna region. This structure has different aims: the study as well as the research and the control of marine environment and of its interactions with coastal areas. Sampling was performed along two different 1.5 km transects at 10 and 20 km outside Cesenatico coasts (Figure 1). Benthos sampling was performed using a fishing tool called "Rapido", a small trawling net, for a fishing time of 4 minutes. This allowed us to collect animals from an area of 0.001752 km^2.

Benthos was collected and separated by species or, if not possible, by systematic group. Each subject (n= 30 for each group when available) was then weighed and measured and subsequently stored at -20°C until analysis, which was performed by Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES) for heavy metals analysis (As, Pb, Cd, Hg). Briefly, amounts up to 700 mg of fresh tissue (for molluscs and fish only muscle was

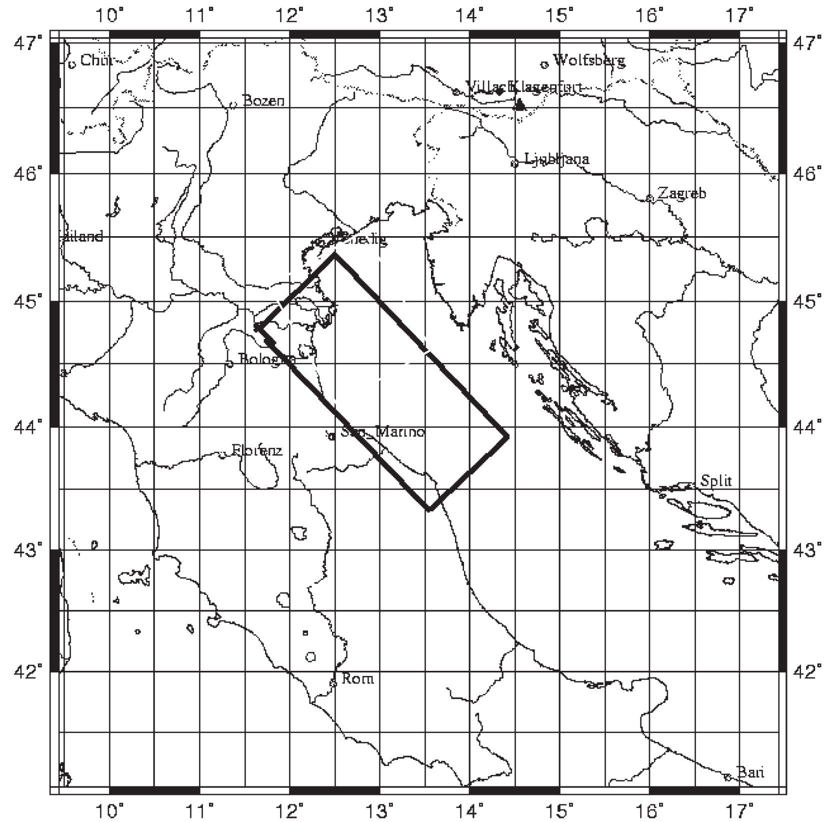


Figure 1: Sampling area

Slika 1: Območje vzorčenja

considered) were collected from homogenised animals and microwave digested. The samples were then transferred to the ICP-AES and analysed. Data are reported on a fresh weight basis as mg/kg. When crabs are of concern, they were separated on the basis of gender for other toxicological purposes; for the same reason, eggs were separated from pregnant females and analysed to evaluate the importance of metal excretion with ovodeposition.

After the analysis, the data were arranged to obtain an estimation of the amount of metals, which could have been ingested with that particular food item.

Starting from literature (Bentivegna et al. 2001, Parker et al. 2005, Revelles et al. 2007), the mean composition of loggerhead diet was defined. Species were then grouped on the basis of the systematic or functional classes (fish, molluscs, crustaceans, other - including all other species) and the percent of contribution to the diet was calculated (Table 1).

Assuming a mean volume and weight for stomach content of 370 ml and g respectively, the weight of each group in an "ideal" stomach was calculated and the amount of each metal provided with that quantity was calculated in three different scenarios: 1) mean concentration: the concentration/kg was calculated including all species; 2) worst scenario: the mean was calculated by considering the class was composed only of the species presenting higher mean concentration; 3) best scenario: the species considered is the one presenting lower concentrations. This calculation allowed us to estimate the amount of each toxic metal/year, if the loggerhead was feeding on that diet.

Table 1: Percent diet composition as obtained from available literature. The equivalent amount of food in a 370 g stomach content is also reported.

Tabela 1: Odstotkovna sestava prehrane, pridobljena iz literature. Zabeležena je tudi ekvivalentna količina hrane v 370 g težki vsebnosti želodca.

Class	% of the diet	Amount (g) estimated in one stomach
Molluscs	23.6	87.32
Fish	4.4	16.28
Crabs	26.7	98.79
Other	0.1	0.37

3. RESULTS

Mean concentration observed in each species considered are reported in Table 2 as mean ± standard error and minimum and maximum value on a wet weight basis. It can be clearly seen that *N. millepunctata* is characterised by a very high As load, while lowest levels were found in *S. solea* and in male crabs.

Lead was found at low concentration in all species, never reaching values higher than 0.551 mg/kg. Very low levels of Hg and Cd were found as well, while in *Natica* and in *Phyllonotus* very high levels of Cd were observed.

Table 3 reports the results of calculation concerning risk assessment and heavy metal load contribution depending on classes and on the scenario considered.

Starting from the obtained calculation and from known percent of absorption, a calculation of the annual amount of each metal, which could potentially be absorbed by a sea turtle eating 370 g/day of each item or group of items, was performed, as reported in Figure 2. The figure also gives the total estimated amount of metal, considering a combination of the 4 food items considered. For mean scenario, the mean value of known absorption percent, in worst scenario the highest absorption, and in the best scenario the lowest absorption were considered.

Table 2: Mean ± standard error and minimum and maximum value (mg/kg) on a wet weight basis.

Tabela 2: Srednja ± standardna napaka ter najmanjša in največja vrednost (mg/kg) na osnovi mokre teže.

Species/systematic group	Mean ± s.e. Minimum-maximum			
	As	***Pb***	***Hg***	***Cd***
Tapes philippinarum	3.007 ± 0.085 1.92-4.41	0.177 ± 0.015 0.058-0.551	0.048 ± 0.0035 0.011-0.086	0.073 ± 0.004 0.052-0.178
Natica millepunctata	44.087 ± 6.826 23.75-73.69	0.098 ± 0.016 0.045-0.184	0.036 ± 0.007 0.012-0.066	0.643 ± 0.210 0.149-1.663
Solea lutea	6.23 ± 0.804 3.58-11.72	0.066 ± 0.009 0.035-0.130	0.016 ± 0.002 0.008-0.024	0.037 ± 0.007 0.018-0.102

Nudibrach	2.31 ± 0.375 1.93-2.685	0.189 ± 0.011 0.178-0.200	0.014 ± 0.002 0.012-0.016	0.078 ± 0.016 0.062-0.094
Phyllonotus truculus	7.792 ± 1.509 5.153-10.38	0.182 ± 0.016 0.150-0.199	0.047 ± 0.004 0.039-0.054	0.649 ± 0.049 0.554-0.717
Sea stars	4.502 ± 0.499 3.573-5.555	0.172 ± 0.039 0.103-0.284	0.010 ± 0.085 1.92-4.41	0.075 ± 0.004 0.066-0.085
Aporrhais pespelecani	2.231 ± 0.061 1.685-3.10	0.127 ± 0.011 0.038-0.266	0.021 ± 0.003 < LOD-0.063	0.109 ± 0.007 0.039-0.188
Solea solea	1.494 ± 0.348 1.146-1.842	0.004 ± 0.001 0.003-0.005	0.009 ± 0.085 1.92-4.41	0.012 ± 0.002 0.010-0.014
Carcinus mediterraneus females	6.111 ± 0.533 3.254-9.44	0.092 ± 0.006 0.054-0.122	0.0042 ± 0.001 0.001-0.007	0.045 ± 0.004 0.021-0.069
Carcinus mediterraneus males	1.595 ± 0.170 1.009-2.771	0.025 ± 0.085 1.92-4.41	0.006 ± 0.002 < LOD-0.017	0.0093 ± 0.002 0.002-0.027
Carcinus mediterraneus eggs	3.194 ± 0.612 1.371-5.647	0.068 ± 0.016 0.015-0.103	0.012 ± 0.003 0.001-0.022	0.011 ± 0.002 0.003-0.023

Table 3: Calculation concerning risk assessment and heavy metal load contribution depending on classes and on the scenario considered.

Tabela 3: Ocena tveganja in obremenjenosti s težkimi kovinami glede na posamezne razrede in upoštevani najslabši možni scenarij.

Species/systematic group	**Amount of food (g)**	**Amount of metal/day with the diet (mg)**			
		As	***Pb***	***Hg***	***Cd***
		“Mean” scenario			
Mollusk	87.32	0.559	0.0133	0.003	0.0129
Fish	16.28	0.0886	0.0009	0.0002	0.0005
Crabs	98.79	0.387	0.008	0.0008	0.0025
Other	0.37	0.001	0.0000657	0.00000468	0.0000282
		Worst scenario			
Mollusk	87.32	4.45	0.0092	0.0035	0.046
Fish	16.28	0.101	0.001	0.0002	0.0006
Crabs	98.79	0.603	0.009	0.0004	0.0044
Other	0.37	0.001	0.00006	0.0000037	0.00002
		Best scenario			
Mollusk	87.32	0.262	0.0155	0.0042	0.0064
Fish	16.28	0.024	0.000065	0.00014	0.00019
Crabs	98.79	0.157	0.0024	0.000649	0.0009
Other	0.37	0.00085	0.000069	0.00000518	0.00002

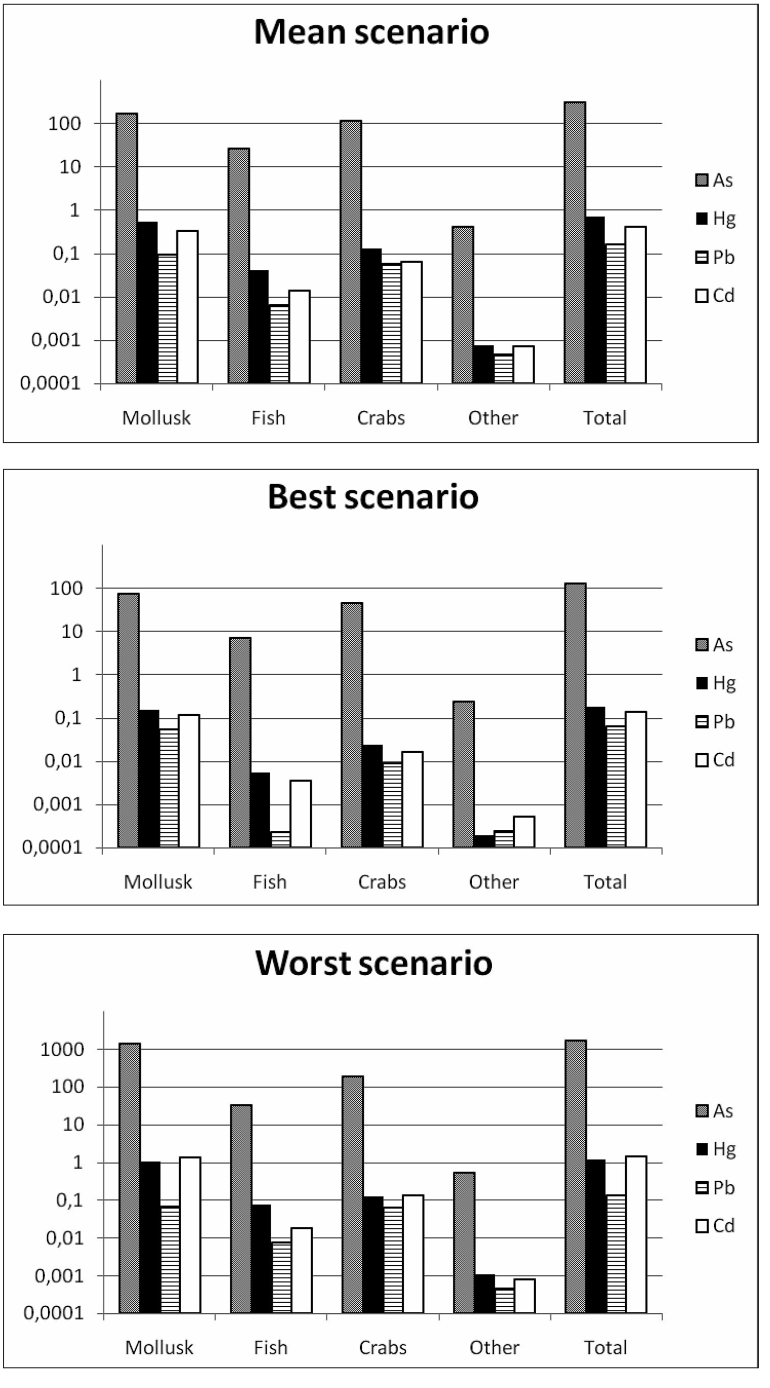


Figure 2: Hypothetical annual amount of metal (mg) absorbed by a single sea turtle depending on the scenario considered (semi-logarithmic scale).

Slika 2: Hipotetična letna količina kovine, ki jo vsrka ena sama glavata kareta glede na najslabši možni scenarij (pol-logaritemska lestvica).

4. DISCUSSION

The obtained data confirm the reduced contamination by lead and mercury of the Adriatic Sea. Cadmium is generally present at medium-low concentrations in species considered, even if *N. millepunctata* and *P. truculus* seem to be important accumulating species and can potentially represent a notable source of cadmium for benthos-eating species. Despite the medium-low concentrations, amounts detected are within the range of subchronic threshold defined for marine species (0.5-10 μg/kg exposure level), responsible of decreases in growth, respiratory disruption, moult inhibition, shortened life span of F1 generation crustaceans, altered enzyme levels, and abnormal muscular contractions in crustaceans (Eisler 1985). Thus it is possible to consider that a diet containing such levels can potentially induce some alteration also in higher organisms, such as sea turtles. It should be noted that molluscs represent highest risk for sea turtles, as they are always over the threshold reported (Table 3) despite the scenario considered, while fish and crabs are a smaller risk for the species.

Most interesting data are those concerning As, which seems to be the most important contaminant in the Adriatic Sea. The obtained data are indeed in agreement with those already observed in loggerhead turtles from the same area, with main contaminant being As (A. Zaccaroni et al., unpublished data).

Even if mean concentrations are within the range of background levels (Eisler 1988), the amount detected are within the range of tissue concentration corresponding to adverse effects in aquatic organisms, so a potential toxic effect can be considered for the species studied, including sea turtles. Indeed, the percent of absorption of arsenic ranges between 80 and 90%, so it is probable that almost all the arsenic present in preys can be absorbed by sea turtles. Anyway, it should be remembered that almost all arsenic in marine organisms is represented by organic compounds, like arsenobetaine, which have proved to be little or non-toxic to organisms. Unfortunately, no speciation of As could be performed in the present study, so it is impossible to define which were the percent of organic and inorganic arsenic species, to better understand the real risk for As intoxication. Anyway, given that no sign of As intoxication was ever observed in sea turtles, and starting from the fact that in blood of loggerhead turtles high amounts of the metalloid can be found, it is possible to consider that the organic arsenic represents the highest amount of total metalloid; some adaptation mechanism should be also considered for marine organisms, as the high amounts observed are comparable with those producing overt toxicity in terrestrial organisms, but no toxicity was observed (Eisler, 1988).

5. CONCLUSIONS

The present data seem to be indicative of a reduced contribution of diet to sea turtles heavy metals body burden as far as Pb, Cd and Hg are concerned, while a great contribution should be considered for As. Anyway, it should also be noted that the mean concentrations of Pb, Hg and Cd in sea turtles' tissues and blood are very low, lower than expected starting from the available literature. Thus, it is probable that low levels of metals can come mainly from the diet.

6. SUMMARY

Various studies have been focused on the monitoring of contaminants in tissues of *Caretta caretta*, using stranded dead animals. Scarce are studies reporting not only on pollutants levels, but also on possible contribution of various diet components in contaminants, i.e. heavy metals, to sea turtles body burden.

The present work evaluates accumulation of toxic heavy metals (As, Pb, Cd, Hg) along trophic chain of *Caretta caretta* in the Northern Adriatic Sea, trying to define which could be main diet components contributing to toxicant body burden for each of the metals considered.

The research focuses on the dynamics of heavy metals transfer from the environment to the highly endangered species like sea turtles, as well as on the assessment of possible toxic effects occurring in the studied animals, including non-acute, highly relevant effects, like immunosupression.

POVZETEK

O kopičenju onesnaževalcev v tkivih nasedlih poginulih glavatih karet *Caretta caretta* je bilo opravljenih že veliko različnih raziskav, medtem ko študij o ravni onesnaževalcev in potencialnem prispevku različnih prehranjevalnih sestavin k obremenjenosti organizmov morskih želv s težkimi kovinami skorajda ni zaslediti.

Avtorji predstavljenega članka so ocenjevali koncentracije toksičnih težkih kovin (As, Pb, Cd, Hg) v prehranjevalni verigi glavate karete v severnem Jadranu in poskušali oceniti, katere so glavne prehranjevalne komponente, ki v največji meri prispevajo k toksični obremenitvi njenega organizma.

Pričujoča raziskava se osredotoča na dinamiko prenosa težkih kovin iz okolja na močno ogrožene vrste, kakršne so morske želve, kot tudi na oceno potencialnih toksičnih vplivov, ki jih je zaslediti v preučevanih živalih, vključno z neakutnimi, a zelo pomembnimi vplivi, kakršna je imunosupresija.

7. LITERATURE

1. Bentivegna, F., M. Ciampa, G. Mazza, A. Paglialonga, A. Travagliani (2001). Loggerhead turtle (*Caretta caretta*) in Tyrrhenian Sea: trophic role of the Gulf of Naples. In: Margaritoulis D., Demetropoulos A. (Eds): Proceedings of the first Mediterranean Conference on Marine turtles, 24-28 October 2001. Rome. 71-75

2. Parker, D.M., W.J. Cooke, G.H. Balazs (2005). Diet of oceanic loggerhead sea turtle (*Caretta caretta*) in the central North Pacific. Fish. Bull. 103: 142–152
3. Revelles, M., L. Cardona, A. Aguilar, G. Fernandez (2007). The diet of pelagic loggerhead sea turtles (*Caretta caretta*) of the Balearic archipelago (western Mediterranean): relevance of long-line baits. J. Mar. Biol. Ass. U.K. 87: 805-813
4. Eisler, R. (1985). Cadmium hazards to fish, wildlife and invertebrates: a synoptic review. U.S. Fish and Wildlife Service Biological Report 85 (1.2), Contaminant Hazard Reviews Report No. 2. 30 pp.
5. Eisler, R. (1988). Arsenic hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish and Wildlife Service Biological Report 85 (1.12), Contaminant Hazard Reviews Report No. 12. 65 pp.

Annalisa ZACCARONI, Flavio GUIDI, Marina SILVI, Dino SCARAVELLI
Centre of Aquaculture and Fish pathology
Research Group on Large Pelagic Vertebrates
Veterinary Faculty, University of Bologna
Cesenatico (FC), Italy
annalisa.zaccaroni@unibo.it

Giuseppe MONTANARI
ARPA Emilia-Romagna,
Struttura Oceanografica Daphne,
Cesenatico (FC), Italy

EVALUATION OF HEAVY METALS ACCUMULATION ALONG BOTTLENOSE (*TURSIOPS TRUNCATUS*) TROPHIC CHAIN IN NORTHERN ADRIATIC SEA

OCENA KOPIČENJA TEŽKIH KOVIN V PREHRANJEVALNI VERIGI VELIKE PLISKAVKE *TURSIOPS TRUNCATUS*

Dino SCARAVELLI, Nicola DI FRANCESCO, Marina SILVI,
Annalisa ZACCARONI

Key words: heavy metals, bottlenose dolphin, Northern Adriatic
Ključne besede: težke kovine, velika pliskavka, severni Jadran

ABSTRACT

Heavy metals are among the most important pollutants in marine environment. Top predator species are particularly at risk of adverse effects due to heavy metal exposure, thus knowing the contribution of diet to pollutants body burden is extremely important. The present work reports on the evaluation of heavy metals presence in some components of bottlenose dolphin diet, trying to define which could be the contribution that each of them give to the body burden of predators. The obtained data confirm the reduced contamination by lead and mercury of the Adriatic Sea, while cadmium is generally present at concentrations within the range of toxic subchronic threshold defined for marine species. Thus it is possible to consider that a diet containing such levels can potentially induce some alteration also in higher organisms, dolphin included. For arsenic As, mean concentrations are in the range of background levels, but the amounts detected are in the range of tissue concentration corresponding to adverse effects in aquatic organisms, so a potential toxic effect can be considered for the species studied and also for dolphins.

IZVLEČEK

Težke kovine sodijo med najhujše onesnaževalce morskega okolja. Zaradi izpostavljenosti pogubnim učinkom teh kovin so še posebno ogroženi vrhunski morski plenilci, zatorej je nadvse pomembno, da vemo, v kolikšni meri k obremenitvi organizmov teh morskih živali prispeva njihova prehrana. Avtorji pričujočega članka so ugotavljali koncentracije težkih kovin v nekaterih sestavinah prehrane velike pliskavke, s čimer so poskušali ugotoviti, v kolikšmi meri prispevajo k obremenjenosti organizmov velikih plenilcev. Zbrani podatki potrjujejo, da je Jadransko morje manj onesnaženo s svincem in živim srebrom, medtem ko se kadmij na splošno pojavlja v koncentracijah znotraj meja toksičnega praga, določenega za morske živalske vrste. Tako je mogoče reči, da prehrana, ki vsebuje takšne ravni kovin, lahko povzroči določene spremembe tudi v višjih organizmih, vključno z delfini. Srednje koncentracije arzenika so sicer na ravni naravnega ozadja, vendar pa se zaznane količine gibljejo v razponu tkivne koncentracije s škodljivimi posledicami za morske organizme. Obstaja torej možnost toksičnega učinkovanja na preučevane morske vrste in tudi na delfine.

1. INTRODUCTION

Studies on the feeding habits of cetaceans can be used to improve knowledge on both predator and prey biology and on the exposure of these species to pollutants. Hence, dietary studies can also be used to monitor the exposure to different contaminants that can affect the health of dolphins and their preys.

Bottlenose dolphins (*Tursiops truncatus* Montagu, 1821) are widely distributed in inshore and offshore waters in the temperate and tropical zones of all oceans and peripheral seas (e.g. Pacific, Atlantic, Indian Oceans, Mediterranean, Black and Red Seas), sometimes entering rivers and estuaries as well as is frequently seen in coastal waters (Wells & Scott, 1999).

Diets of bottlenose dolphins have been studied in various parts of the world, including the northern Atlantic, the Gulf of Mexico, South Africa, Peru, eastern Australia and the Mediterranean (Gunter, 1942; Ross, 1977; Leatherwood et al., 1978; Desportes, 1985; Barros & Odell, 1990; Cockcroft & Ross, 1990; Corkeron et al., 1990; Mead & Potter, 1990; van Waerebeek et al., 1990; Voliani & Volpi, 1990; Relini et al., 1994; Miokovic et al., 1997; Blanco et al., 2001; Santos et al., 2001), but little or no work have been done to evaluate how each component of the diet contributes to dolphins' heavy metals body burden.

The present work describes a heavy metal exposure risk assessment for bottlenose dolphins in Northern Adriatic Sea waters based on the analysis of an artificial diet composed referring to data concerning diet composition available in the literature.

2. METHODS

Sampling was performed directly at fishing boat to fix fish and cephalopods collection location in the study area (Fig. 1). Species were identified and each subject of the sampling group (n= 30 for each group) was then weighed and measured and subsequently stored at -20°C until analysis, which was performed by Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES) for heavy metals analysis (As, Pb, Cd, Hg). Briefly, amounts up to 700 mg of fresh tissue were collected from homogenised animals and microwave digested. The samples were then transferred to the ICP-AES and analysed. Data are reported on a fresh weight basis as mg/kg. When crabs are of concern, they were separated on the basis of gender and the eggs were separated from females and analysed to evaluate the importance of metal excretion with ovoposition.

After analysis, data were treated as follows to obtain an estimation of the amount of metals that could have been ingested with that particular food item:

Starting from literature (Blanco et al., 2001; Santos et al., 2001; Gannon & Waples, 2004; Santos et al., 2007), the mean composition of dolphin diet was defined. Species were then grouped on the basis of the systematic classes (fish, molluscs, crustaceans, other- including all other species) and the percent of contribution to the diet was calculated (Tab. 1).

Assuming a mean weight for stomach content of 10 kg (Santos et al., 2001), the weight of each group in an "ideal" stomach was calculated and the amount of each metal provided

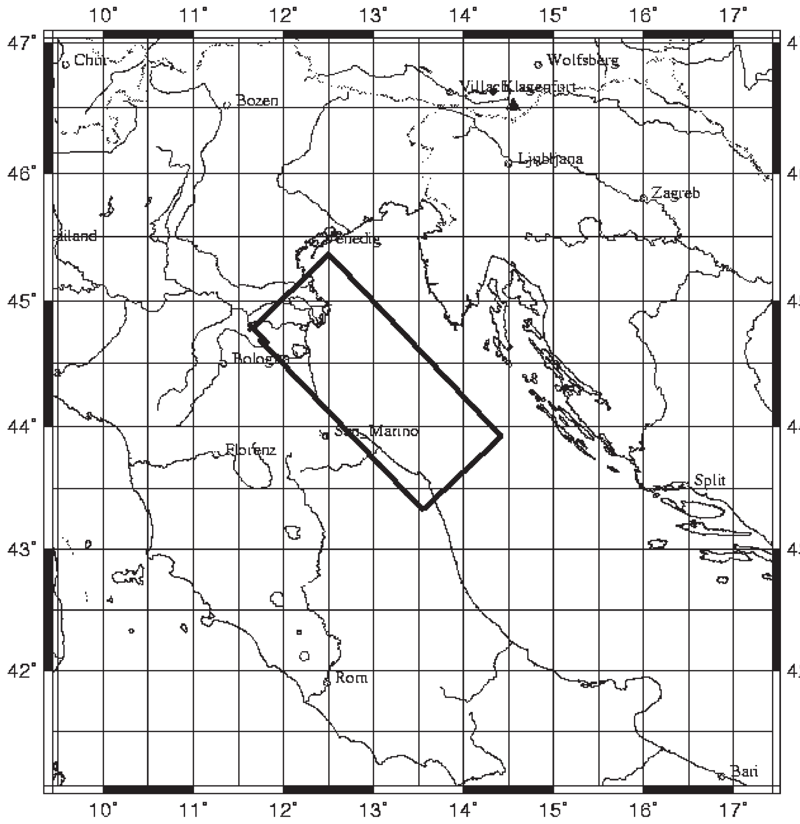


Fig. 1: Sampling area

Slika 1: Območje vzorčenja

with that quantity was calculated in three different scenarios: 1) mean concentration: the concentration/kg was calculated including all species and the mean weight of the stomach content; 2) worst scenario: the mean was calculated considering as the class was composed only by the species presenting higher mean concentration and the highest stomach content found in the literature (15.3 kg); 3) best scenario: the species considered is the one presenting lower concentrations and the lowest stomach content found in the literature (7.6 kg). This calculation allowed to estimate the amount of each toxic metal/year, if the dolphin was feeding on that diet.

Table 1: Percent diet composition as obtained from available literature. The equivalent amount of food in a 10 kg stomach content is also reported.

Tabela 1: Odstotkovna sestava prehrane, pridobljena iz literature. Zabeležena je tudi ekvivalentna količina hrane v desetkilogramski vsebnosti želodca.

Class	**% of the diet**	**Amount (g) estimated in a 10 kg stomach**
Cephalopods	2.15	215
Fish	97.65	9765
Crabs	1.05	105

3. RESULTS

Mean concentrations observed in each species considered are reported in Tab. 2 as mean ± standard error and minimum and maximum value on a wet weight basis.

Highest concentrations were found in all species considered for As, while Pb, Hg and Cd were always detected at low concentrations.

Arsenic seems to be equally distributed in all species considered, as none of them presents extremely high concentrations in any of the samples analysed.

The same is true of all other metals, too, with the only exception of Cd, which reaches mean concentrations in *Sepia officinalis* 4 to 10 folds higher than in other species.

Very low levels of Pb and Hg were observed in all species, with mercury presenting extremely low mean concentration, never higher than 0.02 mg/kg.

Table 2: Mean ± standard error and minimum and maximum value (mg/kg) on a wet weight basis.
Tabela 2: Srednja ± standardna napaka ter najmanjša in največja vrednost (mg/kg) na osnovi mokre teže.

Species/systematic group	**Mean ± s.e. Minimum-maximum**			
	As	***Pb***	***Hg***	***Cd***
Engraulis encrasicolus	3.061 ± 0.168 0.204-5.204	0.023 ± 0.0098 0.001-0.178	0.0047 ± 0.0016 0.001-0.014	0.044 ± 0.0015 0.024-0.068
Sprattus sprattus sprattus	3.183 ± 0.838 1.508-4.067	0.031 ± 0.012 0.008-0.046	0.003 ± 0.0007 0.002-0.0032	0.035 ± 0.0013 0.033-0.037
Solea lutea	6.23 ± 0.804 3.58-11.72	0.066 ± 0.009 0.035-0.130	0.016 ± 0.002 0.008-0.024	0.037 ± 0.007 0.018-0.102
Sardina pilchardus	3.478 ± 0.161 1.279-4.789	0.0709 ± 0.016 0.002-0.279	0.017 ± 0.0028 0.005-0.038	0.035 ± 0.0025 0.023-0.071
Scomber scombrus	2.077 ± 0.046 1.676-3.063	0.0503 ± 0.0209 0.008-0.197	0.008 ± 0.0015 0.002-0.015	0.040 ± 0.0022 0.029-0.080
Solea solea	4.502 ± 0.499 3.573-5.555	0.172 ± 0.039 0.103-0.284	0.010 ± 0.085 0.001-0.41	0.075 ± 0.004 0.066-0.085
Sepia officinalis	5.408 ± 1.117 1.033-9.995	0.048 ± 0.015 0.004-0.187	0.014 ± 0.0037 0.001-0.035	0.119 ± 0.012 0.063-0.239
Carcinus mediterraneus females	6.111 ± 0.533 3.254-9.44	0.092 ± 0.006 0.054-0.122	0.0042 ± 0.001 0.001-0.007	0.045 ± 0.004 0.021-0.069
Carcinus mediterraneus males	1.595 ± 0.170 1.009-2.771	0.025 ± 0.085 0.010-0.102	0.006 ± 0.002 < LOD-0.017	0.0093 ± 0.002 0.002-0.027
Carcinus mediterraneus eggs	3.194 ± 0.612 1.371-5.647	0.068 ± 0.016 0.015-0.103	0.012 ± 0.003 0.001-0.022	0.011 ± 0.002 0.003-0.023

Table 3: Calculation concerning risk assessment and heavy metal load contribution depending on classes and on the scenario considered.

Tabela 3: Ocena tveganja in obremenjenosti s težkimi kovinami glede na posamezne razrede in upoštevani najslabši možni scenarij.

Species/systematic group	**Amount of food (g)**	**Amount of metal with the diet (mg)**			
		As	***Pb***	***Hg***	***Cd***
		"Mean" scenario			
Cephalopods	215	1.1628	0.00873	00234	0.0256
Fish	9765	30.7714	0.2922	0.0474	0.3853
Crabs	105	0.412	0.3096	0.0008	0.00267
		Worst scenario			
Cephalopods	328.95	1,779	0.0133	0.0035	0.0392
Fish	14940.45	47.080	0.4471	0.0726	0.5895
Crabs	160.65	0.6306	0.0132	0.0013	0.004
		Best scenario			
Cephalopods	163.4	0.883	0.0017	0.0195	0.0066
Fish	7421.4	11.087	0.0296	0.0222	0.089
Crabs	79.8	0.127	0.0019	0.00033	0.0007

Starting from the obtained calculation and from the known percent of absorption, a calculation of the annual amount of each metal, which could potentially be absorbed by a dolphin eating 7.6-15.3 kg/day of each item or group of items, was performed, as reported in Fig. 2. The figure reports also a total estimated amount of metal, considering a combination of the 3 food items considered and of total amount. For mean scenario the mean value of known absorption percent, in worst scenario the highest absorption and in the best scenario the lowest absorption were considered.

4. DISCUSSION

The obtained data confirm the reduced contamination by lead and mercury of the Adriatic Sea. Cadmium is generally present at medium-low concentrations in species considered, but despite this, amounts detected are within the range of subchronic threshold defined for marine species (0.5-10 μg/kg exposure level), responsible of decreases in growth, respiratory disruption, moult inhibition, shortened life span of F1 generation crustaceans, altered enzyme levels, and abnormal muscular contractions in crustaceans (Eisler, 1985). Thus it is possible to consider that a diet containing such levels can potentially induce some alteration also in higher organisms, dolphin included. As already shown in other studies from different parts of the world, cephalopods represent the main source for Cd, thus being the highest risk for dolphins, as they are always over the threshold reported (Tab. 3) despite the scenario considered, while fish and crabs are a smaller risk for the species.

Even if mean concentrations are in the range of background levels (Eisler, 1988), the amount of As detected are in the range of tissue concentration corresponding to adverse effects in aquatic organisms, so a potential toxic effect can be considered for the species studied and also for dolphins. Indeed, the percent of absorption of arsenic ranges between 80 and 90%, so it is probable that almost all the arsenic present in preys can be absorbed by bottlenose dolphins. Anyway, it should be remembered that almost all arsenic in marine organisms is represented by organic compounds, like arsenobetaine, which have proved to be little or non-toxic to organisms. Unfortunately, no speciation of As could be performed in present study, so it is impossible to define which were the percent of organic and inorganic arsenic species, to better understand the real risk for As intoxication. Anyway, given that no sign of As intoxication was ever observed in dolphins, and starting from the fact that also in blood of loggerhead high amounts of the metalloid can be found, it is possible to consider that the organic arsenic represents the highest amount of total metalloid; some adaptation mechanism should be also considered for marine organisms, as the high amounts observed are comparable with those producing overt toxicity in terrestrial organisms, but no toxicity was observed (Eisler, 1988).

5. SUMMARY

Starting from UNEP 1999report, Italy is the first producer for heavy metals (Pb, Cd, Cu, Zn) marine pollution, being responsible of 30% of total release of these compounds in the Mediterranean Sea. Being it a closed sea, with a reduced hydric exchange, the Mediterranean is particularly exposed to risks derived from chemical pollution. Knowing pollution degree of this sea by estimating contaminants concentrations in marine species placed at the top of food chains, including marine mammals and cetacean, is thus mandatory. Despite the high number of studies focusing on heavy metals in tissues of different cetacean species, little information is available concerning contaminants transfer along their trophic chains, thus defining which could be the main diet components contributing to toxicant body burden for each of the metals considered.

The present work focuses on the evaluation of heavy metals presence in tissues of bottlenose from the Northern Adriatic Sea and in some components of its diet, trying to define which could be the contribution that each of them give to the body burden of predators.

POVZETEK

Glede na poročilo UNEP (Okoljski program Združenih narodov) za leto 1999 je Italija glavni krivec za onesnaževanje morja s težkimi kovinami (Pb, Cd, Cu, Zn), odgovorna za 30 % vseh izpustov teh snovi v Sredozemsko morje. Ker gre za zaprto morje z omejeno hidrično izmenjavo, je še posebej izpostavljeno tveganjem, ki izvirajo iz kemijskega onesnaževanja. Zatorej je nujno, da ugotovimo stopnjo onesnaženosti morja, in sicer z ocenjevanjem koncentracij onesnaževalcev v morskih živalih na vrhu prehranjevalne verige, vključno z morskimi sesalci. Kljub velikemu številu študij, ki se osredotočajo na težke kovine v tkivih različnih vrst kitov,

je na voljo zelo malo literature o prenosu onesnaževalcev v prehranjevalni verigi, na podlagi katerih bi lahko ugotovili, katere so glavne prehranske komponente, ki prispevajo k toksični obremenitvi organizmov glede vseh upoštevanih kovin.

Avtorji pričujočega članka se osredotočajo na ugotavljanje koncentracij težkih kovin v tkivih velike pliskavke v severnem Jadranu in v nekaterih sestavinah njene prehrane, pri tem pa poskušajo ugotoviti, v kolikšni meri prispevajo k obremenjenosti organizmov velikih plenilcev.

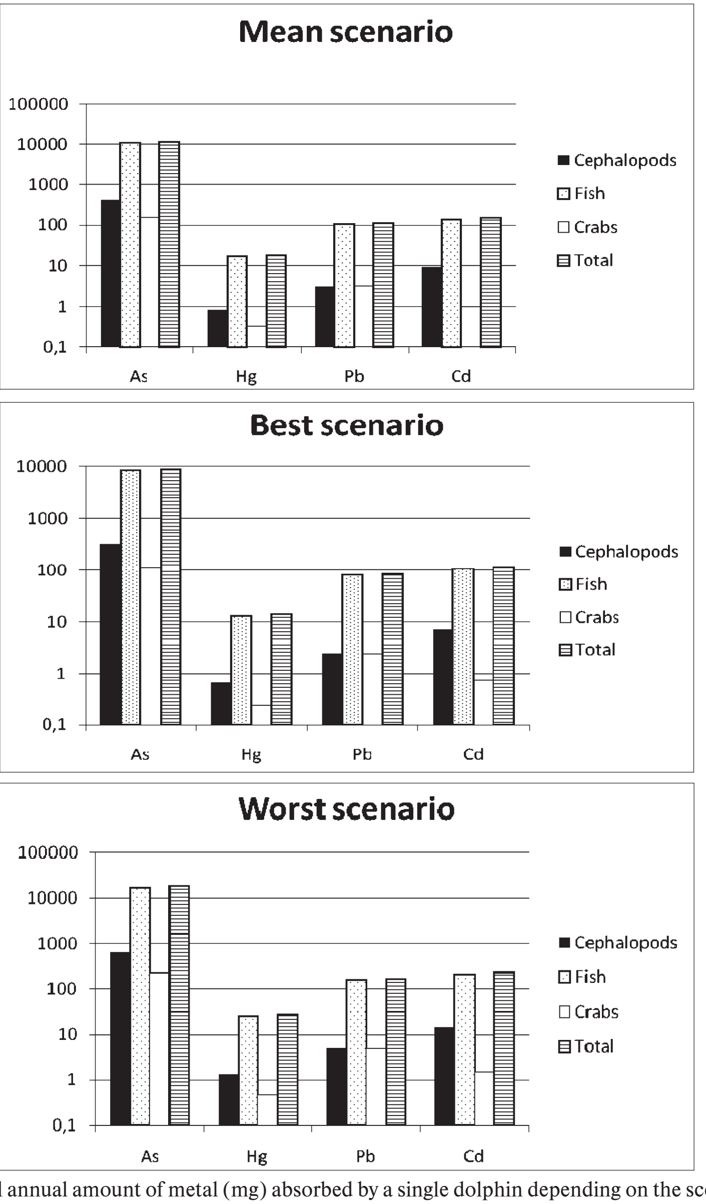


Fig. 2: Hypothetical annual amount of metal (mg) absorbed by a single dolphin depending on the scenario considered (semi-logarithmic scale).

Slika 2: Hipotetična letna količina kovine, ki jo vsrka en sam delfin glede na najslabši možni scenarij (pol-logaritemska lestvica).

6. LITERATURE

1. Barros, N.B., D.K. Odell (1990): Food habits of bottlenose dolphins in the southeastern United States. In *The bottlenose dolphin* (ed. S. Leatherwood and R.R. Reeves), San Diego: Academic Press, 309–328.
2. Blanco, C., O. Salomón, J.A. Raga (2001): Diet of bottlenose dolphin (*Tursiops truncatus*) in the western Mediterranean Sea. *Journal of the Marine Biological Association of the United Kingdom*, 81, 1053–1058.
3. Cockcroft, V.G., G.J.B. Ross, (1990): Food and feeding of the Indian Ocean bottlenose dolphin off southern Natal, South Africa. In *The bottlenose dolphin* (ed. S. Leatherwood and R.R. Reeves), San Diego: Academic Press, 295–308.
4. Corkeron, P.J., M.M. Bryden, K.E. Hedstrom, (1990): Feeding by bottlenose dolphins in association with trawling operations in Moreton Bay, Australia. In *The bottlenose dolphin* (ed. S. Leatherwood and R.R. Reeves), San Diego: Academic Press, 329–336.
5. Desportes, G., (1985): *La nutrition des Odontoc tes en Atlantique Nord-Est (côtes Françaises - Iles Feroë)*. PhD thesis, Université de Poitiers, Poitiers, France.
6. Eisler, R. (1985): Cadmium hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish and Wildlife Service Biological Report 85 (1.2), *Contaminant Hazard Reviews Report No. 2*. 30 pp.
7. Eisler, R. (1988): Arsenic hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Fish and Wildlife Service Biological Report 85 (1.12), *Contaminant Hazard Reviews Report No. 12*. 65 pp.
8. Gannon, D.P., D.M. Waples, (2004): Diets of coastal bottlenose dolphins from the U.S. Mid-Atlantis coast differ by habitat. *Marine Mammal Science*, 20, 527-545.
9. Gunter, G., (1942): Contributions to the natural history of the bottlenose dolphin, *Tursiops truncatus* (Montagu), on the Texas coast, with particular reference to food habits. *Journal of Mammalogy*, 23, 267–276.
10. Leatherwood, S., M.W. Deerman, C.W. Potter, (1978): Food and reproductive status of nine *Tursiops truncatus* from the northeastern United States coast. *Cetology*, 28, 1–6.
11. Mead, J.G., C.W. Potter, (1990). Natural history of bottlenose dolphins along the central Atlantic coast of the United States. In *The bottlenose dolphin* (ed. S. Leatherwood and R.R. Reeves), San Diego: Academic Press, 165–195.
12. Miokovic, D., D. Kovacic, S. Pribanic, (1997): Stomach content analysis of a bottlenose dolphin (*Tursiops truncatus*) from the Adriatic Sea. *European Research on Cetaceans*, 11, 149pp.
13. Relini, L.O., M. Cappello, R. Poggi, (1994): The stomach content of some bottlenose dolphins (*Tursiops truncatus*) from the Ligurian Sea. *European Research on Cetaceans*, 8, 192–195.
14. Ross, G.J.B., (1977): The taxonomy of bottlenose dolphins *Tursiops* species in South African waters, with notes on their biology. *Annals of Cape Province Museum (Natural History)*, 11, 135–194.
15. Santos, M.B., G.J. Pierce, R.J. Reid, I.A.P. Patterson, H.M. Ross, E. Mente, (2001): Stomach content of bottlenose dolphins (*Tursiops truncatus*) in Scottish waters. *Journal of the Marine Biological Association of the United Kingdom*, 81, 873-878.
16. Santos, M.B., R. Fernández, A. López, J.A. Martínez, G.J. Pierce, (2007): Variability in the diet of bottlenose dolphin, *Tursiops truncatus*, in Galician waters, north-western Spain, 1990–2005. *Journal of the Marine Biological Association of the United Kingdom*, 87, 231–241.
17. Voliani, A., C. Volpi, (1990): Stomach contents analysis of a stranded specimen of *Tursiops truncatus*. *Rapports de la Commission Internationale pour l'Éxploration de la Mer Méditerranée*, 32, 238.
18. Waerebeek K. van, J.C. Reyes, A.J. Read, S. McKinnon, (1990) : Preliminary observations of bottlenose dolphins from the Pacific coast of South America. In *The bottlenose dolphin* (ed.: S. Leatherwood and R.R. Reeves), San Diego: Academic Press, 143–154.

19. Wells, R.S., M.D. Scott, (1999): Bottlenose dolphin *Tursiops truncatus* (Montagu, 1821). In *Handbook of marine mammals: Volume VI The second book of dolphins and porpoises* (ed. S.H. Ridgeway and R.J. Harrison), San Diego: Academic Press, 137–182.

Dino SCARAVELLI
Centre of Aquaculture and Fish pathology
Research Group on Large Pelagic Vertebrates
Veterinary Faculty
University of Bologna
Cesenatico (FC)
dinosc@tin.it

SUSTAINABLE TOURISM DEVELOPMENT IN PROTECTED AREAS ON THE PATTERN OF STRUNJAN LANDSCAPE PARK

TRAJNOSTNI RAZVOJ TURIZMA V ZAVAROVANIH OBMOČJIH NA PRIMERU KRAJINSKEGA PARKA STRUNJAN

Igor JURINČIČ, Alenka POPIČ

Key words: nature conservation, protected areas, sustainable tourism, Landscape Park, management plan
Ključne besede: varstvo narave, zavarovana območja, trajnostni turizem, krajinski park, upravljavski načrt

ABSTRACT

The natural environment in Slovenia is highly threatened owing to its fast growing economy in the last four decades. One of the reasons for this state of affairs is the intensive tourism development. To conserve the most valuable parts of nature from degradation and destruction, we protected them by law. In ecological and biological terms, Strunjan Landscape Park is not doubt a significant area, protected since 1990, but on the other hand it is one of the most popular tourist destinations in Slovenian Istria. Within our research work, we attempted to gain a better insight into our nature conservation system, and analyzed tourism flows in the park. The paper discusses the sustainability of tourism in Strunjan Landscape Park, the impact of tourism on natural environment, and proposes some guidelines for future planning and management.

IZVLEČEK

Dinamični gospodarski razvoj v zadnjih štirih desetletjih je povzročil nevarno krčenje naravnega okolja v Sloveniji. Eden izmed vzrokov je tudi intenzivni razvoj turizma. Da bi ohranili najvrednejše dele narave, smo najbolj ranljiva območja zavarovali z zakonom. Med zavarovanimi območji je tudi Krajinski park Strunjan, ki je obenem zelo priljubljena turistična destinacija v Slovenski Istri. Ker je območje pomembno tako z vidika varstva narave kot z vidika razvoja turizma, smo v nalogi pregledali pravne okvire za uresničevanje turistične dejavnosti v parku, napravili analizo turističnega prometa ter določili vsebine, ki so nujne za trajnostni razvoj turizma. Ugotavljali smo, ali se turizem v Krajinskem parku Strunjan razvija v skladu s principi trajnostne rabe prostora in kakšen vpliv ima na naravno okolje, ter glede na rezultate podali nekaj razvojnih predlogov in usmeritev.

1. UVOD

Tourism is one of the fastest growing businesses in the world. In the second half of the 20th century, however, the extremely dynamic and innovative economic development caused a dangerous shrinking and deterioration of living nature. In the last four decades, the Slovenian coast, too, has undergone some exceptional changes that are now reflected in the spatial development's negative trend. Instead of integral spatial planning, i.e. looking for balance between social, economic and environmental moderation, development has been oriented notably at partial solution of the problems and excessive exploitation of the coastal belt. The awareness that the Mediterranean Sea and its coasts are among the most endangered parts of the Mediterranean owing to its very active economy, forced the state to consider a more rational management of the coast. Since gaining its dependence, Slovenia has proclaimed one fifth of its coast a protected area, as it is marked by high biotic and landscape diversity. In contrast to the general belief that these are areas where conservation purposes should exclude all other activities and impede development, the protected areas also present, apart from the implementation of activities in the spheres of conservation, education and scientific research, an opportunity for recreational and tourist activities. One of such areas is Strunjan Landscape Park, which happens to be one of the most popular tourist destinations on the Slovenian coast. As the area is significant both from the aspect of nature conservation and tourism development, we analysed the data on the past development of tourist activities in the area and their impact on nature, studied the legal framework for the implementation of tourism, assessed whether a new approach is needed in tourist development and whether the current tourist development corresponds to the principles of sustainable development.

2. SUSTAINABLE TOURISM

Considering that tourism is primarily an economic activity and, apart from it, the fastest growing business in the world, its unsuitable development may be hazardous for nature conservation and protected areas as well as for the local population and economy. In order to preserve nature for our descendants in a fairly good state, it is of utmost importance that during the planning of tourist activities, too, space and other natural resources are managed sustainably. According to the key strategic documents (Uran et. al 2006, Vesenjak et al. 2006), the development of tourism in Slovenian Istra and Slovenia in general is based on the principles of sustainable development. Sustainable tourism is closely associated with responsible land-use planning, where a special emphasis is given to the care of protected areas (Jurinčič 2004).

2.1 DEFINITION OF SUSTAINABLE AND ECOLOGICAL TOURISM DEVELOPMENT

Sustainable tourism was initially referred to in the Strategy for World Conservation from 1980, prepared by the International Union for Conservation of Nature (IUCN), United Nations Environment Programme (UNEP), and World Wildlife Fund (WWF). The strategy underlines that the mankind that exists as part of nature has no future if valuable natural features are not preserved.

As no uniform definition for sustainable development can be found in professional literature, its meaning is often misused, apart from the fact that ecologically-friendly types of tourism are marketed in an utterly incorrect way. In view of the specifity of a concrete local environment and professional provenance of the researchers, economic, social or natural aspects of sustainable development appear in the foreground (Jurinčič 2004).

To our judgment, the most suitable seems to be the definition acknowledged by the United Nations World Tourism Organization (UNWTO). It is the fruit of prolonged efforts invested by UNWTO in sustainable tourism development: »Sustainable tourism considers the needs of tourists and the host region and at the same time improves the possibilities for future development. This is why it manages the resources by attempting to satisfy the economic, social and aesthetic needs to the greatest possible extent, and thus to preserve the cultural integrity, ecological processes, biodiversity and the systems that are prerequisite for the existence of life.«

Despite the different definitions of sustainable tourism, none of them places in top spot the needs of nature and society, i.e. preservation of ecological processes, biodiversity and systems that are prerequisite for the planning of tourist activities, and sustainable tourism together with it. The nearest to it would be ecological tourism.

Considering that in practice, however, the term tourism is often even equalled with ecological tourism, we can still ascertain, on the basis of conclusions made at world conferences organized during the 2000 International Ecological Tourism Day in Quebec and Johannesburg by UN and UNWTO, that ecological tourism:

– embraces all forms of tourism associated with nature and in which the basic motif of tourist visits is watching and admiring nature and traditional cultures in the natural environment;

– incorporates education and interpretation of the above issues to the visitors;

– is generally, although not always, intended for small organised groups lead by small specialised local companies, as well as by foreign companies of different sizes, although, as a rule, for small groups of tourists;

– provides for, with well planned management of natural areas, economic benefits without jeopardizing the natural and socio-cultural environment.

Consequently, we are dealing with the type of tourism that is most suitable for central parts of nature protected areas, where more rigorous protective regime is in force.

2.2 THE CARRYING CAPACITY AND SUSTAINABLE TOURISM INDICATORS

In order to affirm sustainable tourism in practice, the UNWTO and UNEP recommend, apart from integral spatial planning of the regions and adjusted management of tourist destinations, an analysis of the carrying capacity for separate destinations, made on the basis of sustainable tourism indicators analysis. Sustainable tourism denotes growth within the framework of limiting factors, ascertained during the carrying capacity analysis with indicators of the carrying capacity of destination for sustainable tourism. The most important here is the weakest link. The limits of sustainable tourism development, defined with the carrying capacity, are not stipulated once and for all but can be shifted upwards with suitable measures (Jurinčič 2005).

With the carrying capacity for tourism analysis, the maximum number of visitors that can visit a region or tourist destination simultaneously without causing unacceptable consequences for the place as well as ecological and socio-cultural environment is stipulated. Analysis of this kind is also suitable for the estimation of management plans for nature protected areas (Jurinčič 2003).

The sustainable tourism indicators are a significant tool in the management and planning of the processes unfolding at a certain destination. A systematic monitoring of indicators enables us to compare the data through longer periods of time as well as interpretation and prediction of processes at a certain destination.

The WTO (2004) published a compulsory manual with sustainable development indicators for tourist destinations. The manual is earmarked for the monitoring of sustainable development indicators at tourist destinations and is the result of a very intensive research, in which 64 experts from more than 20 different countries took part, and presents 25 examples on seven continents. It contains guidelines for the monitoring and use of indicators for different areas and their application to individual tourist destinations. But most of all, the guide underlines that the indicators must be adjusted in view of separate destination. There are no uniform or universal indicators that could be used for all destinations, but are to be adjusted in view of destination types (coastal areas, deserts, mountain destinations, wetlands ...).

2.3 THE ROLE OF TOURISM IN THE PROTECTED AREAS

The strategy concerning the conservation of biodiversity in Slovenia presents various orientations for key activities (fishery, agriculture, traffic, industry, salt-making ...) of sustainable use of biodiversity and sustainable development components. Tourism is presented as a branch of industry that can substantially contribute to the conservation of nature and biodiversity, as it helps to evaluate it economically as a commodity that has no market price otherwise. But it certainly has its intrinsic value, i.e. actual value (as opposed to market or book value).

The role of tourism in protected areas is:

– to present local specific features and to revive old tradition, although only by considering the needs and wishes of the local population;

– to complete the existing and to add new tourist products in the way that does not burden the environment and the local population;

– a developmental opportunity of the local population, in the way that it co-creates tourist capacities,

– to create an integral picture of the area that gives a recognisable image of a successful professional work.

3. STRUNJAN LANDSCAPE PARK

The Park encompasses the greater part of the Strunjan Peninsula and constitutes an integral landscape unit, which is of exceptional significance in terms of plant and animal diversity conservation and the valuable natural features of our sea and its coast. Owing to its special features, great biodiversity and the fact that it is the longest uninterrupted part of natural coast in the entire Gulf of Trieste, it is of exceptional importance from the aspect of nature conservation and preservation of ecological stability in the entire Gulf. In further text, classification of conservation categories in the Park is presented.

3.1 THE AREA OF STRUNJAN LANDSCAPE PARK AND MINOR PROTECTED AREAS

The Law on nature conservation (Official Gazette of the Republic of Slovenia No. 96/2004-UPB2) stipulates protected areas according to their size, distinguishing between major and minor protected areas. Strunjan Landscape Park is a major protected area, within which minor protected areas are situated (nature monuments and reserves). Major protected areas are liable to consider the wishes of the local population, to provide for sustainability and man's spiritual as well as physical relaxation, while the purpose of minor protected areas is merely to protect nature.

3.1.1 The area of Strunjan Landscape Park

The entire area of SLP covers 430 ha. Its land part spreads on cca. 305 ha, while its maritime part embraces some 125 ha of the entire Park. The area stretches from Simon Bay to the outfall of the Roja stream in the west of the Strunjan valley and to the inner part of Strunjan Bay. It also encompasses about 200 m wide sea belt, Strunjan salt-pans, Stjuža lagoon and Pinijev drevored (Stone Pine Avenue).

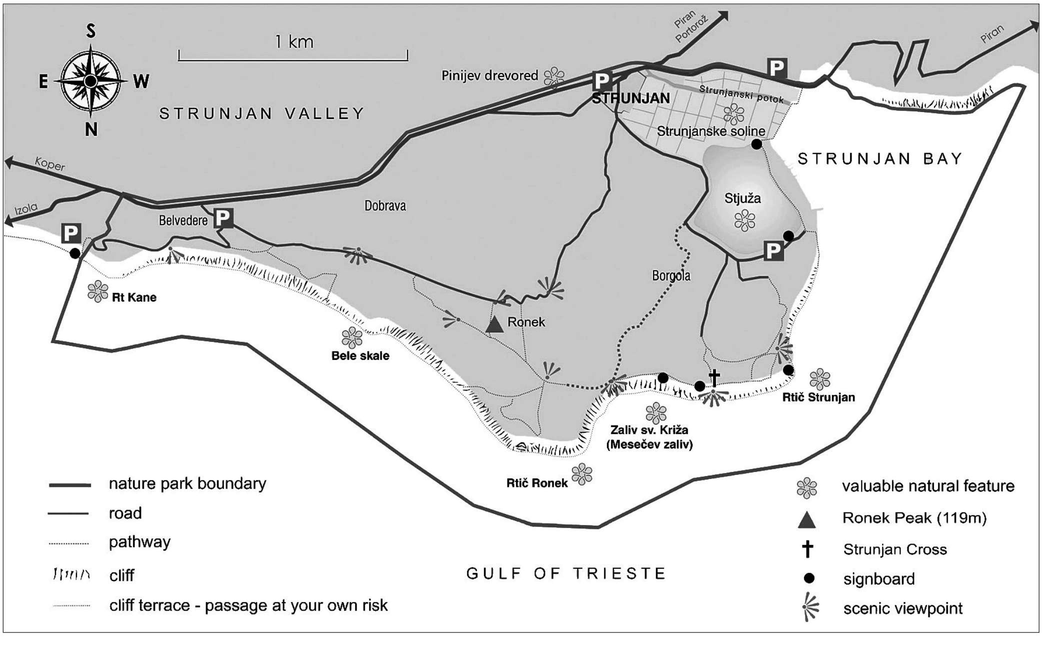


Figure 1: The valuable natural features and cultural heritage in Strunjan Landscape Park (author: Vojko Strahovnik)

Slika 1: Naravne vrednote in kulturna dediščina v Krajinskem parku Strunjan (avtor: Vojko Strahovnik)

Article 5 of the Decree on Strunjan Landscape Park (Official Gazette of the Republic of Slovenia No. 107/2004) lists of the following developmental orientations in the Park:

– stimulation of nature-friendly forms of agriculture;

– ecologically friendly tourism and recreation;

– cultural heritage protection;

– implementation of salt-making activities in traditional manner and use of products associated with them (brine and fango mud);

– use of ecologically friendly technologies in natural resources management, in order to preserve their ecosystemic value and renewable capacity, as well as to conserve plant and animal species habitats, habitat types and valuable natural features.

3.1.2 Minor protected areas within the area of Strunjan Landscape Park

The areas stipulated as minor protected areas in Article 3 of the Decree on Strunjan Landscape Park (Official Gazette of the RS No. 107/2004) are the following:

1. The valuable natural feature Strunjan Cliff is defined, with its maritime part and direct hinterland, as »Strunjan Nature Reserve«, comprising ca. 125 ha. Its most characteristic feature is the flysch cliff, which has survived in all its natural forms and processes. Apart from various geological and geomorphologic phenomena, the characteristic sub-Mediterranean bush and tree species, such as Wig Tree and Manna Ash, as well as true Mediterranean plants can be found in the Reserve. The Strawberry Tree, as a representative of Mediterranean plants, has its only autochthonous site in Slovenia at Cape Ronek. Very rich is the maritime part of the Reserve. On the muddy and sandy bottom of Mesečev zaliv (Moon Bay) spreads an extensive underwater meadow composed of Seagrass *Cymodocea nodosa* and Dwarf Eel-grass *Zostera noltii*. The meadow is also a significant habitat of the Pen Shell, Seahorse and Sea Slug *Discodoris atromaculata*.

The Strunjan Nature Reserve is defined as an area with primary conservation function. Within the Reserve, only activities that protect and preserve natural processes and diversity of habitat types as well as habitats of plant and animal species and communities can be carried out. In the central part of the Reserve, the following is prohibited by law: disturbance, killing or appropriation of wild animals and their developmental forms from nature, commercial fishing, and scuba diving, except for the needs of conserving valuable natural features and biodiversity (as per Article 9 of the Decree on Strunjan Landscape Park, Official Gazette of the RS No. 107/2004).

2. The valuable natural feature Strunjan-Stjuža and the potential area of conservation, delineated as Strunjan salt-pans with Stjuža, comprise the »Strunjan-Stjuža Nature Reserve«, which spreads on ca. 30 ha. The area is known for its Strunjan salt-pans, where the traditional salt-making is still taking place. Various sources give evidence that the pans are more than seven hundred years old are supposed to be older than the Sečovlje salt-pans. Along the pans, the only sea lagoon on the Slovenian coast is situated. The Stjuža lagoon is significant from the nature conservation point of view, for it provides shelter and food for several bird and fish species. The entire reserve embraces an exceptional interlacement of habitats that cannot be found in any other part of the Slovenian coast.

In order to protect the valuable natural features and to conserve the favourable conservation status of habitat types as well as habitats of endangered plant and animal species, traditional salt-making is carried out in the Strunjan-Stjuža Nature Reserve, whereas other activities are performed only if they do not impede the protection of habitat types, populations of endangered plant and animal species, and the traditional salt-making. Among other things, fishing and mariculture are prohibited in the Reserve, as well as camping, appropriation of wild plants and animals, changing of the existing structures of the lagoon floor (except for the purposes of conserving valuable natural features, biodiversity, and for ecological and other excusable reasons). Also forbidden is to destruct, damage or to take way the microbial blanket that covers the floor of the salt-pans basins, as well as any facilities and devices intended for the implementation of traditional salt-making (as per Article 8 of the Decree on Strunjan Landscape Park, Official Gazette of the RS, No. 107/2004).

3. The valuable natural feature Strunjan – Stone Pine Avenue is defined as »Stone Pine Avenue Nature Monument (NM)«. It is 600 m long and consists of 117 between 12 and 14 m high trees. It is of great dendrological value and, above all, a typical and significant element of the littoral landscape.

Any activities in the Stone Pine Avenue NM are to be carried in the way that provide for the conservation of the entire avenue and its separate trees. In the NM, the following is prohibited: to break, cut, lop off or damage branches, leaves, trunks, bark and roots (except when regular professional trimming or works connected with eventual healing of the trees are concerned), to hang or fix foreign bodies such as posters, notices, lamps, electric cable carriers, antenna boards and boxes on the trees' trunks, roots or branches (as per Article 10 of the Decree on Strunjan Landscape Park, Official Gazette of the RS, No. 107/2004).

For the minor protected parts of the Park, a stricter protection regime is in force than for the area of the entire Park. In order to be able to establish to what extent tourism can be implemented within the Park, it is necessary to be well acquainted with the above stated classifications for separate areas and with legal regulations in view of their protection and therefore to provide for sustainable tourism development within them. Furthermore, the Strunjan Cliff and the entire Strunjan-Stjuža Nature Reserve belong to the Natura 2000 network. This all-European network of special areas of conservation has been established in order to conserve animal and plant species and habitats that are rare or already threatened in Europe. For any spatial interventions within nature protected areas (Natura 2000), an assessment of their impacts on the environment must be made in advance.

4. ANALYSIS OF TOURIST TRAFFIC IN STRUNJAN LANDSCAPE PARK

The Decree on Strunjan Landscape Park (Official Gazette of the RS, No. 107/2004) also stipulates the developmental orientations that are implemented by, among other things, environmentally friendly tourism and recreation. The main objective of the Decree is to protect and conserve nature, although landscape parks are considered the least limiting conservation group. This is why sustainable tourism and recreation development is among the major objectives as far as management of this kind of areas is concerned. And as we shall see in further text, tourism is already one of the main (not sustainable) activities in the Park.

Considering that no less than two thirds of the territory of Strunjan Landscape Park belong to the village of Strunjan, which is part of the Piran Council, the data on tourist traffic in the village of Strunjan were taken into account. The eastern part of the Park, which is situated in the Municipality of Izola, also includes the hotel complex of Belvedere, which is about the size of the hotel complex of Salinera. Namely, the Salinera tourist settlement and AMD Piran Autocamp are located within the area of Strunjan village, but outside of the Park. Thus, the tourist traffic intensity in the village of Strunjan can be equalled with the tourist traffic within the area of the entire Park.

The data on tourist visits (number of tourists) cannot provide for an integral assessment of tourists staying at a certain place, but are implicit if we wish to ascertain the actual impacts on this vulnerable area. This is why data on overnight stays in the 1996-2006 period were analysed (SURS 2007).

Table 1: Number and share of overnight stays by domestic and foreign tourists at Strunjan in the 1996- 2006 period (source: SURS 2007)
Tabela 1: Število in delež domačih in tujih prenočitev v Strunjanu v obdobju 1996-2006 (vir: SURS 2007)

YEAR / LETO	No. of overnight stays by domestic guests / Število prenočitev domačih gostov	No. of overnight stays by foreign guests / Število prenočitev tujih gostov	Total / Skupaj	Overnight stays by domestic guests / Prenočitve domačih gostov (%)	Overnight stays by foreign guests / Prenočitve tujih gostov (%)	Total / Skupaj (%)
1996	122,690	24,846	147,536	83.2	16.8	100.0
1997	134,690	27,805	162,495	82.9	17.1	100.0
1998	124,381	28,127	152,508	81.6	18.4	100.0
1999	126,547	26,300	152,847	82.8	17.2	100.0
2000	131,647	36,946	168,593	78.1	21.9	100.0
2001	129,343	42,656	171999	75.2	24.8	100.0
2002	120,558	51,873	172,431	69.9	30.1	100.0
2003	131,369	52,408	183,777	71.5	28.5	100.0
2004	119,601	58,251	177,852	67.3	32.7	100.0
2005	130,660	60,129	190,789	68.5	31.5	100.0
2006	142,172	62,881	205,053	69.3	30.7	100.0

Figure 2 presents the dynamics of overnight stays (domestic, foreign and total number of tourists) at the tourist place of Strunjan for the period of 10 years.

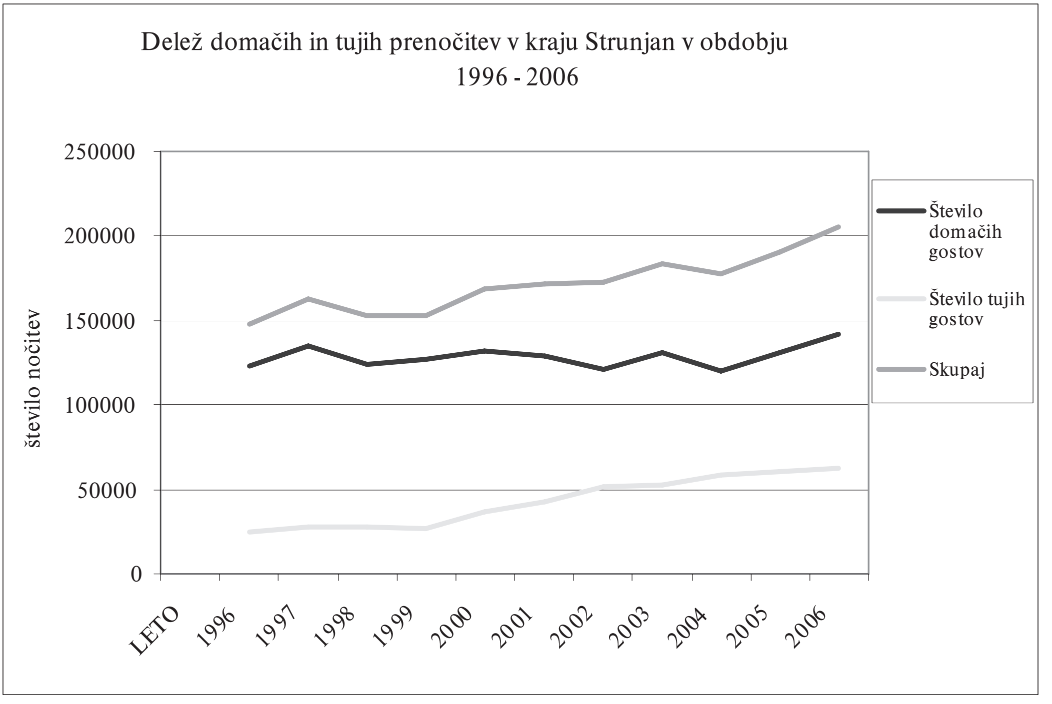


Figure 2: Number of overnight stays at Strunjan in the 1996-2006 period (Source: SURS 2007)
Slika 2: Število prenočitev v kraju Strunjan v obdobju 1996 – 2006 (Vir: SURS 2007)

Table 1 and Figure 2 indicate prevalence of domestic guests in the 1996-2006 period, with their share reaching almost 75% in the 10-year period; the highest was recorded in 1996 (83.2%), the lowest in 2004 (67.3%). The data show that the number of foreign visitors increases from year to year, for while in 1996 24,846 overnight stays by them were recorded, the figure reached no less than 62,881 in 2006. The dynamics of trend regarding the number of all overnight stays shows that except for the year 1998 (owing to the hotel reconstruction) the number of overnight stays increases each year, particularly in the 2004-2006 period, which in turn increases the pressures exerted on the environment. We believe that this is a reason for concern, considering that the village of Strunjan is located within Strunjan Landscape Park and that uncontrolled increased visits can endanger the already highly sensitive environment.

Table 2: Number and share of overnight stays by domestic and foreign guests at Strunjan in 2006 per separate months (Source 2007)
Tabela 2: Število in delež prenočitev domačih in tujih gostov v kraju Strunjan v letu 2006 po mesecih (Vir: SURS 2007)

MONTH / MESEC	**No. of overnight stays by domestic guests / Število prenočitev domačih gostov**	**No. of overnight stays by foreign guests / Število prenočitev tujih gostov**	**Total / Skupaj**	**Overnight stays by domestic guests / Prenočitve domačih gostov %**	**Overnight stays by foreign guests / Prenočitve tujih gostov %**	**Total / Skupaj %**
Januar	5,672	2,483	8,155	69.5	30.5	100
Februar	6,416	2,141	8,557	75	25	100
Marec	7,179	1,780	8,959	80.1	19.9	100
April	7,808	4,144	11,952	65.3	34.7	100
Maj	10,721	5,318	16,039	66.8	33.2	100
Junij	17,123	8,306	25,429	67.3	32.7	100
Julij	26,356	9,576	35,932	73.3	26.7	100
Avgust	19,650	14,346	33,996	57.8	42.2	100
September	14,179	5,870	20,049	70.7	29.3	100
Oktober	8,966	3,610	12,576	71.3	28.7	100
November	9,673	2,012	11,685	82.8	17.2	100
December	8,429	3,295	11,724	71.9	28.1	100

The figure below indicates the of arrivals dynamics by visitors (domestic, foreign, and total) at Strunjan in 2006.

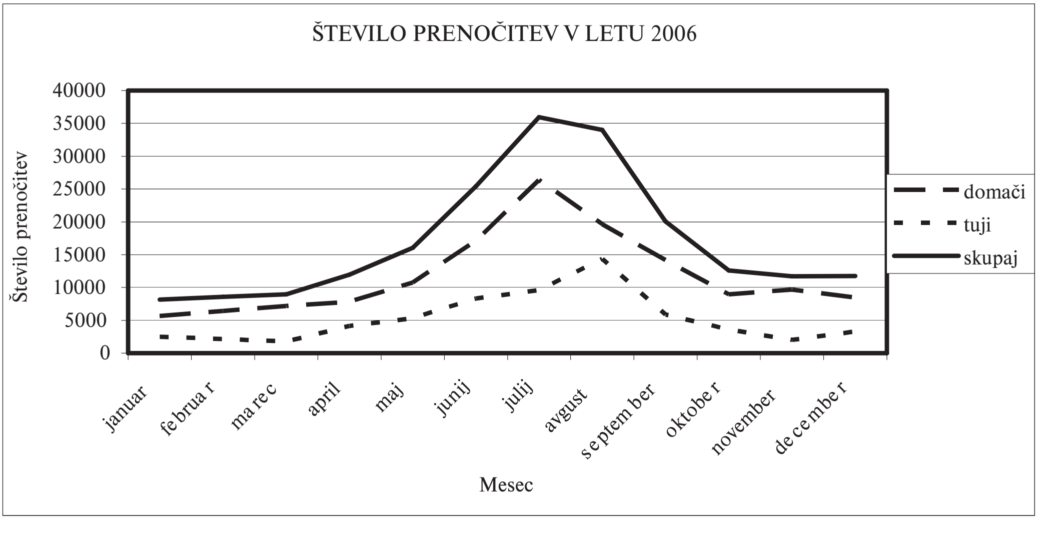


Figure 3: Number of overnight stays per separate months in 2006 (Source: SURS 2007)
Slika 3: Število prenočitev po mesecih v letu 2006 (vir: SURS 2007)

Table 2 and Figure 3 show that the highest concentration of overnight stays is reached in the summer months, i.e. in June, July, August and September. The lowest number of overnight stays at Strunjan is recorded in the months of January, February and March. In 2006, the highest number of overnight stays went to domestic guests, i.e. (26,356 overnight stays). The highest number of overnight stays by foreign guests was recorded in August (14,346). The curve in Graph 3 shows that in mid-September the number of overnight stays by foreign and domestic guests begins to fall rapidly, reaching the lowest value in January.

According to the data, it may be concluded that the greatest pressure on the environment is exerted in the summer months and that the visits should be limited or at least suitable directed and managed. In order to plan tourist activities in compliance with the principles of sustainable use, the carrying capacity of the place must be ascertained prior to making any plans. The carrying capacity of a place is an approach that in the long run provides for solid tourist services on the one hand and for preservation of natural resources on the other. Jurinčič (2003) states that at the peak of the summer season and at weekends that the carrying capacity at Strunjan is already surpassed.

5. THE IMPACTS OF TOURISM IN STRUNJAN LANDSCAPE PARK

The biodiversity conservation strategy in Slovenia delineates tourism as a branch of industry that can greatly contribute to the conservation of nature and biodiversity, as it helps to evaluate it economically as a commodity that otherwise has no market value at all. On the other hand, however, tourism brings, apart from benefits, certain dangers and negative impacts on the environment itself. In this chapter we shall focus mainly on the negative impacts of tourist activities in Strunjan Landscape Park and on potential dangers of tourism for the local environment.

Table 3: Negative impacts and potential dangers from tourism in Strunjan Landscape Park (modified from Trampuš 2002)
Tabela 3: Negativni vplivi ter potencialne nevarnosti turizma v Krajinskem parku Strunjan (prirejeno po Trampuš 2002)

	Negative impacts/Dangers from tourism
Pressures exerted on the environment	Greater water consumption owing to the increased number of visitors
	Pollution of the sea and other water sources due to rubbish dumping and discharge of oils, fuels and waste water into the sea
	Increased motor traffic and, in turn, increased air pollution and noise
	Excessive trampling of the ground and treading of new paths, which results in loss of habitats and vegetation
	Degradation of the shore and sea owing to the transportation by boats and their anchoring
	Increasing crowds and noise owing to the ever greater number of visitors
	Increased amount of refuse in the entire area
	Parking in the natural environment due to parking lot occupancy
	Surpassed carrying capacity of the area

Financial pressures	General increase in prices and taxes owing to the increased demand and thus increased pressures on the local population (diminishing possibilities for the local population to purchase real property)
	Introduction of entrance fees and other financial contributions, and thus creation of new pressures on the local population
	Increased management costs due to increasing number of visits
	Increased conservation and restoration costs due to the increasing number of visits
Social pressures	Forbidden access to a certain area
	Construction of buildings on market principles without use of traditional architecture principles and thus loss of the area's authenticity
	Loss of the local population's ability to participate in decision making
	Forceful introduction of foreign cultures and customs
	Full occupancy of beaches and parking lots

Figure 4: Bad parking example from the summer season (photo: Alenka Popič)
Slika 4: Primer parkiranja v poletni sezoni (foto: Alenka Popič)

6. RECOMMENDATIONS FOR SUSTAINABLE TOURIST DEVELOPMENT IN STRUNJAN LANDSCAPE PARK

During the preparation of development plan concerning tourist activities in Strunjan Landscape Park, concrete long-term objectives are recommended to be stipulated, i.e. of the kind that include a concrete delineation of conservation goals and have been accepted on the basis of debates and agreements with key partners.

Any negative impacts of tourism on traffic and infrastructure are to be reduced through arrangement of public and commercial transport to the protected area from the nearby urban centres with buses, vans and taxis. Traffic in the area can also be relieved by offering transport with boats, (re)constructing cycle tracks and pathways, and building parking lots outside or on the edge of the Park. In the Strunjan Nature Reserve, setting up of quays or bollards is recommended, as well as permanent employment of inspector at sea.

As far as visitors are concerned, we recommend implementation of the following procedures that could contribute to a smaller negative impact of the high number of visits on the natural environment and the local population:

– limitation or reallocation of seasonal visit, particularly in the central part of Strunjan Nature Reserve;

– limitation of the number of bathers and anchoring vessels in the Reserve,

– setting up of info centre in Strunjan Landscape Park,

– providing of guided tourist visits;

– setting up of gates/barriers at places where irregular parking normally occurs, as well as in sensitive/vulnerable areas where regular supervision by nature-conservationist inspectors is taking place;

– supplying more information about the Park via fliers, brochures, websites, radio and other means of promotion; and

– systematic awareness building of the local population and tourists about the significance of the Park for nature conservation and local development.

In view of the fact that some 50 environmental labels and certificates that provide for the supply of products and services in compliance with certain criteria are already known in Europe and that modern tourists increasingly appreciate quality environment in the place in which they spend their holidays, the tourist industry (hotels, camps, tourist agencies, etc.) in Strunjan Landscape Park should do more in terms of acquiring environmental labels and certificates. In this respect, several analyses and initiatives have been made in Slovenia (Terlević 2005, Buček 2007). At the Tourism Directorate within the Ministry of Economic Affairs, a manual has also been prepared for the ecological arrangement and modernisation of Slovenian hotels, whose purpose is to offer to Slovenian tourist companies information on environmental management and its introduction to business (Lebe Sibila 2006).

Considering that the protected areas are very vulnerable entities indeed, the carrying capacity of the Park for tourism should be estimated with an analysis of the key factors and for the planned extent of sustainable tourism. Such an analysis will serve as a suitable professional background for the preparation of the Park's management plan.

When preparing the plan, we recommend the tourist companies to ally with other branches of economy as well. Although the agriculture of Slovenia is currently in a tight spot, the local inhabitants should be acquainted with how agriculture can become an extra source of income. Within Strunjan Landscape Park, several farmers can be found, but no tourist or ecological farms, although the trend of spending holidays in a natural environment is rising rapidly. The future tourist managers and/or planners should stimulate tourism's close association with agriculture, especially with integrated and ecological farming, as for example proposed in the same region in the Dragonja River valley (Jurinčič et Bojnec 2007) and in Karst hinterland (Bojnec et al. 2007). Olive and persimmon picking, for example, could also be introduced for tourists, or purchase of fruit and vegetables from local farmers stimulated by tourist companies. A traditional Saturday market with local produce could further be introduced, promoted by the Tourist Association Portorož among all tourists and visitors in the Piran Municipality. The same applies to the Tourist Info Centre Izola and the town's fishermen, who could participate in the functioning and promotion of the Park by organising sea journeys and fish picnics, as well as by offering the tourists a share in the fishing and purchase of freshly caught fish.

In Sečovlje Salina Nature Park, tourists are offered to gather salt and to participate at the Summer Work Camp. The same could be introduced at the Strunjan salt-pans by charging for the service, with the obtained money allocated for maintenance of the pans.

During further development of tourism in Strunjan Landscape Park, much thought should be dedicated to new tourist nature-friendly capacities, e.g. visits of distinguished geological and geomorphologic features of the Strunjan Nature Reserve with canoes and kayaks in the company of professionally trained guide, setting up of an educative trail under the leadership of a (professionally trained) guide, and guided tours for all age groups. The number of groups, however, should be limited and adapted to the carrying capacity of the vulnerable natural environment.

With the introduction of new capacities, however, education of the people employed in tourism, tourists and local inhabitants should be closely associated as well. Education and informing of the visitors as well as employees increase understanding of the protected area's values and have an impact on the attitude towards conservation measures. Well known is the case, for example, how a guest in the Talaso Strunjan hotel complex was advised by its personnel to go fishing to the Stjuža lagoon, although fishing had been strictly prohibited by the Decree on Strunjan Landscape Park.

As far as marketing of tourism in the protected area of Strunjan Landscape Park is concerned, let us underline that for the time being the Park itself is not promoted, but merely some of its separate parts within the framework of the existing tourist capacities. An integral image and brand is to be made and the Park included in the wider tourist capacities offered in the Piran Council and Southern Primorska region (Vesenjak et al. 2006) as an independent product of natural history tourism and as part of integral products of this destination. Marketing of Strunjan Landscape Park, however, is to be marketed only when the products are completed and the place fit for additional pressures, considering that certain parts are already overburdened during the high season.

7. CONCLUSIONS

Today, Strunjan Landscape Park is not only an exceptional tourist destination with its littoral and health resorts, but also a precious green oasis in the vicinity of well developed Mediterranean towns rich in culture, such as Piran, Izola and Koper, and internationally acknowledged tourist centre Portorož. Owing to its geographical position, exceptionally valuable natural features and cultural heritage, the Park has a great opportunity to develop sustainable tourism within it. On the basis of the carried out research, however, it has been established that tourism is not developing in sustainable direction, for during the summer season it is currently bringing more negative impacts owing to its surpassed carrying capacity. Prior to any tourism planning in the protected areas, the findings and recommendations for the planning of tourism in protected areas are to be implicitly taken into consideration. Every development in the protected area must be, of course, adapted to the nature conservation measures. We believe that a systematic development of sustainable tourism in combination with ecological and integrated farming is a good decision in terms of nature conservation and a successful development of Strunjan Landscape Park.

8. SUMMARY

The basic reason to carry out the research was to gain a better insight into nature conservation, system park tourism and its management. Within our work, we concluded that sustainable tourism plays a major part in the management of protected areas, as it helps to evaluate the valuable natural features as well as to educate the visitors,

In ecological and biological terms, Strunjan Landscape Park is not doubt a significant area, protected by the Governmental degree since 1990, but on the other hand it is one of the most popular tourist destinations on the Slovenian coast.The analysis of the number of visitors in Strunjan Landscape Park during the 1996-2006 period has shown major negative impacts and degradation of natural, social, cultural and economic environment.

For the future planning and management of Strunjan Landscape Park it is therefore important to reduce transportation impact on the protected area. This can be accomplished through schemes that encourage people to leave their cars near the edge or in major cities of the area and use alternative forms of transport, such as buses, bicycles or boats - or to proceed on foot. City dwellers should encourage visitors to take the whole journey by public transport. Tourist visitation can and do have negative impacts on natural resources, but can be managed with appropriate tools for visitor management.

Tourism managers should improve management and marketing with the introduction of eco labels and should link with agriculture and fishing industry in the area. Last but not least, Strunjan Landscape Park needs to organise a suitable surveillance (employ rangers) and adjust its goals to the nature protection measures.

9. LITERATURA

1. Bojnec, Š., I. Jurinčič, K. Vodeb (2007). Razvojne možnosti trajnostnega razvoja turizma na podeželskih območjih v Istri. In: Slovensko kmetijsko podeželje v Evropi, ki se širi in spreminja. 4. konferenca DAES, 8.- 9. november 2007, Moravske toplice. Društvo agrarnih ekonomistov Slovenije. Ljubljana. p. 10
2. Buček, M. (2007). Uvajanje znaka okolje v planinske koče v Sloveniji. Turistica. Portorož. 85 pp.
3. Jurinčič, I. (2003). Načrtovanje in nadzor turističnega obiska v zavarovanih območjih s pomočjo analize nosilne zmogljivosti. In: Gosar A. (ur.) Zavarovana območja in njihov pomen za turizem. Univerza na Primorskem. Koper. 85 pp.

4. Jurinčič, I. (2005). Zmogljivost Koprskega primorja za turizem. Doktorska disertacija. Filozofska fakulteta, Oddelek za geografijo. Ljubljana. 232 pp.
5. Jurinčič, I., Š. Bojnec (2007). Natural park as a brand name : Dragonja's valley in Slovene Istra. In: Strategic development of tourism industry in the 21th century. Conference proceedings. Faculty of Tourism and Hospitality. Ohrid. 9 pp.
6. Lebe Sibila, S. (2006). Priročnik za ekološko ureditev in posodobitev slovenskih hotelov. Ministrstvo za gospodarstvo, Direktorat za turizem. Ljubljana.
7. Terlević, M. (2005). Ekološki znaki v turizmu. Turistica. Portorož. 65 pp.
8. Trampuš, T. (2002). Turizem v Sečoveljskih solinah. Trajnostna raba prostora. Zavod RS za varstvo narave. Piran. 16-18.
9. Uran, M., R. Ovsenik, M. Ovsenik, J. Jerman, D. Radić, M. Tkalčič, Z. Batagelj (2006). Razvojni načrt in usmeritve slovenskega turizma 2007-2011. Ministrstvo za gospodarstvo. Ljubljana. 175 pp. http://www.mg.gov.si/si/delovna_podrocja/turizem/ (21. Aug. 2007)
10. Uredba o Krajinskem parku Strunjan. Ur.l. RS 107/2004
11. Vesenjak, P., A. Alič, B. Omersel Weeks, A. Rakovec, I. Jurinčič, M. Novak, M. Komel, T. Pilih (2006). Regionalna strategija trajnostnega razvoja turizma Južne Primorske 2006-2012. Regionalni razvojni center. Koper. 92 pp.
12. Zakon o ohranjanju narave. Ur.l. RS 96/2004-UPB2
13. Statistični urad Republike Slovenije - SURS (2007). Nastanitvena statistika po vrstah turističnih krajev. http://www.stat.si (14. Nov. 2007)
14. World Tourism Organization – WTO. (2004). Indicators of sustainable development for tourism destinations: a guide book. Madrid. 507 pp.

Igor JURINČIČ
Faculty of Tourism Studies - Turistica Portorož
Obala 11a
SI- 6320 Portorož
igor.jurincic@turistica.si

Alenka POPIČ
Institute of the Republic of Slovenia for Nature Conservation
Regional Unit Piran
Tartinijev trg 12
SI- 6330 Piran
alenkapopic@gmail.com