Basis for a valuation of the Polish Exclusive Economic Zone of the Baltic Sea: Rationale and quest for tools*

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Abstract

This paper summarises current knowledge of goods and services in the Polish Exclusive Economic Zone of the Baltic Sea ecosystem. It reviews specific properties of the Baltic that could be used for economic valuation. Goods and services range from the familiar resources of fish and minerals, which were valued with the Productivity Method, to less obvious services provided by the ecosystem such as biofiltration in coastal sands, valued with either the Replacement Cost or Damage Cost Avoided methods. Disservices to the marine ecosystem are also considered, e.g. erosion and coastal flooding, including the costs of planned mitigating measures. This paper emphasises the importance of using valuation methods to help make better-educated decisions for the sustainability of the Baltic Sea.

1. Introduction

1.1. Ecosystem goods and services

The environmental economics literature started out in the USA in the 1980s, when it tackled problems of travel cost and contingency valuation. In Europe, Pearce & Turner (1990) published a major textbook on ecological economy; this spawned a number of other papers, and a whole series of new journals (e.g. *Environmetrics*, *Ecological Economics*, *Land Economics*). The economic approach to environmental research developed rapidly in the wake of the paper by Costanza et al. (1997), which assessed the value of goods and services provided by the global ecosystem. The last four years have seen the publication of over two hundred peer-reviewed papers dealing with the goods and services provided by ecosystems.

We can classify natural services as those provided by the physical environment (e.g. solar energy, wind power, wave energy) or as biologically mediated ecosystem functions. Some of the latter, which are natural manifestations of interactions between organisms and the environment or amongst the organisms themselves, might also fit into the 'service' category. As such, we can construe ecosystem services as those that benefit humans directly or indirectly. Criticism of environmental economics calculations often stems from the conflicting values of economic growth, economic development, and the neoclassical theory of economics (Czech 2002). Wilfred Beckerman's *Small Is Stupid: Blowing the Whistle on the Greens* (1995) and Bjorn Lomborg's *Sceptical Environmentalist* (2001) expressed a hearty scepticism regarding the approaches of environmentalists and ecologists to economics. In contrast, the responses to them came in the form of the methodologically more rigorous analyses of Chen & Zhang (2000), Bockstael et al. (2000), Faber et al. (2002), and Balmford et al. (2002), who emphasised the true economic reasons for nature conservation. Modellers, e.g. Odum (1996) and Hau & Bakshi (2004), developed the concept of 'emergy' – the cumulative amount of solar energy used to create a service or a product – as a universal unit for calculating environmental and economic costs.

1.2. Socio-economic valuation of nature

In another paper, Costanza (1999) considered the marine environment to be an object of economic valuation in which the oceans contributed 60% to the overall value of the whole biosphere (op. cit). The routine method applied to the non-market value of public goods (including environmental ones) is a stated-preference survey: public awareness is assessed through questions regarding the willingness to pay or to accept. This is known collectively as the Contingent Valuation Method (CV) (Table 1). However, this method is also highly controversial, based as it is on hypothetical situations set before respondents, whose actual behaviour may differ from their declared responses. As far as the valuation of marine services is concerned, only commercial and industrial exploiters of the sea (e.g. seabed miners, fishermen) and scientists express definite opinions. There is no public to lend support, because it has no direct contact: everybody can admire the beauty of a scenic forest or a landscape, but underwater seascapes are hidden from most of us and are not emotionally linked to our culture. On the other hand, though its knowledge and experience of

Table 1. Methods for the valuation of goods and services, modified from http://www.casavaria.com/

Valuation method	Principle
Productivity Method (PM)	The value of the goods produced in a market (e.g. the value of the water that helped to produce a crop)
Hedonic Pricing Method (HPM)	Phenomena that directly affect market prices (e.g. the price of housing in a beautiful area). Valuation of an attribute of a good traded, such as real estate.
Travel Cost Method (TCM)	Consumer surplus of a recreational site based on preferences revealed through travel costs to the site
Damage Cost Avoided (DCA)	Damage valued using the change in production method, but linked to measures through a biophysical damage function.
Substitute (Replacement) Cost Method (SCM), Mitigation Cost Method, Preventive Expenditure	The cost of preventing damage, partial mitigation of damages or cost of replacing a lost ecosystem service (e.g. costs of artificial pollination to replace the lack of insects)
Contingent Valuation Method (CVM), Choice Experiments, and other Stated Preference Methods	How much are people willing to pay for a specific ecosystem service?
Emergy method (n.b. this method is not based on stated or revealed preferences)	How much solar energy was used to provide a product?

marine life may be limited, public opinion supports endangered marine species (e.g. turtles and charismatic mammals) and habitats (primarily coral reefs). Public concern *is* important in valuing ecosystem services, since it has played a major role in shaping the environmental policy of the past thirty years (e.g. Rachel Carson's *Silent Spring* on the impact of organochlorine use – Czech 2002). The improvement in environmental standards for drinking water, air, and green areas is widely recognised. The high EU standards required of sea waters for recreational use are also supported by public campaigns like Blue Flag (http://www.blueflag.com/).

1.3. Biological valuation of nature

This kind of valuation (sometimes called validation or assessment) does not consider the market value of an entity; rather, it identifies its relevance and meaning. It focuses on nature conservation, and values the rarity, uniqueness or richness of biodiversity (Derous & Degraer, unpublished). The main rationale for biological valuation (for its methodology – see Roberts et al. 2003) – is the process of designating Marine Protected Areas (MPA) and the management of marine resources (Boersma & Parrish 1999). The approach to biological valuation is the so-called Delphic judgment, when an expert panel is consulted for competent information.

1.4. Aim of the present study

The area under consideration is the Polish Exclusive Economic Zone (EEZ). This consists of the shallow part of the southern Baltic and is equivalent to c. 10% of the terrestrial area of Poland (Fig. 1). It extends along some 500 km of nearly straight, sandy coastline, with sand and gravel prevailing in the extensive shallows, and anoxic muddy sediments in local depressions that reach depths of only 100 m (e.g. the Gdańsk Deep). The Baltic Sea is a brackish-water (7 PSU above and 9–12 PSU below the halocline in the Polish part), non-tidal, semi-enclosed sea that has retained some features of a very large fjord, i.e. a shallow sill at its entrance and deep inner basins (see Łomniewski et al. (1975) for a review of the properties of the southern Baltic Sea). The only previous attempt to value the Polish coastline was undertaken in 1990–92 by an interdisciplinary team led by the late Professor Ryszard Zeidler (Zeidler 1992). They did not, however, take natural physical and biological processes into consideration; the only methods they applied were Damage Cost Avoided and Property Valuation. In a paper on the effects of tourism on the sandy coastline, Węsławski et al. (2000) did present some data on one particular sector of the coast, the sandy beaches. Earlier, the pooled knowledge of marine scientists (HELCOM 1998) had been the basis for selecting and designating proposed Marine Protected Areas (MPA) in the Polish EEZ, albeit without the application of current biological valuation methodology.

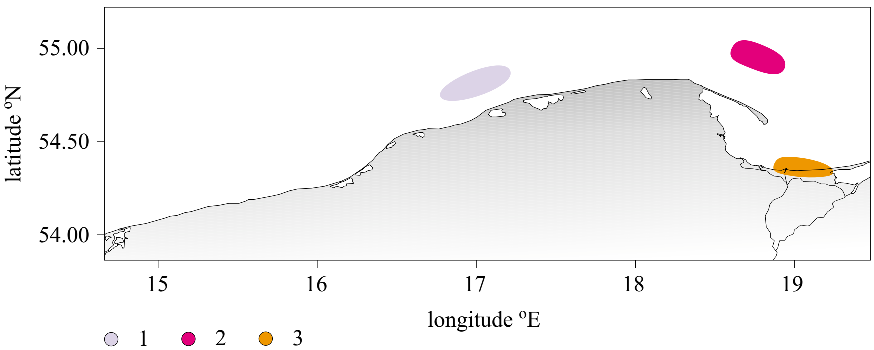

Fig. 1. Distribution of mineral resources in the Polish EEZ. 1 – gravel, 2 – oil and gas, 3 – amber

The aim of the present paper is therefore:

- To review existing data on goods and services provided by the southern Baltic Sea and to propose appropriate methodology for their valuation;
- To review the biological value of southern Baltic Sea;
- To identify gaps in our knowledge that need to be addressed for the sustainable management of the Polish EEZ.

Economic valuation is useful as a guide to decision making, e.g., in evaluating alternative uses of society's resources. In support of this, we intend to sort ecosystem services that could be affected by policy decisions from those that are 'non-human mediated'.

2. Material and methods

The present study is a compilation of information and data published in various sources, including reports and the so-called grey literature. Many ideas were originally formulated during discussions the authors participated in at workshops organised under the auspices of the Centre of Excellence of Shelf Seas Studies at IO PAS (www.iopan.pl/CESSS), the Centre of Excellence for Baltic Development, Education and Research (BALTDER) at IO UG (http://www.ocean.univ.gda.pl/baltder), the Consortium of Polish Marine Research Institutes (http://www.univ.gda.pl/io/MAREI), the ESF Euroconference of Integrated Coastal Zone Management (ESF 2002), IBOY-DIVERSITAS meetings of the SCOPE Committee (http://www.colorado.edu/), and the MARBEF NoE meetings in Crete 2004 and Porto 2005.

Table 1 lists the ecosystem valuation methods, and each example presented below explains their use. In accordance with the Millennium Assessment group (www.millenniumassessment.org), we have divided ecosystem goods and services into the categories of Provisioning (direct products), Regulatory (processes), and Enrichment (educational, cultural, and spiritual values). Where appropriate, we have indicated these categories in the text.

We have adopted the biological valuation methods from Derous & Degraer (unpubl.), a review paper that includes recommendations from a workshop at Gent University held in December 2004. The key ecological criteria we have adopted for the biological valuation of the Baltic Sea include habitat diversity and irreplaceability, and the integrity and naturalness of the ecosystem.

3. Results and discussion

3.1. Goods of the Polish EEZ marine ecosystem

Examples of provisioning goods (Table 2) show the market value of raw materials as the main method of valuation (Productivity Valuation Method). Most of the required data regarding mineral resources are available from the Polish State Geological Institute, and there is currently a market for such goods. The exact value of amber exploitation is not known and remains largely in the grey zone of the economy; nevertheless, if we take the Polish amber market with its 20 000 jobs into account, a conservative estimate would be in the region of 20 million euros. Brackish water is not currently a concern, although it is a potentially valuable resource for coastal aquaculture.

3.2. Space resources

This is a specific category of goods provided by the EEZ. In a developing economy, the demand for useable seabed space increasingly leads to conflicts. Cables, pipelines and fixed installations by definition clash with sediment extraction, fisheries and military testing sites. On the other hand, recreation and tourism call for the relevant amenities to be located at a distance from industrial users. And last but not least, areas designated for natural protection require undisturbed space. Very likely, then, different users will compare the value of a given marine space with that of an equivalent land area, for example: How much does the military customarily pay to use one hectare of land for manoeuvres? Another way of managing this problem is to turn to free market competition for seabed prices: Who is willing to pay more? This is therefore an analysis of opportunity costs to alternative users. Such data are not available, but they can be produced (Table 2).

3.3. Biological resources

Fish, shellfish, seaweed, seabirds, and sea mammals are all categorised as marine biological goods. In the Polish EEZ, commercial fishing fleets target mainly cod, sprat, herring, flatfish, and salmon: declared landings total around 60 million euros. The inshore fishery focuses on salmon and flatfish and is worth c. 10 million euros annually. Offshore angling is developing rapidly, but no data is available on the value of its landings (50 000 visitors in 2004). Resources of other species, such as the brown shrimp (*Crangon crangon*), are not exploitable because of the small body size of Baltic specimens and the dangerous implications of the by-catch mortality of juvenile flatfish and gobiids. Also of importance, but not quantified, are the catches of sand eel (*Ammodytes tobianus*) and brown shrimp as bait

Table 2. Goods provided by the Polish EEZ in the Baltic Sea; for the abbreviations of the valuation methods, see Table 1

Category of goods	Examples	Human impact	Valuation method	Estimated value	Remarks
mineral resources					
	brackish water resources	moderate	PM	???	valuation possible after aquaculture development
	gravel and Sand	high	PM	1 million euro/year	
	grude oil	high	PM	75 million euro/year	
	amber	high	PM	20 million euro/year	
biological resources					
	commercial fishery	high	PM	60 million euro/year	
	bait fishing	high	SCM	???	
	sea-angling	high	CVM	???	
	underwater fishing/scuba diving		???	???	
	inshore fishery	high	PM	10 million euro/year	
other					
	space for waste storage	high	HPM	???	not applicable after international conventions
	space for wind farms	high	HPM	500 million euro	
	space for sea transport	moderate	HPM	???	
	space for installations	high	HPM	???	
	space for recreation	high	HPM	???	
	space for defence	high	HPM	???	compare to costs of land use by the military
	space for nature protection	high	HPM	???	

for longline fisheries. The exploitation of brown algae (*Furcillaria fastigiata* and *Fucus vesiculosus*) and seagrass (*Zostera marina*) came to an end in the mid-twentieth century and will not be resumed for lack of resources but also for conservation purposes. Experiments with trout, Siberian sturgeon, perch, flatfish, and brackish-water exotic shrimp aquaculture are unlikely to move into the commercial phase as their economic potential is low and their consequences have raised considerable environmental concern, especially with respect to non-native taxa. Since most of the marine ecosystem goods are site-specific, there is an urgent need to create up-to-date Geographic Information System (GIS) maps of all the resources listed in Table 2.

3.4. Services of the Polish EEZ marine ecosystem

3.4.1. Gas and climate regulation

Among the regulatory services listed in Table 3, CO_2 uptake and its valuation in terms of CO_2 credits is currently of interest. In 2005 the price of one tonne of CO_2 on the Hamburg stock exchange was approximately 30 euros (http://www.dnv.com/certification). Although there are sufficient data on the primary production of the area's phytoplankton and phytobenthos to calculate their contribution to oxygen production, the amount of organic carbon transported from the atmosphere to the seabed sediments is not known with any accuracy. The well-developed pycnocline in the deeper waters of the Baltic Sea may inhibit vertical mixing, and that portion of the primary production which sinks to greater depths is probably removed from recycling. In the Polish EEZ, the minimum, annual secondary production of seashells and other organisms, an estimated 5000 tonnes, bind organic carbon into relatively inactive $CaCO_3$ (combined information on mollusc production from Witek (1995) and the present authors' own unpublished data). Carbon budget analyses of Baltic coastal waters indicate that the system is almost in balance or slightly heterotrophic (respiration is higher than production) (Witek et al. 1999, 2001). The ecosystem function services associated with the carbon budget are largely human-mediated, since it is the nutrient excess from poor-quality freshwater discharge that drives primary production and eutrophication.

Examples of ecosystem services that are (almost) independent of human mediation are the distributions of heat and humidity. In winter, the nearshore land area is at least 2–4^{o}C warmer than its hinterland as a result of the heat stored by the sea being released during cold periods. This saves measurable amounts of energy for the public heating system, but precisely how much is not known. Emissions of marine aerosols provide the nearshore area with microelements such as iodine, which is vital to human health. The value of this service could be measured by calculating the costs of iodine

Table 3. Services provided by the Polish EEZ; for the abbreviations of valuation, see Table 1. Human impact is arbitrarily described as high – services easily impacted, moderate – resources could be impacted, low – impact does not happen, but is possible, null – impact practically impossible

Category of service	Examples	Human impact	Valuation method	Remarks
gas and climate regulation	carbon sink to pelagic primary production	low	CVM	CO_2 credits
	carbon sink to phytobenthos	low	CVM	CO_2 credits
	heat absorbance and release by the sea	null	PM	municipal heat and insulation savings
	DMS production by microplankton	low	DCA	
	carbon sink to $CaCO_3$ organic binders	low	CVM	CO_2 credits
	oxygen production by marine plants	low	CVM	
	aerosol emission from the sea	null	CVM	microelement supply, as compared to a mountain area
disturbance regulation	elimination of harmful elements from water by biofilters	high		
	eutrophication control by biofilters	high		
	oil spill degradation by microbial processes	low	SCM	the value of the labour force and technology used for oil spill combat in place without the natural services (e.g. artificial water reservoir, field etc)
	oil spill degradation by waves and wind	null	SCM	
erosion and sediment control	storm surge control by sandbanks	moderate	DCA	
	micro-algae mats & TEP production	low	DCA	cost of artificial beach nourishment
	macrophytobenthos cover	high	DCA	

Table 3. (*continued*)

Category of service	Examples	Human impact	Valuation method	Remarks
	macro-organism cover (shell beds)	high	DCA	
	free sand deposits	high	DCA	
remineralisation	denitrification by microbes	low	SCM	cost of technological waste treatment
	biological filtration by micro-organisms in sands	moderate	SCM	
	biological filtration by macro-organisms	moderate	SCM	
	bioturbation	high	SCM	
renewable resources	wind power	null	PM	quota of investment
	wave energy	null	PM	price difference compared to air and ground transport, plus associated job market
	solar energy	null	PM	
provision of biological resources	bio-products for the pharmaceutical and cosmetics industries			
	nursery grounds value	high	SCM	cost of artificial farming
	food web control by top predators	high	SCM	
monitoring the state of the ecosystem	bioindicators and 'early warning system' biomarkers	moderate	SCM	cost difference between chemical and biological monitoring
recreation and tourism	yachting	high	TCM	travel cost method
	windsurfing	high	TCM	contingent valuation method
	beach recreation	high	TCM	travel cost method

Table 3. (*continued*)

Category of service	Examples	Human impact	Valuation method	Remarks
	SCUBA diving	high	TCM	travel cost method
	ethno- and eco-tourism	high	TCM	hedonic pricing method
culture, education & science	local ethnographic products linked with the sea	high	CVM	productivity method
	school programmes	high	CVM	amount of funds offered for courses
	university courses	high	CVM	amount of funds offered for courses
	research projects	high	CVM	value of grants obtained for Polish EEZ studies
	group ethos among seamen	high	CVM	
	popular scientific products in the media	high	CVM	value of production and distribution costs
	increase in international contacts & tolerance	high	CVM	conflict reduction
	nature reserves	high	CVM	

supplements distributed in mountain areas, where this element is deficient (the relevant data are available). The masses of moist air that build up over the sea provide the coastal zone with more annual precipitation than inland areas, which saves an equivalent amount of water in agriculture and horticulture.

3.4.2. Disturbance regulation, erosion, and sediment control

Among the costly disturbances that occur in the marine environment, oil spills catch the public's attention most frequently. The natural potential for processing oil spills, which is discussed in the literature (e.g. Krebs & Bums 1977, MacLachlan & Harty 1981, Vandermeulen 1982), and physical forcing (wave action, solar radiation, wind, and desiccation) are the main factors responsible for weathering, coagulating and concentrating spilled oil (Johnson 1970). Microbial potential, specifically the direct scavenging of microbes on hydrocarbons, is under investigation, as is the role of diatoms as adherents to oil particles. Shore erosion is controlled most efficiently by natural dune vegetation (most often planted). Less is known about the role of biogenic particles (TEP and EPS – mainly polysaccharides), which are excreted as mucous substances binding sediment particles together, thereby inhibiting their mobility. Microphytobenthic diatoms, numerous bacteria, and a number of meiofaunal organisms are known to excrete EPS, but the scale of this phenomenon in the Baltic Sea is unknown. Filtration by micro- and macroorganisms are regulatory services, since they reduce the numbers of suspended particles, increase water transparency, and consequently, lead to the biological processing of various chemical compounds in suspension. The capacity of bivalves to remove suspensions has been estimated in a number of studies of the Baltic Sea. Orlova et al. (2004), for example, reported that the zebra mussels inhabiting the Neva Estuary filtered 3000 tonnes of POC from the suspended matter per season. The increasing eutrophication of the coastal waters of the Polish EEZ has caused populations of filtering organisms to expand; bivalves now occur at greater depths than previously (Wołowicz et al. 2006). Bioturbation, the process by which organically rich surface sediments are moved into deeper layers, is a service provided mainly by macrofauna – notably polychaete worms, priapulids and bivalves. Although the scale of this process in the Polish EEZ is not known, it can be assessed by analysis of the occurrence and abundance of macrofauna species. Preliminary experiments have been carried out on polychaetes and crustaceans (Geringer d'Odenberg 2000, Kotwicki et al. 2005). Among the services provided in the field of disturbance control, filtration and bioturbation are the most vulnerable to anthropogenic impact, since they depend entirely on the presence and condition of particular species.

3.4.3. Provision of renewable energy

These types of services, which include wind, waves and solar radiation, are the least dependent on human activity; industrial emissions, however, may influence cloud formation and alter the level of insolation on a local scale. In the Polish EEZ and local municipalities, wind force and frequency is of importance for wind farms, since the exploitation of solar and wave energy is not a practical proposition for the foreseeable future. Wind power remains an important renewable energy source, and, with an estimated 500 million euros earmarked for investment, interest is very high in constructing wind farms along the Polish coast.

3.4.4. Provision of biological resources

These services are delivered by the structural species (macrophytes, underwater meadows, mussel beds) that create microhabitats and biotic conditions for the development of juvenile fish. The exception is cod spawning, where the limiting factors – temperature, salinity and oxygen – are purely physical; the biological components of the spawning area are of secondary importance. The variable diets and diversified feeding strategies of the top predators (large cod, pike, pike-perch, salmon, cormorants, gulls, sea eagles, seals, porpoises) keep the ecosystem in balance by controlling medium-sized, fast-breeding fish species. This contrasts with the very selective and extensive predation by humans that targets the largest fish (Fig. 2). These processes are highly dependent on and vulnerable to human activities; they are also relatively well understood (e.g. atlas of spawning

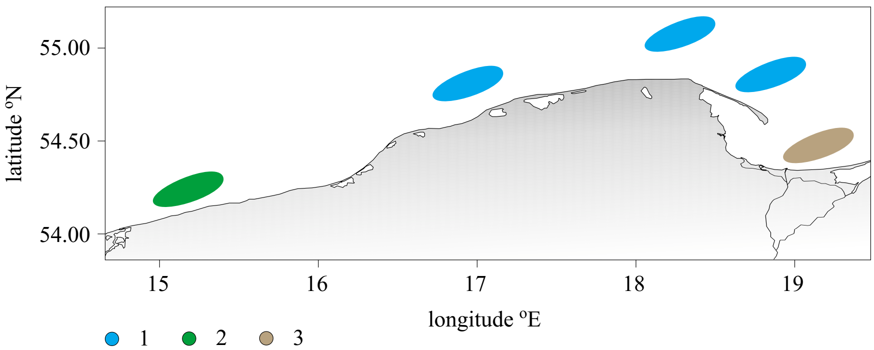

Fig. 2. The location of the main fishing grounds in the Polish EEZ. 1 – cod, 2 – herring, 3 – salmon

grounds in the Polish EEZ, extensive studies of top predator diets (Witek 1995, Jackowski 2002)).

3.4.5. Remineralisation and nutrient control

In the 1990s, from 55 000 to 148 000 tonnes of nitrogen and from 5000 to 9000 tonnes of phosphorus entered the Gulf of Gdańsk from the River Vistula each year. During the same period, from 39 000 to 99 000 tonnes of nitrogen and from 4000 to 7000 tonnes of phosphorus were carried into the Szczecin Lagoon and Pomeranian Bay by the River Oder (IMGW 1991 –2000). Taken together, these two estuaries receive about a quarter of all the riverine nitrogen and about a third of the total phosphorus input to the Baltic Sea (HELCOM 1989, 1998). Nutrient budgets, calculated with the LOICZ methodology (Gordon et al. 1996), have shown that, in the Gulf of Gdańsk, 23% of the nitrogen load and 34% of the phosphorus load were retained in the system and only 77% of the nitrogen and 66% of the phosphorus loads reached the open sea (Witek et al. 2003). The estimated retention in the Oder Estuary was at a similar level: the coastal system retained about 25% each of the nitrogen and phosphorus loads (Grelowski et al. 2000, Pastuszak et al. 2002). According to these calculations, all of the retained phosphorus and a small part of the retained nitrogen were buried in the bottom sediments, while the majority of the retained nitrogen ($> 70\%$ in the Gulf of Gdańsk and $> 90\%$ in the Oder Estuary) was denitrified and thus ultimately removed from the ecosystem (Table 3). On the other hand, nutrient retention in sediments, here regarded as a service, may sometimes lead to harmful algal blooms in coastal waters, which turns it into a disservice.

3.4.6. Monitoring ecosystem health, indicators, markers, the development of new technologies, etc.

A number of Baltic species could be used as early warning systems or environmental quality control organisms with regard to chemical contamination, mutagens and pathogens that are difficult to trace chemically in the sea (Rainbow et al. 2004, Rzeźnik-Orignac 2004, Sokołowski et al. 2004, Smolarz et al. in press, Wołowicz et al. 2006).

A number of marine organisms are prospective biotechnological targets for medical and pharmacological needs, since strong selection towards survival in cold and brackish waters may have produced unique genetic forms in the Baltic.

3.4.7. Recreation and tourism

Some eight million tourists visit the sandy beaches of the Polish coastline every year (Węsławski et al. 2000). This tourism supports the local economy in areas such as catering, accommodation and amenities. Developing rapidly in Poland, underwater tourism is centred on the readily accessible shipwrecks and stony reefs in the Gulf of Gdańsk. All forms of recreation and tourism are limited by the state of the environment, since no recreational activity is permitted in polluted areas (e.g. poor bathing water quality).

3.4.8. Culture, education, science – improving (enriching) services

Poland has only two public educational facilities for the marine sciences – the Gdynia Aquarium and the Marine Station in Hel – which respectively received 500 000 and 300 000 visitors in 2004. This, combined with popular documentaries about the sea on both Polish and foreign TV channels (TVP1 and TVP2 – Polish State Television; Discovery, National Geographic), shows that there is a great thirst among the public for marine knowledge. If we add to the above figures the number of visitors to the coastal Słowiński National Park (over 300 000 per annum), we have a number that exceeds the overall annual attendance at Polish league football matches (reportedly 700 000 in 2004). Even so, in the popular mind, it is football – the Polish 'national' sport – not environmental conservation that has a powerful political lobby. The aesthetic values of the marine coastline influence its cultural landscape. The attractive environment and easy communication among the people who live near or visit harbours and their vicinities are key factors in the formation of a multicultural society, in which various ethnic and racial groups can find niches for themselves. Thus, in contrast to the situation in other parts of Poland, multiculturalism could be perceived as a feature common to coastal communities. Multiculturalism is always founded on the open-mindedness of their people towards other cultures (Bouchet 1995, Joordens 1999).

In present-day Poland there are few ethnic groups identifying themselves with the sea. One group of the Kashubian people is linked with the Puck Bay area, their traditional fishing grounds, where the inhabitants of a few villages in the area still identify themselves strongly with the traditional way of life (Kuklik 2005).

The marine environment of the Polish EEZ provides employment for an estimated 160 000 inhabitants (Table 4), and the majority of these jobs (70%) are dependent on the healthy state of the marine ecosystem. A degraded marine ecosystem will only support employment connected with more traditional industries (shipyards, shipping), whereas the rapidly growing tourist and service sectors are heavily dependent on environmental

Table 4. Jobs in Poland directly related to the sea

Type of job directly linked to the sea	Estimated number of employees	Dependence on the health of the marine ecosystem	Dependence on marine resources
merchant seaman	10000	no	no
salvage seaman, coastguard	1000	no	no
deep-sea fishery	2500	high	very high
inshore fishery	1000	high	very high
amber industry	20000	no	very high
shipyard worker	15000	no	no
coastal tourist services	80000	very high	moderate
sea fish processing	10000	high	high
coastal protection & inspection	1000	low	no
maritime education & research	1000	low	moderate
shipment of cargo & services	2000	low	no
construction & maintenance of wind farms	???	low	no
seabed mining	1000	low	very high
harbour workers	10000	low	no
yachting and other sea sports services	1000	high	no
state border defence and Navy	5000	low	no
Total	160500		

well-being. Unfortunately, marine professionals in Poland do not have much political clout (Table 5), unlike their counterparts in the traditional seafaring nations of the EU like the United Kingdom, Ireland, Portugal or Greece.

Table 5. Values and connotations linked with jobs directly dependent on ecosystems in Poland

Ecosystem	Typical job	Values associated	Negative connotations	Political importance
forest	forester	relaxed, 'natural' job	none?	medium
fields	farmer	hard work with economic risk	primitive, difficult life	very high
lakes and rivers	inland fisherman	relaxed, poor, not exposed	not appealing	negligible
sea	seaman, sea fisherman	independent, manly, profitable	family problems	low
sea shore	tourist service	opportunity to meet lots of people	as with any service job	low

3.5. Biological valuation

Biological valuation emphasises the uniqueness and conservational value of selected areas (habitats, species). Among the proposed Marine Protected Areas in the Polish EEZ (Fig. 3) is the Słupsk Bank (Ławica Słupska), a unique stony outcrop rich in marine life, which is located in an otherwise uniformly flat, sandy area. The NATURA 2000 area in Puck Bay is located in the only marine bay in the Polish EEZ, which contains most of the Polish coastal species and habitats (including the endemic bivalve – *Parvicardium hauniense*, and threatened species like the red alga *Furcellaria fastigiata*), and is an important area for wintering seabirds (www.iopan.gda.pl/projects/puckbay).

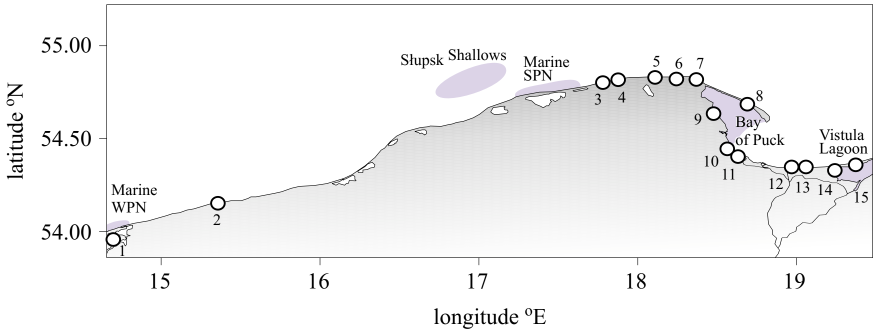

Fig. 3. Planned Marine Protected Areas and Natura 2000 sites in the Polish EEZ. 1 – Woliński National Park (MWP), 2 – Liwia Luza bird reserve, 3 – Słowiński National Park (SPN), 4 – Mierzeja Sarbska, 5 – Białogóra nature reserve, 6 – Widowo nature reserve, 7 – Cape Rozewie nature reserve, 8 – Nadmorski Landscape Park, 9 – Beka bird reserve, 10 – Redłowo botanical reserve, 11 – Tri-City Landscape Park, 12 – Ptasi Raj bird reserve, 13 – Mewia Łacha bird reserve, 14 – Kąty Rybackie bird reserve, 15 – Mierzeje Wiślana Landscape Park

3.6. Disservices generated by marine ecosystem within the Polish EEZ

Problems in marine areas are caused both by natural events and by human-mediated processes (Table 6). The most significant natural processes are sea level rise, storms (and the consequent inundations of coastal land), erosion, eutrophication and toxic blooms. The last-mentioned are likely to be human-induced on a local scale, whereas the others are large-scale climatic phenomena. Long-term Sea Level Rise (SLR) scenarios predict that the Mean Sea Level (MSL) will increase by 30 cm (ASLR1) to 100 cm (ASLR2) in 2100 (Zeidler 1992). This means that when storm surges of

1.5 m are added, the SLR impact zone will extend up to +2.5 m above the current sea level. In practical terms, this means that about 150 000 people will have to be relocated and a further 50 000 will be adversely affected. The measures under discussion are Full Protection (FP) and retreat. The most spectacular gains resulting from the implementation of FP are expected in the areas most likely to be affected by floods: the cost of FP is 2 billion euros, whereas the value loss at risk in the case of retreat is estimated at 7.5 billion euros. The costs of natural disaster prevention are negotiable, since coastal defence need not be taken literally; according to Helcom Recommendation 158, natural coastal processes will not be disturbed. Some of the ecosystem disservices are at least partly human-mediated or induced (CO_2 emissions as a result of the greenhouse effect, sea level rise – see the web page of the Intergovernmental Panel on Climate Change – http://www.ipcc.ch/).

Table 6. Disservices caused by the marine ecosystem to the Polish EEZ

Disservice of the EEZ ecosystem	Problem caused	Evaluation method	Estimated monetary value
sea level rise	permanent loss of land	damage costs avoided (full protection cost)	1 billion euros (Pruszak 2003)
storms and sea floods	temporary loss of land, destruction of facilities	damage costs avoided	???
erosion and abrasion	permanent loss of land	damage costs avoided (present protection costs)	???
toxic blooms	temporary drop in water quality	costs incurred by tourists staying away; fish mortality	???
eutrophication	Loss of marine ecosystem quality		
pollution	Loss of marine ecosystem quality		
pathology, parasites, diseases	Mortality, food web disruption, drop in food health		
salt wedge intrusions into groundwater	drop in drinking water quality	damage costs avoided	???

4. Conclusions

- Much information on the Polish EEZ still needs to be gathered, since most of the potential environmental values have yet to be estimated.
- Better communication between the natural and social sciences is urgently needed, especially in the light of new methodologies for environmental economics that are emerging in the EU.

- Openness, participation, competence and transparency should be guiding principles in the decision-making process regarding environmental issues.
- The lack of jurisdiction for MPA in Poland is the most serious threat to integrated coastal zone management and to meeting EU directives.
- An economic analysis of MPA establishment should be the focus of future environmental programmes in the Polish EEZ.

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References

Balmford A. at al., 2002, *Economic reasons for conserving Wild Nature*, Science, 297 (5583), 950–953.

Beckermann W., 1995, *Small is stupid: blowing the whistle on the greens*, Duckworth, London, 225 pp.

Bockstael N. E., Freeman A. M., Kopp R. J., Portney P. R., Smith V. K., 2000 *On measuring economic values for nature*, Environ. Sci. & Technol., 34 (8), 1384 –1389.

Boersma P. D., Parrish J. K., 1999, *Limiting abuse: marine protected areas, a limited solution*, Ecol. Econ., 31 (2), 287–304.

Bouchet D., 1995, *Ambiguity in intercultural communication*, [in:] *Cultural dimension in international marketing*, Odense Univ., Odensy.

Chen Z. X., Zhang X. S., 2000, *Value of ecosystem services in China*, Chinese Sci. Bull., 45 (1), 17–22.

Costanza R., 1999, *The ecological, economic and social importance of the oceans*, Ecol. Econ., 31 (2), 199–213.

Costanza R., d'Arge R., de Groot R., Farber S., Grasso M., Hannon B., Limburg K., Naeem S., O'Neill R. V., Paruelo J., Raskin R. G., Sutton P., van den Belt M., 1997, *The value of the world's ecosystem services and natural capital*, Nature, 387 (6630), 253–260.

Czech B., 2002, *The imperative of macroeconomics for ecologists*, BioScience, 52 (11), 964–966.

Derous S., Degraer S., *Biological valuation: Towards a scientifically acceptable and widely applicable valuation strategy in the marine environment*, (unpubl.). [Unpublished materials from the Gent workshop on biological valuation, December 2004.]

ESF, 2002, *Integrating marine science in Europe*, ESF Marine Board Position Paper 5, Strasbourg, 148 pp.

Farber S. C., Costanza R., Wilson M. A., 2002, *Economic and ecological concepts for valuing ecosystem services*, Ecol. Econ., 41 (3), 375–392.

Geringer d'Oedenberg M., 2000, *Rola makrofauny bentosowej w strumieniach tlenu i azotu nieorganicznego między osadem a wodą przydenną w przybrzeżnej strefie Zatoki Puckiej*, Ph. D. dissertation, Inst. Oceanogr., Univ. Gdańsk, Gdynia, 170 pp.

Gordon D. C., Boudreau P. R., Mann K. H., Ong J.-E, Silvert W. L., Smith S. V., Wattayakom G., Wulff F., Yanagi T., 1996, *LOICZ biogeochemical modeling guidelines*, LOICZ Rep. & Stud., 5, 1–96.

Grelowski A., Pastuszak M., Sitek S., Witek Z., 2000, *Budget calculations of nitrogen, phosphorus and* BOD_5 *passing through the Oder estuary*, J. Marine Syst., 25 (3)–(4), 221–237.

Hau J. L., Bakshi B. R., 2004, *Promise and problems of emergy analysis*, Ecol. Model., 178 (1)–(2), 215–225.

HELCOM, 1989, *Deposition of airborne pollutants to the Baltic Sea area. 1983 –1985 and 1986*, Baltic Sea Environ. Proc., 32, 58 pp.

HELCOM, 1998, *Red list of marine and coastal biotope complexes of the Baltic Sea, Belt Sea and Kattegat*, Baltic Sea Environ. Proc., 75, 115 pp.

IMGW, 1991–2000, *Environmental conditions in the Polish zone of the southern Baltic Sea during 1990–1999*, Oddz. Mor. Inst. Meteorol. Gosp. Wod., Gdynia, (yearbooks, in Polish with English summary).

Jackowski E., 2002, *Ryby Zatoki Puckiej*, Wyd. Mor. Inst. Ryb., Gdynia, 108 pp.

Johnson R., 1970, *The decomposition of crude oil in sand columns*, J. Mar. Biol. Ass. UK., 50, 925—937.

Joordens J., 1999, *Coastal management research: A personal reflection on the conference outcome*, J. Coastal Conserv., 5 (2), 181–186.

Kotwicki L., Huttel M., Cook P., 2005, *Macrofauna as bioturbators in shallow sandy sediments in Baltic*, http://www.iopan.gda.pl/rbdo/mekodb/litus/

Krebs C. T., Bums K. A., 1977, *Long-term effects of an oil spill on populations of the salt marsh crab Ucapugnax*, Science, 197 (4302), 484–487.

Kuklik M., 2005, *Kaszubska tradycja*, p. 70, [in:] *Plaża. Przewodnik użytkownika*, J. M. Węsławski, M. Szymelfenig & J. Urbański (eds.), CESSS–IO PAN, Sopot, 112 pp.

Lomborg B., 2001, *The sceptical environmentalist*, Cambridge Univ. Press, Cambridge, 500 pp.

Łomniewski K., Mańkowski W., Zaleski J., 1975, *Morze Bałtyckie*, PWN, Warszawa, 507 pp.

MacLachlan A., Harty B., 1981, *Effects of oil on water filtration by exposed sandy beaches*, Mar. Pollut. Bull., 12, 374–378.

Odum H. T., 1996, *Environmental accounting: EMERGY and environmental decision making*, Wiley, New York, 370 pp.

Orlova M., Golubkov S., Kalinina L., Ignatieva N., 2004, *Dreissena polymorpha (Bivalvia, Dreissenidae) in the Neva Estuary (eastern Gulf of Finland, Baltic Sea): is it a biofilter or source of pollution?*, Mar. Pollut. Bull., 49, 196–205.

Pastuszak M., Witek Z., Grelowski A., 2002, *Role of the Oder estuary in the transformation of the riverine nutrient loads*, 34 ECSA Symp. 'Estuaries and other brackish areas – pollution barriers or sources to the sea?', Gdańsk, (abstracts).

Pearce D. W., Turner R. K., 1990, *Economics of natural resources and the environment*, John Hopkins Univ. Press, Baltimore, MD, 373 pp.

Pruszak Z., 2003, *Akweny morskie. Zarys procesów fizycznych i inżynierii środowiska*, IBW PAN, Gdańsk, 272 pp.

Rainbow P. S., Fiałkowski W., Sokołowski A., Smith B. D., Wołowicz M., 2004, *Geographical and seasonal variation of trace metal bioavailabilities in the Gulf of Gdańsk, Baltic Sea, using mussels (Mytilus trossulus) and barnacles (Balanus improvisus) as biomonitors*, Mar. Biol., 144 (2), 271–286.

Roberts C. M., Branch G., Bustamante R. H., Castilla J. C., Dugan J., Halpern B. S., Lafferty K. D., Leslie H., Lubchenco J., McArdle D., Ruckelshaus M., Warner R. R., 2003, *Application of ecological criteria in selecting marine reserves and developing reserve networks*, Ecol. Appl., 13 (1), 215–228.

Rzeźnik-Orignac J., 2004, *Udział meiofauny w transferze metali ciężkich w łańcuchu troficznym w Zatoce Gdańskiej (Bałtyk) i w Zatoce Marennes-Oleron (Atlantyk)*, Ph. D. dissertation, Inst. Oceanogr., Univ. Gdańsk, Gdynia, 264 pp.

Smolarz K., Renault T., Soletchnik P., Wołowicz M., *Neoplasia detection in Macoma balthica L. (Bivalvia) from the Gulf of Gdańsk, Baltic Sea, Poland: comparison of flow cytometry, histology and chromosome analysis*, Dis. Aquat. Organ., (in press).

Sokołowski A., Wołowicz M., Hummel H., Smolarz-Górska K., Fichet D., Radenac G., Thiriot-Quievreux C., Namieśnik J., 2004, *Abnormal features of Macoma balthica (Bivalvia) in the Baltic Sea: alerting symptom of environmental changes?*, Mar. Pollut. Bull., 49 (1)–(2), 17–22.

Vandermeulen J. H., 1982, *Some conclusions regarding the long-term biological effects of some major oil spills*, Philos. T. Roy. Soc. B, 297, 335–351.

Węsławski J. M., Malinga B., Kotwicki L., Opaliński K., Szymelfenig M., Dutkowski M., 2000, *Sandy coastlines – are there conflicts between recreation and natural values?*, Oceanol. Stud., 29 (2), 5–18.

Witek Z., 1995, *Produkcja biologiczna i jej wykorzystanie w ekosystemie morskim w zachodniej części Basenu Gdańskiego*, Wyd. Mor. Inst. Ryb., Gdynia, 145 pp.

Witek Z., Drgas A., Ameryk A., Ochocki S., 2001, *Production and mineralisation of organic matter in the Pomeranian Bay*, Bull. Sea Fish. Inst., 3 (154), 49–69.

Witek Z., Humborg C., Savchuk O., Grelowski A., Łysiak-Pastuszak E., 2003, *Nitrogen and phosphorus budgets of the Gulf of Gdańsk*, Estuar. Coast. Shelf Sci., 57 (1)–(2), 239–248.

Witek Z., Ochocki S., Nakonieczny J., Podgórska B., Drgas A., 1999, *Primary production and decomposition of organic matter in the epipelagic zone of the Gulf of Gdańsk, the estuary of the Vistula*, ICES J. Mar. Sci., 56 (Suppl.), 3–14.

Wołowicz M., Sokołowski A., Salem Bawazir A., Lasota R., 2006, *Effect of eutrophication on the distribution and ecophysiology of the mussel Mytilus trossulus (Bivalvia) in the southern Baltic Sea (the Gulf of Gdańsk)*, Limnol. Oceanogr., 51 (2), 580–590.

Zeidler R., 1992, *Assessment of the vulnerability of Poland's coastal areas to sea level rise*, HTS, Gdańsk, 165 pp.