Environmental Pollution 182 (2013) 461–478

Contents lists available at ScienceDirect

Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

Review

Sources, factors, mechanisms and possible solutions to pollutants in marine ecosystems

Khan M.G. Mostofa [a,*], Cong-Qiang Liu [a], Davide Vione [b,c], Kunshan Gao [d], Hiroshi Ogawa [e]

[a] State Key Laboratory of Environmental Geochemistry, Institute of Geochemistry, Chinese Academy of Sciences, 46 Guanshui Road, Guiyang 550002, China
[b] Università degli Studi di Torino, Dipartimento di Chimica, I-10125 Turin, Italy
[c] Centro Interdipartimentale NatRisk, I-10095 Grugliasco, TO, Italy
[d] State Key Laboratory of Marine Environmental Science, Xiamen University, Xiamen, Fujian, China
[e] Atmospheric and Ocean Research Institute, The University of Tokyo, 1-15-1 Minamidai, Nakano, Tokyo 164-8639, Japan

ARTICLE INFO

Article history:
Received 13 March 2013
Received in revised form
10 June 2013
Accepted 2 August 2013

Keywords:
Pharmaceuticals
Algal blooms
Acidification
Ship breaking
Overfishing

ABSTRACT

Algal toxins or red-tide toxins produced during algal blooms are naturally-derived toxic emerging contaminants (ECs) that may kill organisms, including humans, through contaminated fish or seafood. Other ECs produced either naturally or anthropogenically ultimately flow into marine waters. Pharmaceuticals are also an important pollution source, mostly due to overproduction and incorrect disposal. Ship breaking and recycle industries (SBRIs) can also release various pollutants and substantially deteriorate habitats and marine biodiversity. Overfishing is significantly increasing due to the global food crisis, caused by an increasing world population. Organic matter (OM) pollution and global warming (GW) are key factors that exacerbate these challenges (*e.g.* algal blooms), to which acidification in marine waters should be added as well. Sources, factors, mechanisms and possible remedial measures of these challenges to marine ecosystems are discussed, including their eventual impact on all forms of life including humans.

1. Introduction

Marine ecosystems are adversely affected because of increasing demand from human activities and the effect of global warming (GW), thereby facing a number of challenges (Mostofa et al., 2012). The key problems in marine ecosystems can be summarized as follows:

- Emerging contaminants (ECs) are discharged into water environments, including seawater, because of human activities (Teijon et al., 2010; De Laender et al., 2011; Richardson and Ternes, 2011; Vidal-Dorsch et al, 2012; Mostofa et al., 2013a);
- Production of algal toxins or red-tide toxins during algal blooms is increasing due to the effects of organic matter (OM) pollution and GW (Prince et al., 2008; Castle and Rodgers Jr., 2009; Yates and Rogers, 2011; Mostofa et al., 2013b);
- Marine surface waters are undergoing acidification (Doney et al., 2009; Beaufort et al., 2011; Cai et al., 2011; Xiao et al., 2011), which is known to cause changes in marine chemistry and production of algal toxins (Gao et al., 2012a, and references therein);
- Ship breaking and recycle industries (SBRIs) along with oil exploration and transportation can have catastrophic effects on biodiversity due to OM, metals and other pollutants (Reddy et al., 2007; Pasha et al., 2012; Neşer et al., 2012a; Abdullah et al., 2013);
- Overfishing depletes ecosystems and has led to a global decline in fish catches (Myers and Worm, 2003; Block et al., 2005; Rooker et al., 2008; Srinivasan et al., 2010).

Such problems are increasingly threatening the world's marine resources, and they are directly or indirectly linked with the world's growing population. It has been shown that >40% of the world's oceans is highly affected by human activities (Halpern et al., 2008). Coastal areas are understandably suffering from the biggest impact, and human activities have depleted >90% of formerly important species, destroyed >65% of seagrass and wetland habitats, degraded water quality, and accelerated species invasions in diverse and productive estuaries and coastal seas (Lotze et al., 2006). A recent review showed that 63% of assessed stocks are in need of rebuilding (Worm et al., 2009). At the same time, GW and related phenomena can accelerate the occurrence of algal blooms

---

[*] Corresponding author.
E-mail addresses: mostofa@vip.gyig.ac.cn (K.M.G. Mostofa), liucongqiang@vip.skleg.cn (C.-Q. Liu).

0269-7491/$ – see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.envpol.2013.08.005

and acidification processes in marine ecosystems (Cooper et al., 2007; Albright, 2011; Anlauf et al., 2011; Mostofa et al., 2013b, 2013d). ECs are usually bioaccumulated into fish or other aquatic organisms and seafood, from which they can be transferred to humans and other organisms (Richardson and Ternes, 2011; van de Merwe et al., 2011).

Yet, marine ecosystems are also a key vital resource for fish and seafood, meeting the demand for fish proteins at relatively low prices (Meryl, 1996; FAO, 2008). More than half of the total animal proteins consumed in several small island states, as well as in Bangladesh, Cambodia, Equatorial Guinea, French Guiana, Gambia, Ghana, Indonesia and Sierra Leone comes from fish (FAO, 2008). Insufficient attention has been paid so far to the critical impacts of sequential declining in marine ecological communities (*e.g.* from ECs emissions, algal blooms, and overfishing), particularly by developing countries. Considering the importance of a sustainable use of marine resources and biodiversity, world communities should pay much more attention to the solution of current problems created by human activities on marine ecosystems.

This paper will provide an overview of important problems such as ECs, harmful algal blooms, acidification, ship breaking and recycle industries (SBRIs), and overfishing. The sources, factors, mechanisms and remedial measures of such challenges are discussed. As far as pharmaceuticals are concerned, the Chinese case of "100 tablets in a bottle" will be discussed as a major cause of ECs release into the environment, and as a suggestion for strategies aimed at the reduction of pharmaceutical pollution in other countries.

2. Emerging contaminants (ECs)

Emerging contaminants (ECs), a diverse group of both organic and inorganic compounds, occur in very small amount (usually at concentration levels of nanograms to micrograms per liter), are persistent, have potential health effects on organisms including humans, fish and wildlife, and may have other adverse ecological effects (Mostofa et al., 2013a). ECs include: pharmaceuticals; personal care products (PCPs); endocrine-disrupting compounds (EDCs); steroids and hormones; drinking water disinfection byproducts (DBPs); perfluorinated compounds (PFCs); brominated flame retardants including polybrominated diphenyl ethers; sunscreens/UV filters; surfactants; fragrances; antiseptics; pesticides and herbicides; organotins; plasticizers; heavy metals including As, Sb, Pb and Hg; algal toxins or red-tide toxins (De Laender et al., 2011; Richardson and Ternes, 2011; Vidal-Dorsch et al, 2012; Mostofa et al., 2013a).

Most ECs in the aquatic environment originate from three major sources (Hirsch et al, 1999; Fent et al., 2006; Mostofa et al., 2013a): (*i*) anthropic emissions including atmospheric deposition, effluents of municipal, industrial and agricultural activities, aquaculture, livestock and compounds excreted from the human body (*e.g.* pharmaceuticals and their metabolites); (*ii*) natural production, including most notably algal (or phytoplankton) blooms in surface water; and (*iii*) photochemical and/or microbial origin, following alteration of primarily emitted organic substances by photoinduced and/or microbial processes during transport from rivers to lakes, oceans or other water sources (secondary pollution).

2.1. Sources of pharmaceuticals

Point sources of pharmaceuticals and other drugs are (Jones et al., 2001; Fent et al., 2006; Corcoran et al., 2010; Richardson and Ternes, 2011; Mostofa et al., 2013a, 2012):

- Discharge of expired and unused pharmaceuticals or drugs from household. The Chinese case of '100 tablets in a bottle' will be discussed later as a showcase example;
- Disposal of unused pharmaceuticals from hospitals;
- Wastewater and solid wastes discharged from pharmaceutical industries;
- Hormones and antibiotics used in aquaculture and livestock;
- Compounds excreted from the human body in the form of non-metabolized parent molecules or as metabolites, after drug ingestion and subsequent excretion. Note that in some cases there is an excretion of 50–80% of the parent compound (Hirsch et al, 1999).

All of the above issues are strongly affected and exacerbated by the increase in world's population.

2.2. Factors affecting the pharmaceutical pollution

Incorrect drug disposal is particularly important as a cause of pollution by pharmaceuticals (Hirsch et al, 1999; Jones et al., 2001; EMEA, 2006; Fent et al., 2006; Islam et al., 2010). It is in this context that a popular initiative by Chinese pharmaceutical manufacturers (the so-called '100 tablets in a bottle') comes into play as a case study of what should be avoided. The manufacture and commercialization of widely sold drugs in relatively big tablet stocks, with relatively low cost per single tablet, was initially welcome as a way to decrease expenditure for medicines. Following commercial success, at least 88 pharmaceuticals have been sold in China in the '100 tablets in a bottle' format, with a wide variety of active principles (see Table 1; Mostofa et al., 2012).

The main environmental drawback of this initiative is that only a fraction of the tablets is actually used before the expiration period, while the remaining ones are often discharged into household wastes or (even worse) wastewater. In the cases of paracetamol (anti-inflammatory and antipyretic) and prednisone acetate (used for allergic or autoimmune inflammatory diseases), the structures of which are reported in Fig. 1, it has been estimated that the ratio of consumed *vs*. disposed-of tablets would be around 10–20% *vs*. 80–90% (Mostofa et al., 2012).

It should be highlighted that incorrect drug disposal is a worldwide problem (EMEA, 2006; Roig, 2008). In Europe, the disposal of waste pharmaceuticals is bound by strict control in the cases of manufacturers, wholesalers, retailers and hospitals (EU, 1994). However, the general public is under no obligation to do such action (Daughton and Ternes, 1999). Therefore, most people will either flush unused pharmaceuticals down the drain, or dispose of them in household wastes. The latter will ultimately enter waste landfill sites or, to a lesser degree, be incinerated (Jones et al., 2001). Similar situations are observed in Japan and North America, whereas specific legislative requirements are introduced to ensure that any pharmaceutical reaching the market is assessed for its likely environmental fate and biological effects (EMEA, 2006). There is more limited regulation concerning the environmental impact of pharmaceuticals, and of effluents released from pharmaceutical industries in China, India, Bangladesh, and other developing countries (EMEA, 2006; Islam et al., 2010).

The combination of over-production and excessive disposal of pharmaceuticals can cause environmental pollution *via* several pathways. First of all, unused pharmaceuticals can mix up with natural waters, either through leaching of household wastes by rainwater or upon direct input of household wastes into natural waters (Mostofa et al., 2012; Jones et al., 2001; Fent et al., 2006). Second, residues of pharmaceuticals are present in manufacturers' wastewaters resulting from production processes (Holm et al., 1995; Mostofa et al., 2012). The released compounds are transmitted to fish or other aquatic organisms and seafood, from which they can reach humans through food consumption (Mostofa et al., 2012, 2013a; Teijon et al., 2010; Ramirez et al., 2009). Furthermore, over-manufacturing of drugs (such as in the ‘100 tablets in a bottle’ case) has additional production costs as well as environmental impact, due to raw materials, electricity, gases, organic solvents, which are all needed in the process. Finally, it may also result in increased expenditure for medicines by the people

Table 1
List of pharmaceuticals or medicines sold as ‘100 tablets in a bottle’ in China.

No	Name of the pharmaceuticals (in Chinese)	Name of the pharmaceuticals (in English)	Specifications
1	制霉菌素片	Nystatin Tablets	50万u × 100
2	左旋咪唑片	Levomisole Tablets	25 mg × 100
3	去痛片	Somedon Tablets	0.5 g × 100
4	罗痛定片	Rotundine Tablets	30 mg × 100
5	吲哚美辛片	Indometacin Tablets	25 mg × 100
6	地西泮片	Diazepam Tablets	2.5 mg × 100
7	谷维素	Oryzanol Tablets	10 mg × 100
8	阿托品片	Atropine Tablets	0.3 mg × 100
9	山莨菪碱片	Anisodamine Tablets	5 mg × 100
10	尼群地平片	Nitrendipine Tablets	10 mg × 100
11	地高辛片	Digoxin Tablets	0.25 mg × 100
12	硝酸异山梨酯片	Isosorbide Dinitrate Tablets	5 mg × 100
13	速效救心丸	Available Save Heart Tablets	40 mg × 100
14	卡托普利片	Captopril Tablets	25 mg × 100
15	螺类酯	Snails Ester Tablets	20 mg × 100
16	溴乙新片	Bromhexine Tablets	8 mg × 100
17	复方甘草片	Compound Liquorice Tablets	100
18	硫糖铝片	Sucralfate Tablets	0.25 g × 100
19	碳酸氢钠片	Sodium Bicarbonate Tablets	0.3 g × 100
20	甲氧氯普胺片	Metoclopramide Tablets	5 mg × 100
21	马来酸多潘立酮	Domperidone Maleate Tablets	30 mg × 100
22	酚酞片	Phenolphthalein Tablets	100 mg × 100
23	复方地芬诺酯片	Compound Diphenoxylate Tablets	2.5 mg × 100
24	护肝片	Liver-Protecting Tablets	0.35 g × 100
25	金胆片	Jindan Tablet Tablets	0.32 g × 100
26	消炎利胆片	Nflammation-Resolving Gall-Bladder-Excreting Tablets	0.24 g × 100
27	呋塞米片	Furosemide Tablets	20 mg × 100
28	氢氯噻嗪片	Hydrochlorothiazide Tablets	25 mg × 100
29	阿司匹林肠溶片	Aspirin Tablets	25 mg × 100
30	氯苯那敏片	Chlorphenamine Tablets	4 mg × 100
31	地塞米松片	Dexamethasone Tablets	0.75 mg × 100
32	强的松片	Prednisone Tablets	5 mg × 100
33	安宫黄体酮	Medroxyprogesterone Acetate Tablets	2 mg × 100
34	乙烯雌酚片	Diethylstilbestrol Tablets	0.5 g × 100
35	炔诺酮片	Norethindrone Tablets	0.625 mg × 100
36	苯乙双胍片	Phenformin Tablets	25 mg × 100
37	呋喃硫胺	Thiamine Tetrahydrofuryl Disulfide Tablets	25 mg × 100
38	维生素B2片	Vitamin B2 Tablets	5 mg × 100
39	维生素C片	Vitamin C Tablets	0.1 g × 100
40	千柏鼻炎片	Qingrejiedu Oral Tablets	100
41	乳癖消	Breast Mass Resolving Tablets	0.32 g × 100
42	刺五加片	Acanthopanax Root Tablets	100
43	茶苯海明片	Dimenhydrinate Tablets	25 mg × 20
44	磷酸川芎嗪片	Ligustmzine Phosphate Tablets	50 mg × 100
45	盐酸普罗帕酮片	Propafenone Hydrochloride Tablets	50 mg × 100
46	呋塞米片	Furosemide Tablets	20 mg × 100
47	复方芦丁片	Compound Rutin Tablets	20 mg × 100
48	青霉胺片	Penicillamine Tablets	0.125 g × 100
49	呋喃妥因肠溶片	Nitrofurantoin Enteric-Coated Tablets	50 mg × 100
50	四环素片	Tetracycline Tablets	25 mg × 100
51	土霉素片	Terramycin Tablets	25 mg × 101
52	复方磺胺甲恶唑片	Compound Sulfamethoxazole Tablets	100
53	氯霉素片	Chloramphenicol Tablets	100
54	制霉素片	Nystatin Tablets	100
55	灰黄霉素片	Griseofulvin Tablets	10 mg × 100

(*continued on next page*)

Table 1 (*continued*)

56	盐酸吗啉胍片	Moroxydine Hydrochloride Tablets	10 mg × 100
57	醋酸地塞米松	Dexamethasone Acetate Tablets	
58	氢氯噻嗪片	Hydrochlorothiazide Tablet	25 mg × 100
59	叶酸片	FolicAcid Tablets	5 mg × 100
60	葡醛内酯片	Glucurolactone Tablets	50 mg × 100
61	安乃近片	Metamizole Sodium Tablets	0.5 g × 100
62	吡拉西坦片	Piracetam Tablets	0.4 g × 100
63	盐酸苯海索片	Benzhexol Hydrochloride Tablets	2 mg × 100
64	吡罗昔康片	Piroxicam Tablets	10 mg × 100
65	盐酸美西律片	Mexiletine Hydrochloride Tablets	50 mg × 100
66	桂利嗪片	CinnarizineTablets	25 mg × 100
67	布洛芬片	Ibuprofen Tablets	0.1 g × 100
68	氨茶碱片	Aminophylline Tablets	0.1 g × 100
69	磷酸川芎嗪片	Ligustmzine Phosphate Tablets	50 mg × 100
70	硝酸甘油片	Nitroglycerin Tablets	0.5 mg × 100
71	盐酸赛庚啶片	Cyproheptadine Hydrochloride Tablets	2 mg × 100
72	富马酸酮替芬片	Ketotifen Fumarate Tablets	1 mg × 60
73	盐酸金刚烷胺片	Amantadine Hydrochloride Tablets	0.1 g × 100
74	戊四硝酯片	Pentaerithrityl Tetranitrate Tablets	10 mg × 100
75	呋喃唑酮片	Furazolidone Tablets	0.1 g × 100
76	马来酸氯苯那敏片	Chlorphenamine Maleate Tablets	4 mg × 100
77	呋喃妥因肠溶片	Nitrofurantoin Enteric-coated Tablets	50 mg × 100
78	咳必清	Pentoxyverine Citrate Tablets	25 mg × 100
79	醋酸泼尼松片	Prednisone Acetate Tablets	5 mg × 100
80	鱼腥草素钠片	Sodium Houttyfonate Tablets	30 mg × 100
81	白葡萄球菌片	Staphylococcus Albus Tablets	40 mg × 100
82	双氯芬酸钠肠溶片	Diclofenac Sodium Enteric-coated Tablets	25 mg × 100
83	二羟丙茶碱片	Diprophylline Tablets	0.2 g × 50
84	呋塞米片	Furosemide Tablets	20 mg × 100
85	复方罗布麻片I	Compound Kendir Lenves Tablets	100
86	复方妥英麻黄茶碱片	Compound Phenytoin Sodium, Ephedrin Hydrochloride and Theophylline Tablets	100
87	胱氨酸片	Cystine Tablets	50 mg × 100
88	甲氧氯普胺片	Metoclopramide Tablets	5 mg × 100

and contribute to increasing medical costs, because the purchase of excess drugs would compensate for their lower unit cost (Mostofa et al., 2012).

2.3. *Impacts of pharmaceuticals*

Adverse effects of pharmaceuticals to fish and aquatic life are typically detected in aquatic ecosystems (Jobling et al., 2002; Brooks et al., 2005; Runnalls et al., 2007; Corcoran et al., 2010; Nassef et al., 2010; Santos et al., 2010; Cuthbert et al., 2011). Adverse effects include for instance the production of reactive oxygen species in fish (Gonzalez et al., 1998; Fent et al., 2006). Pharmaceuticals are detected in water at concentrations in the range of ng L^{-1} to μg L^{-1}, and they are also found in fish or other organisms (Corcoran et al., 2010; Santos et al., 2010; Mostofa et al., 2013a). The highest pharmaceutical concentrations (μg L^{-1} to mg L^{-1}) are found in river waters, in the effluents of hospitals/clinics and in those near pharmaceutical industries, as well as at the outlet of sewerage treatment plants (Holm et al., 1995; Jones et al., 2001; Fent et al., 2006; Santos et al., 2010). Note that concentration levels at which toxic effects of pharmaceuticals on aquatic organisms have been observed are generally between ng L^{-1} and mg L^{-1} (Crane et al., 2006; Corcoran et al., 2010; Santos et al., 2010). The adverse effects of pharmaceuticals on aquatic life can be summarized as follows:

- Compounds such as estrogens and diclofenac, ibuprofen, propranolol, sulphonamides, fibrates, beta blockers, antibiotics, carbamazepine, serotonin, synthetic steroids, and antineoplastics have an additive acute and chronic toxicity. Among the observed effects there are: reduction in growth, sperm count, egg production, and reproduction; sexual disruption; inhibition of settlement of larvae; disruption in mitochondrial function, intestine, and immune systems; impaired spermatogenesis; disruption in energy metabolism; cytotoxicity in liver, kidney, and gills; oxidative stress in membrane cells; changes in appetite (Jobling et al., 2002; Crane et al., 2006; Fent et al., 2006; Runnalls et al., 2007; Shved et al., 2008; Corcoran et al., 2010; Nassef et al., 2010; Santos et al., 2010; Cuthbert et al., 2011). As far as ecosystems are concerned, effects may include a decline in biodiversity at different trophic levels such as bacteria, algae, zooplankton, fish, crustaceans, and invertebrates. The intersex condition in the most severely affected fish is associated with reduced fertility (Jobling et al., 2002).
- Endocrine-disrupting pharmaceuticals can adversely affect the reproductive organs and the thyroid system, with population-level consequences. The latter include impact on reproduction of fish and other organisms, increase of exotic species, habitat loss, and lethal diseases in aquatic organisms including fish, amphibians and reptiles (Sumpter, 2005; Orlando and Guillette, 2007; Ankley et al., 2009; Kloas et al., 2009; Santos et al., 2010).
- The antidepressants fluoxetine and sertraline, as well as their metabolites, have been detected in effluents of wastewater treatment plants, at concentration levels shown to cause

abnormalities in development and in endocrine function of Japanese medaka (*Oryzias latipes*) (Brooks et al., 2005).

- Antibiotics such as tetracycline at environmental concentrations and laboratory conditions (up to mg L^{-1}) may induce development of resistance in microbial assemblages, may have adverse effect on immune systems, and may inhibit growth and reproduction in fish, microorganisms, algae and aquatic plants (Thomulka and McGee, 1993; Pro et al., 2003; Crane et al., 2006; Yamashita et al., 2006; Santos et al., 2010). Antibiotics may affect fish indirectly, by modulating microbial functions in aquatic ecosystems and by subsequently affecting processes such as denitrification, nitrogen fixation, and organic breakdown (Constanzo et al., 2004).
- Azole antifungal drugs can cause structural changes and functional impairment of cell membranes, ultimately inhibiting fungal growth, decreasing egg production and plasma vitellogenin concentration in fish, inhibiting ovarian growth, and causing reproductive effects in both male and female fish (Ankley et al., 2006; Panter et al., 2004; Villeneuve et al., 2007; Corcoran et al., 2010).
- Diclofenac residues are responsible for the decline of vulture populations, and for the inhibition of growth of the marine phytoplankton species *Dunaliella tertiolecta* (Oaks et al., 2004; DeLorenzo and Fleming, 2008; Nassef et al., 2010; Cuthbert et al., 2011).
- Considering different trophic levels, algae are usually more sensitive to specific pharmaceuticals than *Daphnia magna*, which is in turn more sensitive compared to most fish (Ferrari et al., 2004; Crane et al., 2006; Fent et al., 2006). Therefore, phytoplankton would be more affected by pharmaceuticals than zooplankton and other aquatic organisms (Ferrari et al., 2004: Fent et al., 2006).
- Benthic species are likely more exposed than pelagic species to pharmaceuticals bound to sediment (Corcoran et al., 2010).

Most effect concentrations of pharmaceuticals in fish have been determined under relatively short-term exposure (*e.g.*, days to weeks). Because fish may be chronically exposed to many pharmaceuticals over time (*e.g.*, for months or possibly years), sufficient concentrations could accumulate in their bodies to cause adverse effects (Corcoran et al., 2010).

2.4. Possible solutions to pharmaceutical pollutants

Fortunately, the Chinese government is now considering taking initiative to enforce a modification of production processes and reduce the bulk amount of tablets per envelope, in particular shifting to paper or plastic sheet that would make tablet management easier and reduce the wasted amount (Mostofa and Liu, 2012). This story tells us that governments should (and could) take measures to prevent and discourage manufacturing policies such as the '100 tablets in a bottle' one, or to modify them in case they have been started. Indeed, commercialization of drug tablets in formats that allow efficient use and that reduce waste would provide a benefit both for the environment in terms of reduced pollution, and for the consumer in the form of lower expenditure in medicines, despite the higher cost per tablet that smaller formats would entail.

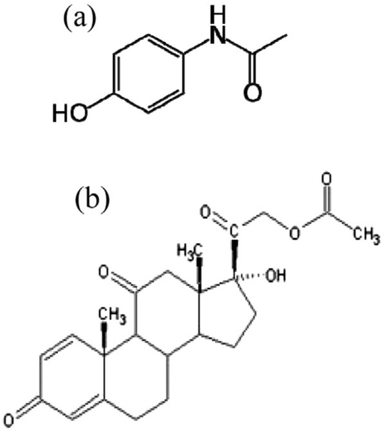

Fig. 1. Molecular structure of paracetamol ($C_8H_9NO_2$) (a) and prednisone acetate ($C_{12}H_{22}O_{11}$) tablets (b).

A major issue concerning the disposed-of drugs is that the active principles and/or metabolites are not efficiently removed by traditional wastewater treatment plants (Castiglioni et al., 2006). Research activity is currently under way to try to upgrade existing technologies, so that removal efficiencies are improved (Ternes, 2004). In the meanwhile, the reduction of wastes is the more reasonable approach. This is all the more true, considering that even the most traditional technologies for wastewater treatment are very far from having a worldwide distribution.

3. Algal toxins or red tide toxins

Algal toxins or red tide toxins are naturally-derived and toxic ECs produced during harmful algal blooms in surface waters (Imai et al., 2006; Prince et al., 2008; Castle and Rodgers Jr., 2009; Yates and Rogers, 2011). The occurrence, abundance and geographical distribution of toxin-producing algae or cyanobacterial blooms have substantially increased during the last few decades, because of increased anthropogenic input of organic matter pollution and nutrients and because of global warming (Phlips et al., 2004; Yan and Zhou, 2004; Luckas et al., 2005; McCarthy et al., 2007; Mostofa et al., 2013b, 2013d).

3.1. Impacts of algal toxins or red tide toxins

Algal toxins or red tide toxins produced during algal blooms in surface waters are responsible for physiological, ecological and environmental adverse effects:

- Deterioration of water quality with high eutrophication (Howarth, 2008; Castle and Rodgers Jr., 2009).
- Depletion of dissolved oxygen below the pycnocline (Castle and Rodgers Jr., 2009).
- Loss of seagrasses and benthos (Bricelj and Lonsdale, 1997).
- Loss of phytoplankton competitor motility (Prince et al., 2008).
- Inhibition of enzymes and photosynthesis (Prince et al., 2008).
- Cell and membrane damage (Prince et al., 2008).
- Mortality of fish, coral reefs, livestock and wildlife (Bricelj and Lonsdale, 1997; Imai and Kimura, 2008; Southard et al., 2010; Yates and Rogers, 2011).
- Shellfish or finfish poisoning caused by neurotoxic compounds (brevetoxins), produced by blooms of red-tide dinoflagellates such as *Karenia brevis* or other algae (Backer et al., 2005, 2008; Moore et al., 2008).
- Illness or even death of higher organisms or humans, associated with consumption of contaminated fish, seafood and water, inhalation of contaminated aerosol, and contact with contaminated water during outdoor recreational or occupational activities (Fleming et al., 2005; Moore et al., 2008; Backer et al., 2005, 2008).
- Adverse health effects (*e.g.* eczema or acute respiratory illness) from direct contact with, ingestion, or inhalation of cyanobacteria or various toxins, during recreational or occupational activities (*e.g.* water skiing, water craft riding, swimming,

fishing) (Fleming et al., 2005; Backer et al., 2005, 2008; Moore et al., 2008; Mostofa et al., 2013b and references therein). Such effects can be observed when algal scum appears on the water surface, in coastal sea beaches or in freshwater ecosystems.

3.2. Mechanism behind the occurrence of harmful algal bloom

The mechanism behind the increasing occurrence of harmful algal blooms is apparently an effect of global warming on waters with high content of DOM and POM through high photosynthesis (Mostofa et al., 2013d). Organic matter (OM) including DOM and POM (*e.g.* phytoplankton or algae) is one of the key factors that can fuel production of additional DOM (autochthonous), nutrients and various photochemical and microbial products (Bushaw et al., 1996; Granéli et al., 1998; Cai et al., 2011; Letscher et al, 2013; Mostofa et al., 2011, 2013b). The complex photoinduced processes can be summarized as follows (Mostofa et al., 2013b; Zepp et al., 2011; Stedmon et al., 2007a, 2007b; Ma and Green, 2004):

$$\begin{aligned} &\mathrm{DOM} + \mathrm{POM} + h\nu \rightarrow \mathrm{H_2O_2} + \mathrm{CO_2} + \mathrm{DIC} + \mathrm{LMW\ DOM} + \mathrm{NO_3^-} \\ &\quad + \mathrm{NH_4^+} + \mathrm{PO_4^{3-}} + \text{autochthonous DOM} + \text{other species} \end{aligned} \tag{1}$$

where DIC is usually defined as the sum of an equilibrium mixture of dissolved CO_2, H_2CO_3, HCO_3^-, and CO_3^{2-}, while LMW DOM means low molecular weight DOM formed upon photoinduced fragmentation of larger organic compounds (Bushaw et al., 1996; Granéli et al., 1998; Mostofa and Sakugawa, 2009; Remington et al., 2011). Increased stability of the water column as a consequence of warming may enhance the photoinduced degradation of DOM and POM, by combination of high temperature and longer exposure of the water surface layer to sunlight (Huisman et al., 2006; Mostofa et al., 2013d).

Despite very different mechanisms involved, microbial processes have several analogies with photochemical ones as far as the final products are concerned (Mostofa et al., 2013b; Letscher et al, 2013; Zhang et al., 2009; Millero, 2007; Ma and Green, 2004):

$$\begin{aligned} &\mathrm{DOM} + \mathrm{POM} + \text{microbes} \rightarrow \mathrm{H_2O_2} + \mathrm{CO_2} + \mathrm{DIC} + \mathrm{LMW\ DOM} \\ &\quad + \mathrm{NO_3^-} + \mathrm{PO_4^{3-}} + \mathrm{NH_4^+} + \text{autochthonous DOM} \\ &\quad + \text{other species} \end{aligned} \tag{2}$$

The compounds formed from DOM and POM because of photochemical and microbial processes would be substantially increased due to increased temperature following global warming. These compounds act as nutrients, enhancing photosynthesis and, as a consequence, primary production as summarized in earlier reports (Fig. 2; Mostofa et al., 2013b, 2013d).

This phenomenon has the consequence of increasing the worldwide incidence of harmful algal blooms, in waters with high contents of DOM and POM (*e.g.* algae or phytoplankton) in the presence of sufficient light or high water temperature. This can lead to further eutrophication of DOM-rich waters. Indeed, more extensive eutrophication and hypoxia have been observed in river-dominated ocean margins because of climate and land use changes (Bianchi and Allison, 2009; Greene et al., 2009; Howarth et al., 2011).

Regeneration of autochthonous DOM and nutrients from POM in DOM-rich waters (Kopáček et al., 2004; Stedmon et al., 2007a, 2007b; Letscher et al, 2013; Mostofa et al., 2013a) is a key factor for the enhancement of photosynthesis or primary production and for the subsequent harmful algal blooms (Vähätalo et al., 2003; Bronk et al., 2007; Mostofa et al., 2013b). The process is favored in surface waters by the increase of water temperature and of the vertical stratification period, and by the extension of the euphotic zone that is expected to take place because of global warming (Huisman et al., 2006; Mostofa et al., 2013d). The self-powering potential of this process is of particular concern, and it could possibly have a role in the increasing occurrence of harmful algal blooms or toxic phytoplankton populations (Harvell et al., 1999; Davis et al., 2009; Mostofa et al., 2013b). In contrast, global warming can affect waters with low contents of DOM in the opposite direction, by inhibiting the production and regeneration of various compounds (Mostofa et al., 2013d). This would ultimately limit photosynthesis and primary production and, as a consequence, reduce algal blooms. The process can proceed either by gradually decreasing the total contents of DOM and nutrients, or by reducing the nutrients at equal DOM.

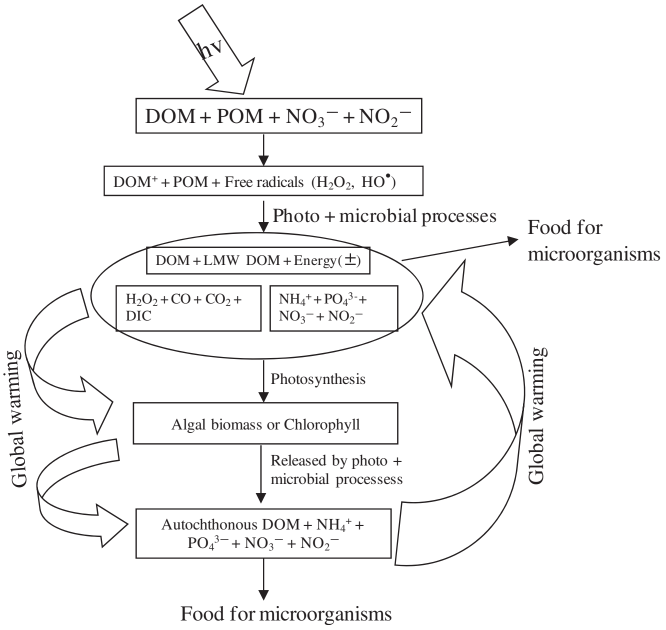

Fig. 2. A conceptual schematic diagram about the response to global warming effects of photoinduced and microbial processes of DOM and POM photoproducts, as well as their possible effects on key biogeochemical processes in natural waters. Data source: Mostofa et al. (2013d).

Introduction of allochthonous nutrients can have negligible effects in waters with high contents of DOM and POM, which often regenerate nutrients on their own (Kopáček et al., 2004; Vähätalo and Zepp, 2005; Jiang et al., 2011; Mostofa et al., 2013b; Letscher et al, 2013). For example, riverine delivery of both inorganic and organic nitrogen has only a minor (<15%) impact on Arctic shelf export production (Letscher et al, 2013). In addition, regeneration of DOM and nutrients could severely worsen the quality of DOM- and POM-rich waters, particularly in lakes, estuaries, coastal waters and in the Arctic and Antarctic regions (Vähätalo et al., 2003; Larsen et al., 2011; Hessen et al., 2009; Imai et al., 2006; Ask et al., 2009; Karlsson et al., 2009; Elofsson, 2010; Letscher et al., 2013). A conceptual model for the generation and occurrence of harmful algal blooms by global warming, linked to photochemical and microbial processing of DOM and POM is presented in Fig. 2 (Mostofa et al., 2013d).

3.3. Possible solutions to harmful algal blooms

Remedial measures are needed for controlling algal blooms, particularly in lakes and coastal seawaters (McCarthy et al., 2007;

Prince et al., 2008; Castle and Rodgers Jr., 2009; Jiang et al., 2011; Yates and Rogers, 2011). Prevention measures are basically centered on avoiding eutrophication (Ollikainen and Honkatukia, 2001; Imai et al., 2006; Gren, 2008; Elofsson, 2010 and references therein). In fact, control of organic matter inputs including both DOM and POM can reduce the regeneration of photoproducts, microbial products and nutrients (NH_4^+, NO_3^- and PO_4^{3-}). Such measures would reduce photosynthesis and, as a consequence, primary production in natural waters, also limiting the positive-feedback processes described above. Unfortunately, such measures could work less well in already eutrophic environments, due to nutrient regeneration phenomena. In such cases, removal of algae or phytoplankton during algal blooms using fine, small-mesh nets and removal of sediments (when feasible) could reduce the further photoinduced and microbial release of DOM and nutrients from primary production (Mostofa et al., 2013d).

4. Changes of pH and ocean acidification

The pH value of the surface water layer is substantially increased during the summer stratification period or during algal blooms, particularly if the water is rich in DOM and POM (Ishida et al., 2006; Blackford and Gilbert, 2007; Xiao et al., 2011; Minella et al., 2011).

In the case of the southern North Sea, annual pH ranges varied from <0.2 in areas of low biological activity to >1.0 in areas influenced by riverine inputs (Blackford and Gilbert, 2007). The pH increase in surface stratified waters during summer is mostly related to products of photoinduced degradation or respiration of DOM and POM and to photosynthesis, which consumes CO_2. Moreover, microbial degradation products could account for the pH decrease in deeper water layers (Feely et al., 2008; Byrne et al., 2010; Cai et al., 2011). DOM photodegradation experiments have shown a pH increase after a certain irradiation time (Gennings et al., 2001; Köhler et al., 2002; Brinkmann et al., 2003). In contrast, microbial degradation of DOM and POM (dark incubation experiments or field observations in subsurface layers) is commonly found to decrease pH (Feely et al., 2008; Byrne et al., 2010; Cai et al., 2011).

A complex chain of interrelationships would be operational between water pH and several photoinduced processes involving DOM and POM, including the production of nutrients (NH_4^+, PO_4^{3-}, NO_3^-, NO_2^-), DIC, or other substances arising from DOM and/or POM photobleaching (Zeebe and Wolf-Gladrow, 2001; Sulzberger and Durisch-Kaiser, 2009; Remington et al., 2011; Mostofa et al., 2013b). On the one side, DOM and POM photoprocessing could affect water pH. On the other side, pH can alter nutrient speciation including for instance the proportion of NH_3 to NH_4^+ and of PO_4^{3-} to HPO_4^{2-}, which are very sensitive to small pH variations around 8 (Zeebe and Wolf-Gladrow, 2001). Variation of pH would also modify the photochemical production of low molecular weight acids, DIC and nutrients from DOM and POM, because acidified waters are usually more photoreactive (Tranvik et al., 1999; Vione et al., 2009; Remington et al., 2011). Moreover, nitrification rates can decrease to zero at pH ~6.0–6.5, as the NH_3 substrate disappears from the system (Huesemann et al., 2002).

4.1. Ocean acidification

Seawater acidification that would be linked to the buildup of atmospheric CO_2 is a key challenge and could have significant consequences for marine ecosystems (Yamamoto-Kawai et al., 2009; Beaufort et al., 2011; Boyd, 2011; Cai et al., 2011; Gao et al., 2012a). Note that the average pH in surface ocean has dropped by approximately 0.1 units globally, which is about a 30% increase in $[H^+]$ (Orr et al., 2005; Fabry et al., 2008). Under the IPCC emission scenarios (A1F1) (Houghton et al., 2001), the average surface-ocean pH could decrease by 0.3–0.4 units from pre-industrial values by the end of this century (Caldeira and Wickett, 2005).

Global warming is operational at the same time and can induce modifications in the euphotic zone. Moreover, it can lengthen the summer stratification period as discussed earlier. Such changes can impact the vertical O_2 profiles, particularly in deep marine ecosystems (Brewer and Peltzer, 2009; Byrne et al., 2010; Mostofa et al., 2013b), where lower O_2 availability can have important effects on marine organisms. Moreover, high $[CO_2]$ is found to enhance the release of dissolved organic carbon from phytoplankton cells (Riebesell, 2004). Released DOM could undergo degradation with formation of various products and nutrients, which might favor algal blooms according to the conceptual model shown in Fig. 2 (Mostofa et al., 2013b). Acidification is thus expected to act in a complex system (Beaufort et al., 2011), where it might be difficult to completely distinguish which ecosystem effects can be purely attributed to pH decrease, and which ones to other consequences of GW and other ocean changes that are simultaneously active. The scenario could be made even more complex by interactions between several factors (Gao et al., 2012a).

4.2. Impacts of ocean acidification

Ocean acidification would decrease the saturation states of carbonate minerals and subsequently change the calcification rates of some marine organisms, thereby affecting aquatic food chains (Cooley et al., 2010; Hofmann et al., 2010; Kroeker et al., 2010; Beaufort et al., 2011; Albright, 2011). The most likely effects of ocean acidification are predicted and identified on coral reefs, shellfish and other aquatic organisms, and can be summarized as follows:

- Shellfish or marine calcifiers are particularly sensitive to increase in acidity/decrease in pH. This phenomenon can cause dissolution of magnesium calcite, which is an important component of these organisms (*e.g.*, echinoderms and some coralline algae). Impact on the calcification rates of marine calcifying organisms can affect early developmental stages, which include fertilization, sexual reproduction, cleavage, larval settlement, survival and growth, finally causing a substantial population decline (Caldeira and Wickett, 2003; Andersson et al., 2008; Arnold et al., 2009; de Moel et al., 2009; Moy et al., 2009; Hofmann et al., 2010; Albright, 2011). Shells made of high magnesium or amorphous calcium calcite would be more impacted, because they tend to be dissolved at lower concentrations of carbonic acid compared to shells made of less soluble forms such as calcite and aragonite (Brečević and Nielsen, 1989; Politi et al., 2004; Kroeker et al., 2010). For instance, amorphous calcium carbonate is 30 times more soluble than calcite (Brečević and Nielsen, 1989; Politi et al., 2004). A significant reduction of shell mass and thickness has been observed for several Southern Ocean marine algae and animals, the most likely reason being the recent decrease in seawater pH (Mapstone, 2008).
- Coral reefs are extremely sensitive to acidification, which can: dissolve reef carbonate; reduce the development of coral larvae into juvenile colonies; decrease growth rates of juvenile scleractinian corals; increase sperm mortality; cause a decline in the early developmental stages (fertilization, sexual reproduction, metabolism, cleavage, larval settlement and reproductive stages); reduce algal symbiosis and post-settlement growth; delay the onset of calcification and alter crystal morphology and composition; increase juvenile mortality because of slower post-settlement growth; reduce effective population size and fecundity, and disrupt the generation of

sturdy skeletons and the resilience of reef-building corals (Done, 1999; Langdon and Atkinson, 2005; Fine and Tchernov, 2007; Cohen et al., 2009; Morita et al., 2010; Albright, 2011; Albright and Langdon, 2011; Nakamura et al., 2011). Such effects have an impact on the overall growth and reproduction, and on populations of corals as a whole. The synergistic effects of elevated seawater temperature and of CO_2-driven ocean acidification are responsible for coral bleaching, reduction of primary productivity, and for the decline in growth and calcification rates (Gao and Zheng, 2010; Albright, 2011; Anlauf et al., 2011; Gao et al., 2012a, 2012b). Differently from corals, it has been shown that calcareous algae that also contribute to build the reef frame can recruit, grow, and calcify under lower pH conditions (Kuffner et al., 2008).

- In some marine invertebrates, calcification of larval and juvenile or smaller individuals is often more sensitive to acidification compared to adults or larger individuals (Kurihara, 2008; Maier et al., 2009; Waldbusser et al., 2010).
- Any decline in shellfish and coral reefs, which constitute the foundation of marine ecosystems, would substantially affect food webs and marine population dynamics, including fish and other organisms (Doherty and Fowler, 1994; Wilkinson, 2000; Riegl et al., 2009; Cooley et al., 2010; Albright, 2011). In fact, coral reefs are generally used as habitats by many marine organisms and are a center for biodiversity, where nearly one-third of all fish species live (NMFS, 2004). Changes in food chains could significantly alter global marine harvests, which in 2006 provided 110 million metric tons of food for humans and were valued at US$160 billion (Cooley et al., 2010).
- Photosynthesis, calcification and nitrogen fixation of some coccolithophores, prokaryotes and cyanobacteria are either unmodified or increased or decreased in high-CO_2 water (Riebesell et al., 2000; Doney et al., 2009; Beaufort et al., 2011; Gao et al. 2012b; Mostofa et al., 2013b). Toxins produced by harmful algae might increase due to ocean acidification (Tatters et al., 2012). Interaction of ocean acidification and solar UV−B radiation decrease the growth and photochemical yield of the red tide alga *Phaeocystis globosa* (Chen and Gao, 2011).

4.3. Factors affecting ocean acidification

An important issue that should be taken into account, as far as acidification is concerned, is that dissolution of atmospheric CO_2 into ocean water is not the only possible cause of pH modification. Therefore, it might not be easy to experimentally determine the exact contribution of CO_2 buildup to the pH decrease. For instance, significant variations of the partial pressure of CO_2 in seawater (pCO_2) have been observed along the P16 N transect at 152 °W in the North Pacific (Fabry et al., 2008). Moreover, it has been shown that acidification of seawater can also be caused by eutrophication, or by several factors including photosynthesis, respiration, temperature, light, and nutrients (Bollmann and Herrle, 2007; Zondervan, 2007; Feng et al., 2008; Beaufort et al., 2011; Cai et al., 2011). All these factors could significantly modify water alkalinity and, therefore, the variation of pH upon CO_2 dissolution. Another example, although referred to inland freshwaters, is the recovery of acidification in waters of European countries (Curtis et al., 2005; Battarbee et al., 2013), which suggests that several processes with the potential to modify water pH can be operational at the same time.

Here an account is given of some additional processes that could potentially modify the pH of oceanic waters. Of course, it should be considered that CO_2 dissolution is operational on a global scale, while other processes have a more local impact. Anyway, in limited locations the pH changes due to local processes can be significant compared to those caused by CO_2 dissolution, which should be taken into account in the interpretation of pH data.

In addition to enhanced dissolution of atmospheric CO_2, pH at the seawater surface can be modified by the following processes:

(i) Photoinduced and microbial processes in low-DOM waters can produce relatively low amounts of products such as CO_2, DIC, H_2O_2, low molecular weight (LMW) substances, other acid-containing organic photoproducts, and autochthonous DOM (Mostofa et al., 2013b, 2013d). In the absence of allochthonous nutrients, the low amount of such compounds would give a limited support to primary productivity and cause limited CO_2 consumption, which could keep pH values lower compared to more productive sites. Such a behavior works in the opposite direction than the mechanism causing algal blooms in water with high contents of DOM and POM (Mostofa et al., 2013b, 2013d). Interestingly most freshwater cyanobacteria, and in particular the species associated with harmful algal blooms are poor competitors with other phytoplankton at low pH (Shapiro, 1973; Paerl and Ustach, 1982).

(ii) Atmospheric acid deposition and acid rain (involving most notably HNO_3 and H_2SO_4) can have an impact on the pH values and the geochemistry of surface waters (Beamish, 1976; Worrall and Burt, 2007). Model results suggest that acid rain could also affect the pH of seawater (Doney et al., 2007). Agricultural activities, through the oxidation of nitrogen fertilizers to nitrate, can further contribute to the decrease of seawater alkalinity (Mackenzie, 1995; Doney et al., 2007) which, as a consequence, can decrease water pH. Seawater acidification due to acid rains or agriculture would be very limited on a global scale, but it could be quite important in coastal areas where the impact of human activities is considerably higher than in the average ocean (Doney et al., 2007).

(iii) Global warming can substantially increase the surface-water temperature, which can enhance the rate of photoinduced and microbial degradation of DOM and POM. It may modify seasonal patterns in chlorophyll or primary production, contents of nutrients, carbon cycling, pH values, microbial food web stimulation, and the depth of the mixing layer (Huisman et al., 2006; Mostofa et al., 2013b, 2013d). More stable stratification during the summer period would favor photochemical processes in the euphotic zone, thereby leading to more extensive photoprocessing of DOM. In some cases these processes have been shown to increase the pH of the surface water layer, while the opposite effect (pH decrease) has been observed in sub-surface water (Byrne et al., 2010; Cai et al., 2011).

(iv) Worldwide increase in harmful algal blooms may be connected with regeneration of CO_2, DIC and nutrients from such algae or phytoplankton, thereby enhancing autochthonous DOM (Fig. 2; Mostofa et al., 2013b; Ballare et al., 2011; Zepp et al., 2011; Zhang et al., 2009). Such effects might induce high production of CO_2 in surface waters, with a potential role in acidification.

4.4. Possible solutions to ocean acidification

The possible remedial measures for acidification are not easy to be implemented and, in some cases, they could have uncertain effects. On a global scale, limitation of the ocean acidification is clearly a part of the important task of fighting against global warming. Therefore, it implies the difficult goal of limiting CO_2 emissions which, as far as acidification is concerned, would be far more important compared to other greenhouse gases. Other remedial actions against acidification could work on a local scale, provided that the effects they are intended to control are important in decreasing the pH and alkalinity of water. In some coastal waters, a beneficial action could be achieved by controlling the anthropogenic emissions of SO_2 and NO_x in the atmosphere and the discharge of N-containing fertilizers from agricultural activities. In this way one could reduce acidic depositions and acid rain, as well as the input of compounds that take part to transformation reactions that lower the pH of water.

Waters with low primary production are more exposed to acidification processes. From this point of view, a way to decrease the susceptibility of oligotrophic water to acidification could be to favor the primary production, *e.g.* by enhancing the release of terrestrial DOM in natural waters through increased runoff (Evans et al., 2001). However, partial eutrophication of very oligotrophic waters could be a risky procedure if not properly controlled. As shown before, elevated primary productivity could start a self-augmenting process that could lead to increased probability of harmful algal blooms (Bianchi and Allison, 2009; Greene et al., 2009; Howarth et al., 2011; Mostofa et al., 2013b).

5. Ship breaking and recycling industries (SBRIs)

Ship breaking is the process of cutting and breaking apart old ships to recycle scrap metals, along with simultaneous scrapping or disposal of expired or unused ships (Demaria, 2010; Abdullah et al., 2013). Ship breaking is currently carried out mostly by developing countries, and the level of activity in terms of light displacement ton (LDT) by country from 1994 to 2009 is: India (42%), Bangladesh (23%), China (15%), Pakistan (8%), Vietnam (1%), Turkey (1%), and others (10%) (NCSG, 2011; Abdullah et al., 2013). SBRIs are important sources of hazardous contaminants along the coastal seashore, most notably in the case of old oil tankers, bulk carriers, general cargo, container ships and passenger ships. On the other hand, SBRIs are also key sources of cheap iron and steel, for construction and other development purposes in the respective countries.

5.1. Kinds of pollutants released from SBRI

SBRIs during ship breaking or demolition can produce three kinds of pollutant. They are (*i*) liquid wastes, which include for instance: oils and oil products (engine oil, bilge oil, hydraulic and lubricant oils and grease); persistent organic pollutants including polychlorinated biphenyls (PCBs, used *e.g.* in transformers); polycyclic aromatic hydrocarbons (PAHs); ozone depleting substances (ODSs) (*e.g.* CFCs and Halons); preservative coatings; organotins including monobutyltin (MBT), dibutyltin (DBT) and tributyltin (TBT); waste inorganic liquids (*e.g.* sulfuric acid); waste organic liquids; reusable organic liquids; miscellaneous (mainly sewage) (Hossain and Islam, 2006; Sarraf et al., 2010; Pasha et al., 2012; Neşer et al., 2012a); (*ii*) solid wastes, which include for instance: various types of asbestos; paint chips; heavy metals such as mercury (Hg), cadmium (Cd), lead (Pb), arsenic (As), chromium (Cr), copper (Cu), manganese (Mn), iron (Fe), zinc (Zn), nickel (Ni) and aluminum (Al); polyvinyl chloride (PVC); solid ozone-depleting substances (ODSs, *e.g.* polyurethane); solid PCB-contaminated wastes (*e.g.* capacitors and ballasts); plastic; sludge; glass; cuttings; ceramics (Hossain and Islam, 2006; Reddy et al., 2007; Sarraf et al., 2010; Pasha et al., 2012; Neşer et al., 2012b); and (*iii*) gaseous wastes, which include for instance: sulfur fumes; dioxins produced during burning of chlorine-containing products such as PCBs and PVC; ODSs, when they are released into the atmosphere; toxic components of marine paints and anti-fouling paints (such as lead, arsenic and pesticides) that can be volatilized at high temperature during the furnace of cutting ships in re-rolling mills; miscellaneous gases during ship demolition, and so on (Hossain and Islam, 2006; Sarraf et al., 2010; Pasha et al., 2012).

5.2. Impacts of released pollutants from SBRIs

The toxic and hazardous materials from yards or waste dumping sites of SBRIs are often released into the surrounding environment, thereby polluting water and adversely affecting living organisms as well as humans. Impacts on both marine areas and nearby land environments can be summarized as follows:

- Decline in fish communities, size and standing stock, along with fish contamination in nearby marine waters (up to 100 km distance, or more) (Reddy et al., 2007; Demaria, 2010);
- Decline in fish habitats, eggs and larvae (Soni, 1997; Demaria, 2010; Abdullah et al., 2013);
- Decline in primary production (*e.g.* algae or phytoplankton), zooplankton communities and their standing stock, which affects all the aquatic food web (Hossain and Islam, 2006; Reddy et al., 2007; Demaria, 2010; Abdullah et al., 2013);
- Decline in benthic invertebrates and their standing stock (Hossain and Islam, 2006; Abdullah et al., 2013);
- Adverse health problems for workers and nearby village people, including diseases (*e.g.* throat burning, kidney diseases, respiratory disorders, endocrine disruption, reproductive abnormalities, neurological problems, asthma, angiosarcoma, cancer, diarrhea), upon exposure to contaminated environments including water, soil, air, seafood, flora and fauna (Islam and Hossain, 1986; UNESCO, 2004; Hossain and Islam, 2006; Demaria, 2010; Hasan et al., 2013);
- Unsuitable and harmful coastal seawaters for recreational purposes (Desai and Vyas, 1997; Trivedi, 1997);
- Toxic effects and population decline for marine birds, mammals, crustaceans, turtles and reptiles, through uptake of contaminated fish, polluted waters and other seafood (UNESCO, 2004; Hossain and Islam, 2006; Abdullah et al., 2013);
- Decline in flora, fauna and other aquatic plants or mangroves (UNESCO, 2004; Hossain and Islam, 2006);
- Deaths of cattle upon feeding on contaminated food (Demaria, 2010);
- Contribution to acid rains from atmospheric emissions during the furnace of cutting ships in re-rolling mills (Bhatt, 2004);
- Overall loss of biodiversity (species diversity, genetic diversity and ecosystem diversity) of nearby marine and terrestrial ecosystems (UNESCO, 2004; Hossain and Islam, 2006; Abdullah et al., 2013).

Fisheries of Bombay Ducks (*Harpodon neherius*), Hilsa fish, prawns and other species have declined by approximately 50–100% at three places that are 50 km away from ship-breaking industries in India (Dholakia, 1997; Demaria, 2010). Heavy metals and other toxic contaminants have been detected in fish communities, various kinds of seafood, suspended particulate matter (SPM), marine sediments and soils, with values that can be several times higher than the maximum standard level (Khan and Khan, 2003; Reddy et al., 2005; Basha et al., 2007; Mitra et al., 2012; Neşer et al., 2012b; Hasan et al., 2013). Therefore, all organisms including humans are susceptible to adverse health effects through uptake of contaminated seafood.

5.3. Factors affecting the SBRI's pollution

Because a substantial part of world's SBRI activity is carried out in developing countries, most of the pollutants released from SBRIs are usually discharged into the surrounding coastal marine ecosystems, often without any pretreatment. Main reasons for such an alarming level of pollution are: (*i*) lack of knowledge about environmental impacts of those pollutants; (*ii*) lack of technology to treat or recycle pollutants released from SBRIs; (*iii*) search for profit by SBRI owners, who are often unwilling to take remedial measures; (*iv*) lack of proper rules and regulations to control SBRIs in developing countries. The latter issue is closely linked to the fact that SBRIs are often closely related to other important economic activities such as construction, which slows down strict implementation and enforcement of regulations.

5.4. Possible solutions to SBRI's pollution

It is vital to make a safe and environmentally sound yard of all SBRIs, along with solving their pollution problems. SBRI evolution toward sustainable development can be provided through reasonable and enforceable legislative and judicial action, which takes a balanced approach but does not diminish the value of coastal conservation (Abdullah et al., 2013). Each country should take initiatives for sustainable development and follow certain obligations, which can be listed as follows (Mostofa et al., 2012; Pasha et al., 2012; Hassan, 2010; Hossain and Islam, 2006):

- Each SBRI yard should be conducted in an exclusive zone, from which pollutants could not be directly released into marine and terrestrial ecosystems;
- Advanced techniques from developed countries should be supplied to each SBRI, so that they can treat or recycle pollutants;
- Awareness should be raised among workers, SBRI owners, the general population, as well as people who are directly involved, on the release of various pollutants and their hazardous impact on surrounding environments, organisms and humans.

6. Overfishing

6.1. Factors affecting fish communities through overfishing

The decline in fish stocks, habitats and the biodiversity of marine waters can have several causes, but overfishing is certainly a major one (Rotschild et al, 1994; Pauly et al., 2002; Platt et al., 2003). Unfortunately, the substantially increasing demand of fish proteins for an increasing world's populations is being met by a combination of industrial-scale commercial fishing, various netting techniques, as well as illegal and unregulated or unreported fishing (Table 2; Nurul Amin et al., 2006; BOBLME, 2010; WGBFAS Report, 2012; Myers and Worm, 2003; Srinivasan et al., 2010).

The decline of fish communities also has other causes, including toxic algal blooms (Etheridge, 2010; Mostofa et al., 2013b, 2013c), emission of emerging contaminants by agriculture and industry (including SBRIs, see above), as well as other human activities (Richardson and Ternes, 2011; Sarraf et al., 2010; Abdullah et al., 2013; Pasha et al., 2012). Last but not least, there are the effects of global warming with associated water stratification, depletion of dissolved O_2 and acidification (Matear and Hirst, 2003; Keeling et al., 2010; Mostofa et al., 2013b). These problems add to overfishing by impacting water quality and/or enhancing the deterioration of food resources for fish, with consequences that span from disease and mortality of fish communities to severe reduction of fish breeding in marine ecosystems.

Industrialized fisheries can typically reduce community biomass by 80% within 15 years of exploitation (Myers and Worm, 2003). Overfishing has affected 36–53% of fish stocks in more than half of the world's exclusive economic zones (EEZs), from 1950 to 2004 (Srinivasan et al., 2010). Overfishing is not exclusive of saltwater: fish catch, particularly of brown trout, has decreased by approximately 50% over a 15-year period in many Swiss rivers and streams (Burkhardt-Holm et al., 2002). The catch per unit effort (CPUE) of trawl shrimp has decreased by approximately $\sim$52% in 2000–2001 (284.23 kg day^{-1}) compared to 1992–1993 (592.78 kg day^{-1}) in coastal waters of Bay of Bengal (Nurul Amin et al., 2006). However, during the same period the total fishing effort has increased by approximately 58%, from 7065 fishing days in 1992–1993 to 11,160 fishing days in 2000–2001 (Table 2). More intensive exploitation is not without effect: the maximum sustainable yield (MSY) of trawl shrimp has declined by approximately 54% in 2001 (3441 tons) compared to 1989 (7000–8000 tons) (Nurul Amin et al., 2006).

6.2. Impacts and mechanisms regarding some specific fish species

6.2.1. Hilsa fish

A rare anadromous species in tropical water is the Hilsa fish (*Clupeidae Tenualosa ilisha*), the catches of which have increased by approximately 101% from 1983–1984 (144,438 tons) to 2007–2008 (290,000 tons) in Bangladesh, and by 567% from 1966–1975 (1457 tons) to 1995–2004 (9726 tons) at Hooghly – Matlah estuary in India (Table 2; BOBLME, 2010). Moreover, there has been a 6–13% increase from 2005–2006 (15,836 tons) to 2007–2008 (17,952 tons) and 2008–2009 (16,744 tons) at the Ayeyarwaddy and Yangon Division of the Irrawaddy Delta, southwest coast, Myanmar (BOBLME, 2010). Hilsa fish (locally known as Ilish) migrates for spawning from the Bay of Bengal into estuaries and into most of the upstream rivers up to 100 km in Bangladesh/India/Myanmar, during the monsoon (July–November) and the spring warming (February–May) (UNDP, 1985; BOBLME, 2010). Landings of Hilsa

Table 2
Changes in the catch per unit effort (CPUE), fishing effort and catches of various fishes in marine ecosystems.

Fishes	Year		% Changes	References
	From	To		
CPUE for trawl shrimp (kg day^{-1})	1992–1993 (592.8)	2000–2001 (284.2)	(–) 52	Nurul Amin et al., 2006
Fishing effort for trawl shrimp (days)	1992–1993 (7065)	2000–2001 (11,160)	(+) 58	Nurul Amin et al., 2006
Hilsa in total catch at the Bay of Bengal, Bangladesh (tons)	1983–1984 (144,438)	2007–2008 (290,000)	(+) 101	BOBLME, 2010
Hilsa in total catch at around the Hooghly estuary (tons)	1966–1975 (1457)	1995–2004 (9726)	(+) 567	BOBLME, 2010
Hilsa in total catch at the Irrawaddy Delta in Myanmar (tons)	2005–2006 (15,836)	2007–2008 (17,952)	(+) 13	BOBLME, 2010
Hilsa in total catch at the Irrawaddy Delta in Myanmar (tons)	2005–2006 (15,836)	2008–2009 (16,744)	(+) 6	BOBLME, 2010
Catches western Baltic cod in subdivision 22–24 (tons)	1970 (43,959)	2011 (16,332)	(–) 63	WGBFAS, 2012
Large predatory fishes (blue marlin, cod)	1950	2000	(–) 90	Myers and Worm, 2003
Europe/Asia/N. America/S. America/Africa	1950	2000	(–) 7.0–50	Srinivasan et al., 2010

The numbers in parentheses are the amounts for different units.

fish have significantly declined, by up to 100% in different river mouths and several coastal locations. This is due to a decrease in freshwater discharge from upstream rivers or international rivers, and to cross-dam construction either for electricity or for the Irrigation and Flood Control Project in both Bangladesh and India (Haldar et al., 1992; Haldar and Rahman, 1998; BOBLME, 2010). Such a decline might also be due to deterioration of water quality, because of environmentally driven changes (*e.g.* pollutants released from ship breaking and recycle industries, agricultural pesticides, sewage and other industries), loss of habitat, overfishing (Farakka Barrage on the Bhagirathi River), and global warming (Dholakia, 1997; Haldar et al., 2001; BOBLME, 2010; Demaria, 2010). The traditional habitat of the Hilsa fish is the Bengal delta in the Bay of Bengal, the world's largest flooded wetland that includes the combined basin of three main river systems: Bhagirathi, Padma (two tributaries of Ganges) and Meghna, a tributary of Brahmaputra, along with the river Hooghly of India and the Irrawaddy of Myanmar. Moreover, Hilsa is also found in Satil Arab, Tigris and Euphrates of Iran and Iraq, and in Indus of Pakistan. River water nurses millions of larvae, which become juvenile and adult Hilsa and then migrate towards the sea. Overfishing and human-driven environmental changes can significantly affect Hilsa populations (Dholakia, 1997; Haldar et al., 2001; BOBLME, 2010; Demaria, 2010).

6.2.2. Bluefin tuna

Top pelagic predators such as bluefin tuna, *Thunnus thynnus*, are often found in the Mediterranean Sea, Black Sea, Atlantic Ocean, and Pacific Ocean, but they have undergone a substantial decline (Farley and Davis, 1998; Carlsson et al., 2007; Kitagawa et al., 2010; Riccioni et al., 2010; MacKenzie and Mariani, 2012). Atlantic bluefin tuna (ABFT) is a highly migratory species that feeds in cold waters in North Atlantic and migrates to tropical seas to spawn (Muhling et al., 2011b). Mediterranean fisheries have been the main source of bluefin tuna since mid 1990s, but the total reported catch data are at the same time interesting and alarming. Yearly catches have declined by approximately 43% (20,000 tons) in the late 1980s from the 35,000 tons in the 1950s and 60s (ICCAT, 2009; Marion et al., 2010). However, there has been an increase as high as 150% (50,000 tons) in 1995, after which a ∼30% decrease (35,000 tons) was observed in 2005. The most recent (2010) stock assessment showed a global decline of between 29% and 51% over the past 21–39 years, based on summed spawning stock biomass from both the Western and Eastern Mediterranean stocks (Collette et al., 2011). The bluefin has also declined globally, including the eastern and western Atlantic because of over-harvesting (Myers and Worm, 2003; ICCAT Scientific Commitee, 2010; MacKenzie and Mariani, 2012). The spawning stock biomass of the western Atlantic has collapsed by approximately 75–80%, which could even entail a danger of extinction (ICCAT, 2003; Block et al., 2005; MacKenzie et al., 2009). The reason for such a decline is for the most part commercial overfishing, because bluefin tuna is a highly prized fish and it is the favorite one for sushi and sashimi in Japan and, to some extent, also in other countries such as USA, EU and Russia (Bestor, 2000; Hutchings, 2000; Myers and Worm, 2003; Teo and Block, 2010). The record price set in 2011 was $396,000 for a single large specimen (Frayer, 2011). Moreover, as demand and fish prices rise, exports of fish products from developing nations will tend to rise, leaving fewer fish for local consumption and putting fish protein increasingly out of reach for low-income families (Meryl, 1996).

It is demonstrated that Atlantic bluefin tuna (ABFT) has two main stocks, with spawning grounds in the Gulf of Mexico and in the Mediterranean Sea. It has a high degree of spawning site fidelity, as found from field observations of electronically tagged specimens (Block et al., 2005; Carlsson et al., 2007; Rooker et al., 2008; Westneat, 2009; Froese and Pauly, 2010). Moreover, new studies using satellite tags show that some parts of ABFT (up to ∼44%) can spawn in distant oceanic regions, other than the two main breeding grounds (Block et al., 2005; Galuardi et al., 2010; Muhling et al., 2011a). Mortality of bluefin tuna during spawning is quite elevated (Block et al., 2005; Teo and Block, 2010) and might be caused by spawning grounds and conditions, because of increased thermal and hypoxic stress induced by longevity in warm surface waters (Block et al., 2005). As suggested before, global warming can increase surface water temperature, lead to a longer summer stratification period and increase the occurrence of harmful algal blooms through high photosynthesis (Huisman et al., 2006; Mostofa et al., 2013d). All these issues can alter the food web in surface waters (Huisman et al., 2006; Mostofa et al., 2013d) and might be responsible for increased mortality of larvae, juveniles and adult bluefin tuna in the spawning grounds (Kimura et al., 2010; Chapman et al., 2011; Muhling et al., 2011b; MacKenzie and Mariani, 2012). These effects would add to overfishing in inducing population decline.

6.2.3. Cod

Total landings of cod in the ICES sub-divisions 22–24 in the western Baltic Sea have declined by approximately 63% in 2011 (16,332 tons) compared to 1970 (43,959 tons) (Table 2; WGBFAS, 2012). The estimate is based on fish catching by several countries including Denmark, Finland, Germany, Estonia, Lithuania, Latvia, Poland, and Sweden. Moreover, the global diffusion of industrial-scale commercial fishing has caused a 90% decline of the oceans' populations of large predatory species, such as blue marlin and cod, in the past half century (Myers and Worm, 2003). Such global changes in large predatory fish may have severe consequences on the food web in marine ecosystems (Steele and Schumacher, 2000; Jackson et al., 2001; Worm et al., 2002). In fact, the stability of ecological communities significantly depends on the strength of interaction between predators and preys (Bascompte et al., 2005). The disruption of existing interactions on two consecutive levels of a trophic chain can potentially alter the structure and dynamics of the entire food web, through trophic cascades (Paine, 1980; Pace et al., 1999; Pinnegar et al., 2000; Shurin et al., 2002). For instance, a food web model has shown that overfishing of sharks may have contributed to the depletion of herbivorous fish through trophic cascades, thus enhancing the degradation of Caribbean reefs (Bascompte et al., 2005). Strongly interacting tritrophic food chain (TFC) includes species at the base, such as parrotfishes (*Scaridae*) and other herbivores, which are important grazers of macroalgae (Randall, 1967). The removal of herbivores by fishing is partly responsible for the shift of Caribbean reefs from coral- to algae-dominated (Hughes, 1994). These interaction strength combinations can reduce the likelihood of trophic cascades after the overfishing of top predators (Bascompte et al., 2005). A TFC can be exemplified by the case in which a top predator *P* (*e.g.*, the shark) eats a consumer *C* (*e.g.* parrotfish), which in turn eats a resource *R* (*e.g.*, algae and corals) (Block et al., 2005). Therefore, any decline in the shark may substantially increase the parrotfish, thereby decreasing algae or corals in water.

6.3. Possible solutions to overfishing

The forbidding of fishing activities at specific times in specific areas, termed as 'time and area closures' might be a common management tool to protect the spawning fish or parent populations. In this way, one can protect or restore proper age and sex distribution, spawning stocks, and aid the most vulnerable fish populations to recover from overfishing (Beets and Friedlander, 1998; Sala et al., 2001; Heyman et al., 2005; Pelletier et al., 2008;

Druon, 2010; Teo and Block, 2010). It is also vital to create marine reserves or protected areas in each country, within the territorial coastal marine waters, in which fishing is banned. In this way one can protect sea plants, animals and habitats, thereby preserving marine biodiversity. Some countries have already taken initiatives, and other countries should follow them. For example:

(1) Australia has created the world's largest Marine Reserve Network of reef and marine life, covering nearly 1.2 million square miles – a third of the nation's waters – around the country's borders (Edyvane, 1999; McGuirk, 2012). This is an example to be followed, if one wants to save biodiversity and avoid overfishing.
(2) With the goal of establishing an "ecologically coherent" network of marine protected areas within Northeast Atlantic waters, the Convention for the Protection of the Marine Environment of the North-East Atlantic (the 'OSPAR Convention') has been signed by 16 Parties including Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, UK, Northern Ireland and the European Union (Ardron, 2008).
(3) Since 1999, China has banned fishing in different areas of the Bohai Sea, Yellow Sea and East China Sea, beginning on June 1 for three to three-and-a-half months, as well as in northern parts of the South China Sea, including waters around Huangyan Island, for the next two and a half months (Cheng et al., 2004). The aim is to protect fishery resources and to preserve their sustainable growth and productivity.
(4) To increase the popular Hilsa fish in different parts of the Bay of Bengal and its coastal rivers, Bangladesh has banned fish catching during the peak breeding period from September 25 to October. Moreover, it has banned catch, transportation, marketing, selling and possessing of juvenile Hilsa (*jatka*, up to 23.0 cm size), between 1 November and 31 May every year (BOBLME, 2010).

In the case of the highly exploited Mediterranean Sea, the diffusion of aquaculture has played a significant role in compensating for declining catches and in providing an alternative economic activity to struggling fisheries (Grigorakis and Rigos, 2011). This is an example that could be followed in other parts of the world, but high attention should be paid at the environmental impact of aquaculture, including water pollution by pharmaceutical compounds such as antibiotics (Rico et al., 2012 and references therein).

7. Effect of world's population on marine problems

The first issue is how humans relate with problems in marine ecosystems. An increasing world's population has an increasing demand for food, medicines, goods and habitats. All these issues are directly or indirectly associated with marine problems, such as overfishing, increasing emission of pharmaceuticals and other ECs, increasing activity of SBRIs, and increase in plastic wastes, oil exploration and transportation, and algal blooms (Fig. 3). In particular, algal blooms are closely connected to the increase in OM (DOM and POM) inputs and to the effect of global warming.

The second issue is the way problems in marine ecosystems affect humans and other organisms. The fast depletion of fish stocks by overfishing and environmental deterioration could constitute an economic as well as an ecological problem, ruining fishing communities and seriously damaging the whole fishing-based supply chain. An example in this sense is constituted by recent difficulties of fisheries in the Mediterranean, which has undergone overfishing for decades (Grigorakis and Rigos, 2011). Release of pollutants to marine environments is a serious threat to human health, because food consumption including most notably seafood is a major route of transmission of ECs to both humans and other organisms (Fig. 4).

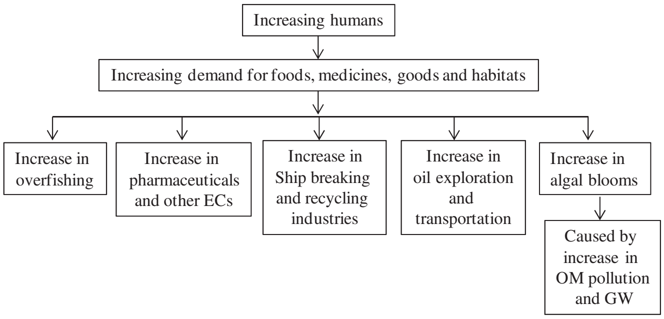

Fig. 3. Relationship between increasing human population and problems in marine ecosystems.

To have an idea of the pollution load, one can consider that world's population was 3 billion in 1960, 7 billion in 2012 and will be approximately 10.6 billion in 2050 (UNFPA, 2011). The present pollution of marine waters by human activities can be roughly assessed by considering that each person can pollute 20 L/day, which makes approximately 5.1×10^4 billion L/year worldwide (Mostofa et al., 2012). This volume might seem small when compared to the total volume of waters in oceans, $\sim 1.37 \times 10^{12}$ billion L (Garrison, 2007), but one should consider that a considerable fraction of the pollution is concentrated in coastal or estuarine zones that can be key breeding areas for some marine species. Considering the demands of the world's population (7 billion in 2012 + 10.5 billions in next 50 years), marine ecosystems could be polluted approximately three times more in the next 50 years compared to the last 50 years (Mostofa et al., 2012). At equal technology, there seems to be little doubt that some control of the world's population could be important to solve problems in marine ecosystems.

8. Awareness among citizens of all countries

Awareness is an important factor to make citizens understand problems such as the effect of pollution on water environments and the loss of marine biodiversity, and it should be raised in people engaged in all relevant sectors as well as in the general population. There are three series of arguments that could be used to raise awareness. The first is how marine pollution affects humans and other organisms through the food chain, which has been discussed

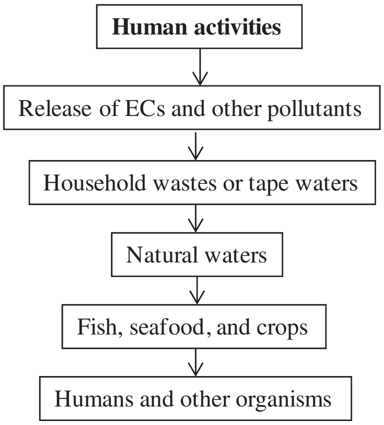

Fig. 4. Transmission of contaminants to humans and other organisms through food consumption.

previously. The second is how the loss of marine biodiversity affects the food chain. There is a close connection between marine biodiversity and the availability of food for fish and other organisms, which are further linked with humans. This can be expressed as follows:

$$\text{Loss of marine biodiversity} \rightarrow \text{Loss of food for fish and other organisms} \rightarrow \text{Loss of food for humans and other organisms}$$

The third issue is connected with the way problems in marine ecosystems can be mitigated or solved. The highly trans-boundary nature of marine environments requires that in each marine problematic sector, recommended solutions should be followed by many or all countries. One-country initiatives may be largely insufficient (Mostofa and Liu, 2012), which accounts for the key role played by awareness. Moreover, there is wide space for action by aware citizens in everyday life to limit avoidable pollution in marine ecosystems, drug disposal being one such example. There should also be increased awareness that if immediate protection measures for marine ecosystems are not taken, there will be danger to future generations though contaminated fish or lack of fish and other seafood. The increasing demand for food by the increasing world's populations is in fact a two-sided issue. One the one side, it places a huge burden on marine resources. On the other side, any drastic changes in marine resources may severely impact availability of *e.g.* fish protein, which could further exacerbate the food demand problem. Therefore, among the many needs, a key one is that of raising awareness among citizens of all countries on 'save the marine resources and biodiversity from the devastating consequences of unavoidable changes, save the future generations'.

9. Conclusions and recommendations

(1) Pollution caused by ECs will require a huge technological effort to be decreased. However, at least in the case of pharmaceuticals, a huge benefit could derive from a relatively simple action. By modifying the commercialization of drugs in many countries, from '100 tablets in a bottle'-like solutions into paper or plastic sheet that can be bought one by one, one could drastically reduce the amount of disposed-of pharmaceuticals.

(2) An attempt to limit the consequences of overfishing can be made by following ecosystem-based management strategies, restricting fishing (*i*) in essential habitats during the breeding period of marine species; and (*ii*) in some specific marine locations that have high biodiversity.

(3) Algal blooms and their produced toxins could be influenced differentially by different ocean change factors (GW, OA, increased UV exposure). The effect of ocean changes on harmful algae would depend on latitude, but the exact relationship is almost unknown.

(4) SBRIs should be conducted in an exclusive zone, and developed countries should supply state-of-the-art techniques to control and/or recycle pollutants produced from such industries.

(5) Despite a substantial improvement in environmental technologies, unless a real technological revolution occurs, control of world's population appears as a key issue in limiting the problems of marine ecosystems.

(6) The success of many remedial actions is critically dependent on the awareness of citizens of all countries, who should understand that saving marine resources and biodiversity from the consequences of unavoidable changes is vital for future generations.

(7) When considering all previous issues, it is clear that international organizations could potentially play an essential role in raising awareness and in coordinating policies aimed at the protection of marine ecosystems. Comprehensive research is also vital, to achieve sustainable management and share the developed techniques among all countries.

Acknowledgments

We thank Mr. Cui Lifeng of Institute of Geochemistry, Chinese Academy of Sciences, China for generous assistance to have list of medicines from Chinese Pharmaceutical companies. The abstract of this paper has been partly presented as an Invited Speaker conference at the "BIT's 1st Annual World Congress of Ocean-2012", held on Bohai Sea Green Pearl Cruise Ship & World Expo Center, Dalian, China, September 20–22, 2012. This work was supported by the National Natural Science Foundation of China (Grant no. 41021062). DV acknowledges financial support by University of Torino – EU Accelerating Grants, project TO_Call2_2012_0047 (Impact of radiation on the dynamics of dissolved organic matter in aquatic ecosystems – DOMNAMICS).

References

Abdullah, H.M., Mahboob, M.G., Banu, M.R., Seker, D.Z., 2013. Monitoring the drastic growth of ship breaking yards in Sitakunda, a threat to the coastal environment of Bangladesh. Environmental Monitoring and Assessment 185, 3839–3851.

Albright, R., 2011. Reviewing the effects of ocean acidification on sexual reproduction and early life history stages of reef-building corals. Journal of Marine Biology 2011, 1–14. http://dx.doi.org/10.1155/2011/473615.

Albright, R., Langdon, C., 2011. Ocean acidification impacts multiple early life history processes of the Caribbean coral *Porites astreoides*. Global Change Biology 17 (7), 2478–2487.

Andersson, A.J., Mackenzie, F.T., Bates, N.R., 2008. Life on the margin, implications of ocean acidification on Mg-calcite, high latitude and cold-water marine calcifiers. Marine Ecology Progress Series 373, 265–273.

Ankley, G.T., Daston, G.P., Degitz, S.J., Denslow, N.D., Hoke, R.A., Kennedy, S.W., Miracle, A.L., Perkins, E.J., Snape, J., Tillitt, D.E., Tyler, C.R., Versteeg, D., 2006. Toxicogenomics in regulatory ecotoxicology. Environmental Science and Technology 40, 4055–4065.

Ankley, G.T., Bencic, D.C., Breen, M.S., Collette, T.W., Conolly, R.B., Denslow, N.D., Edwards, S.W., Ekman, D.R., Garcia-Reyero, N., Jensen, K.M., 2009. Endocrine disrupting chemicals in fish: developing exposure indicators and predictive models of effects based on mechanism of action. Aquatic Toxicology 92, 168–178.

Anlauf, H., D'Croz, L., O'Dea, A., 2011. A corrosive concoction, the combined effects of ocean warming and acidification on the early growth of a stony coral are multiplicative. Journal of Experimental Marine Biology and Ecology 397, 13–20.

Ardron, J.A., 2008. The challenge of assessing whether the OSPAR network of marine protected areas is ecologically coherent. Hydrobiologia 606, 45–53.

Arnold, K.E., Findlay, H.S., Spicer, J.I., Daniels, C.L., Boothroyd, D., 2009. Effect of CO_2-related acidification on aspects of the larval development of the European lobster, *Homarus gammarus* L. Biogeosciences Discussions 6, 1747–1754.

Ask, J., Karlsson, J., Persson, L., Ask, P., Bystrom, P., Jansson, M., 2009. Whole-lake estimates of carbon flux through algae and bacteria in benthic and pelagic habitats of clearwater lakes. Ecology 90, 1923–1932.

Backer, L.C., Kirkpatrick, B., Fleming, L.E., Cheng, Y.-S., Pierce, R., Bean, J.A., Clark, R., Johnson, D., Wanner, A., Tamer, R., Baden, D.G., 2005. Occupational exposure to aerosolized brevetoxins during Florida red tide events: impacts on a healthy worker population. Environmental Health Perspectives 1135, 644–649.

Backer, L.C., Carmichael, W., Kirkpatrick, B., Williams, C., Irvin, M., Zhou, Y., Johnson, T.B., Nierenberg, K., Hill, V.R., Kieszak, S.M., Cheng, Y.-S., 2008.

Recreational exposure to microcystins during a *Microcystis aeruginosa* bloom in a small lake. Marine Drugs 6, 389–406.

Ballare, C.L., Caldwell, M.M., Flint, S.D., Robinson, S.A., Bornman, J.F., 2011. Effects of solar ultraviolet radiation on terrestrial ecosystems. Patterns, mechanisms, and interactions with climate change. Photochemical and Photobiological Sciences 10, 226–241.

Bascompte, J., Melián, C.J., Sala, E., 2005. Interaction strength combinations and the overfishing of a marine food web. Proceedings of the National Academy of Sciences of the United States of America 102, 5443–5447.

Basha, S., Gaur, P.M., Thorat, R.B., Trivedi, R.H., Mukhopadhyay, S.K., Anand, N., Desai, S.H., Mody, K.H., Jha, B., 2007. Heavy metal content of suspended particulate matter at world's largest ship-breaking yard, Alang-Sosiya, India. Water Air and Soil Pollution 178, 373–384.

Battarbee, R.W., Simpson, G.L., Shilland, E.M., Flower, R.J., Kreiser, A., Yang, H., 2013. Recovery of UK lakes from acidification: an assessment using combined palaeoecological and contemporary diatom assemblage data. Ecological Indicators (in press).

Beamish, R.J., 1976. Acidification of lakes in Canada by acid precipitation and the resulting effects on fishes. Water Air and Soil Pollution 6, 501–514.

Beaufort, L., Probert, I., de Garidel-Thoron, T., Bendif, E.M., Ruiz-Pino, D., Metzl, N., Goyet, C., Buchet, N., Coupel, P., Grelaud, M., 2011. Sensitivity of coccolithophores to carbonate chemistry and ocean acidification. Nature 476, 80–83.

Beets, J., Friedlander, A., 1998. Evaluation of a conservation strategy: a spawning aggregation closure for red hind, *Epinephelus guttatus*, in the US Virgin Islands. Environmental Biology of Fishes 55, 91–98.

Bestor, T.C., 2000. How sushi went global. Foreign Policy 121, 54–63.

Bhatt, P.N., 2004. Monitoring of Marine Pollution at Alang–Sosiya Seacoast with Respect to Oil and Grease. Final Progress Report. Dept. of Analytical Chemistry. Bhavnagar University, Gujarat, India.

Bianchi, T.S., Allison, M.A., 2009. Large-river delta-front estuaries as natural recorders of global environmental change. Proceedings of the National Academy of Sciences of the United States of America 106, 8085–8092.

Blackford, J.C., Gilbert, F.J., 2007. pH variability and CO_2 induced acidification in the North Sea. Journal of Marine Systems 64, 229–241.

Block, B.A., Teo, Steven L.H., Walli, A., Boustany, A., Stokesbury, M.J.W., Farwell, C.J., Weng, K.C., Dewar, H., Williams, T.D., 2005. Electronic tagging and population structure of Atlantic bluefin tuna. Nature 434, 1121–1127.

BOBLME, 2010. Status of Hilsa *Tenualosa ilisha* Management in the Bay of Bengal. Report to FAO Bay of Bengal Large Marine Ecosystem BOBLME Project. BOBLME-2010-Ecology-01, pp. 1–70.

Bollmann, J., Herrle, J.O., 2007. Morphological variation of *Emiliania huxleyi* and sea surface salinity. Earth and Planetary Science Letters 255, 273–288.

Boyd, P.W., 2011. Beyond ocean acidification. Nature Geosciences 4, 273–274.

Brewer, P.G., Peltzer, E.T., 2009. Limits to marine life. Science 324, 347–348.

Brečević, L., Nielsen, A.E., 1989. Solubility of amorphous calcium carbonate. Journal of Crystal Growth 98, 504–510.

Bricelj, V.M., Lonsdale, J., 1997. *Aureococcus anophagefferens*: causes and ecological consequences of brown tides in the U.S. mid-Atlantic coastal waters. Limnology and Oceanography 42, 1023–1038.

Brinkmann, T., Sartorius, D., Frimmel, F.H., 2003. Photobleaching of humic rich dissolved organic matter. Aquatic Sciences 65, 415–424.

Bronk, D.A., See, J.H., Bradley, P., Killberg, L., 2007. DON as a source of bioavailable nitrogen for phytoplankton. Biogeosciences 4, 283–296.

Brooks, B.W., Chambliss, C.K., Stanley, J.K., Ramirez, A., Banks, K.E., Johnson, R.D., Lewis, R.J., 2005. Determination of select antidepressants in fish from an effluent dominated stream. Environmental Toxicology and Chemistry 24, 464–469.

Burkhardt-Holm, P., Peter, A., Segner, H., 2002. Decline of fish catch in Switzerland. Aquatic Sciences 64, 36–54.

Bushaw, K.L., Zepp, R.G., Tarr, M.A., SchulzJander, D., Bourbonniere, R.A., Hodson, R.E., Miller, W.L., Bronk, D.A., Moran, M.A., 1996. Photochemical release of biologically available nitrogen from aquatic dissolved organic matter. Nature 381, 404–407.

Byrne, R.H., Mecking, S., Feely, R.A., Liu, X., 2010. Direct observations of basin-wide acidification of the North Pacific Ocean. Geophysical Research Letters 37, L02601.

Cai, W.J., Hu, X., Huang, W.J., Murrell, M.C., Lehrter, J.C., Lohrenz, S.E., Chou, W.C., Zhai, W., Hollibaugh, J.T., Wang, Y., 2011. Acidification of subsurface coastal waters enhanced by eutrophication. Nature Geosciences 4, 766–770.

Caldeira, K., Wickett, M.E., 2003. Anthropogenic carbon and ocean pH. Nature 425, 365.

Caldeira, K., Wickett, M.E., 2005. Ocean model predictions of chemistry changes from carbon dioxide emissions to the atmosphere and ocean. Journal of Geophysical Research 110, C09S04.

Carlsson, J., McDowell, J.R., Carlsson, J.E.L., Graves, J.E., 2007. Genetic identity of YOY bluefin tuna from the eastern and western Atlantic spawning areas. Journal of Heredity 98, 23–28.

Castiglioni, S., Bagnati, R., Fanelli, R., Pomati, F., Calamari, D., Zuccato, E., 2006. Removal of pharmaceuticals in sewage treatment plants in Italy. Environmental Science and Technology 40, 357–363.

Castle, J.W., Rodgers Jr., J.H., 2009. Hypothesis for the role of toxin-producing algae in Phanerozoic mass extinctions based on evidence from the geologic record and modern environments. Environmental Geosciences 16, 1–23.

Chapman, E.W., Jørgensen, C., Lutcavage, M.E., Hilborn, R., 2011. Atlantic bluefin tuna (*Thunnus thynnus*): a state-dependent energy allocation model for growth, maturation, and reproductive investment. Canadian Journal of Fisheries and Aquatic Sciences 68, 1934–1951.

Chen, S., Gao, K., 2011. Solar ultraviolet radiation and CO_2-induced ocean acidification interacts to influence the photosynthetic performance of the red tide alga Phaeo-cystis globosa (*Prymnesiophyceae*). Hydrobiologia 675, 105–117.

Cheng, J.-H., Lin, L.-S., Ling, J.-Z., 2004. Effects of summer close season and rational utilization on redlip croaker (*Larimichthys polyactis* Bleeker) resource in the East China Sea region. Journal of Fisheries Sciences of China 16, 554–560.

Cohen, A.L., McCorkle, D.C., De Putron, S., Gaetani, G.A., Rose, K.A., 2009. Morphological and compositional changes in the skeletons of new coral recruits reared in acidified seawater, insights into the biomineralization response to ocean acidification. Geochemistry Geophysics Geosystems 10, 1–12.

Collette, B., Amorim, A.F., Boustany, A., Carpenter, K.E., de Oliveira Leite Jr., N., Di Natale, A., Die, D., Fox, W., Fredou, F.L., Graves, J., Viera Hazin, F.H., Hinton, M., Juan Jorda, M., Kada, O., Minte Vera, C., Miyabe, N., Nelson, R., Oxenford, H., Pollard, D., Restrepo, V., Schratwieser, J., Teixeira Lessa, R.P., Pires Ferreira Travassos, P.E., Uozumi, Y., 2011. Thunnus thynnus. In: IUCN 2012. IUCN Red List of Threatened Species. Version 2012.2 www.iucnredlist.org.

Constanzo, S.D., Murby, J., Bates, J., 2004. Ecosystem response to antibiotics entering the aquatic environment. Marine Pollution Bulletin 51, 218–223.

Cooley, S.R., Kite-Powell, H.L., Doney, S.C., 2010. Ocean acidification's potential to alter global marine ecosystem services. Oceanography 22, 172–181.

Cooper, T.F., De'ath, G., Fabricius, K.E., Lough, J.M., 2007. Declining coral calcification in massive *Porites* in two nearshore regions of the Northern Great Barrier Reef. Global Change Biology 14, 529–538.

Corcoran, J., Winter, M.J., Tyler, C.R., 2010. Pharmaceuticals in the aquatic environment: a critical review of the evidence for health effects in fish. Critical Reviews in Toxicology 40, 287–304.

Crane, M., Watts, C., Boucard, T., 2006. Chronic aquatic environmental risks from exposure to human pharmaceuticals. Science of the Total Environment 367, 23–41.

Curtis, C., Evans, C., Helliwell, R., Monteith, D., 2005. Nitrate leaching as a confounding factor in chemical recovery from acidification in UK upland waters. Environmental Pollution 137, 73–82.

Cuthbert, R., Taggart, M.A., Prakash, V., Saini, M., Swarup, D., Upreti, S., Mateo, R., Chakraborty, S.S., Deori, P., Green, R.E., 2011. Effectiveness of action in India to reduce exposure of *Gyps* Vultures to the toxic veterinary drug diclofenac. PLoS ONE 65, e19069.

Daughton, C.G., Ternes, T.A., 1999. Pharmaceuticals and personal care products in the environment: agents of subtle change? Environmental Health Perspectives 107, 907–938.

Davis, T.W., Berry, D.L., Boyer, G.L., Gobler, C.J., 2009. The effects of temperature and nutrients on the growth and dynamics of toxic and non-toxic strains of *Microcystis* during cyanobacteria blooms. Harmful Algae 8, 715–725.

De Laender, F., Hammer, J., Hendriks, A.J., Soetaert, K., Janssen, C.R., 2011. Combining monitoring data and modeling identifies PAHs as emerging contaminants in the Arctic. Environmental Science and Technology 45, 9024–9029.

de Moel, H., Ganssen, G.M., Peeters, F.J.C., Jung, S.J.A., Brummer, G.J.A., Kroon, D., Zeebe, R.E., 2009. Planktic foraminiferal shell thinning in the Arabian Sea due to anthropogenic ocean acidification? Biogeosciences 6, 1917–1925.

DeLorenzo, M.E., Fleming, J., 2008. Individual and mixture effects of selected pharmaceuticals and personal care products on the marine phytoplankton species *Dunaliella tertiolecta*. Archives of Environmental Contamination and Toxicology 54, 203–210.

Demaria, F., 2010. Shipbreaking at Alang–Sosiya India, an ecological distribution conflict. Ecological Economics 70, 250–260.

Desai, A., Vyas, P., 1997. Preliminary Studies on Microbial Ecology of Ship-breaking Yard at Alang, Gujarat. Gujarat Ecology Commission, Ecological Restoration and Planning for Alang–Sosiya Ship-breaking Yard, Gujarat.

Dholakia, A.D., 1997. Studies on Coastal Fauna. Gujarat Ecology Commission, Ecological Restoration and Planning for Alang–Sosiya Ship-breaking Yard, Gujarat.

Doherty, P., Fowler, T., 1994. An empirical test of recruitment limitation in a coral reef fish. Science 263, 935–939.

Done, T.J., 1999. Coral community adaptability to environmental change at the scales of regions, reefs and reef zones. American Zoologist 39, 66–79.

Doney, S.C., Mahowald, N., Lima, I., Feely, R.A., Mackenzie, F.T., Lamarque, J.-F., Rasch, P.J., 2007. Impact of anthropogenic atmospheric nitrogen and sulfur deposition on ocean acidification and the inorganic carbon system. Proceedings of the National Academy of Sciences of the United States of America 104, 14580–14585.

Doney, S.C., Fabry, V.J., Feely, R.A., Kleypas, J.A., 2009. Ocean acidification: the other CO_2 problem. Annual Review of Marine Science 1, 169–192.

Druon, J., 2010. Habitat mapping of the Atlantic bluefin tuna derived from satellite data, its potential as a tool for the sustainable management of pelagic fisheries. Marine Policy 34, 293–297.

Edyvane, K., 1999. Conserving Marine Biodiversity in South Australia – Part 1 – Background, Status and Review of Approach to Marine Biodiversity Conservation in South Australia. South Australian Research and Development Institute.

Elofsson, K., 2010. The costs of meeting the environmental objectives for the Baltic Sea: a review of the literature. AMBIO 39, 49–58.

EMEA, 2006. Committee for Medicinal Products for Human Use CHMP. Guideline on the Environmental Risk Assessment of Medicinal Products for Human Us http://www.emea.europa.eu/pdfs/human/swp/444700en.pdf or Doc. Ref. EMEA/CHMP/SWP/4447/00.

Etheridge, S.M., 2010. Paralytic shellfish poisoning: seafood safety and human health perspectives. Toxicon 56, 108–122.

EU, 1994. Assessment of potential risks to the environment posed by medicinal products for human use, excluding products containing live genetically modified organisms. EU Ad Hoc Working Party, III/5504/94 Draft 4.

Evans, C., Cullen, J.M., Alewell, C., Kopácek, J., Marchetto, A., Moldan, F., Prechtel, A., Rogora, M., Veselý, J., Wright, R., 2001. Recovery from acidification in European surface waters. Hydrology and Earth System Sciences Discussions 5, 283–298.

Fabry, V.J., Seibel, B.A., Feely, R.A., Orr, J.C., 2008. Impacts of ocean acidification on marine fauna and ecosystem processes. ICES Journal of Marine Science 65, 414–432.

FAO, 2008. The State of World Fisheries and Aquaculture 2008, p. 192. Rome, 2009.

Farley, J.H., Davis, T.L.O., 1998. Reproductive dynamics of southern bluefin tuna, *Thunnus maccoyii*. Fishery Bulletin 96, 223–236.

Feely, R.A., Sabine, C.L., Hernandez-Ayon, J.M., Ianson, D., Hales, B., 2008. Evidence for upwelling of corrosive acidified water onto the continental shelf. Science 320, 1490.

Feng, Y., Warner, M.E., Zhang, Y., Sun, J., Fu, F.X., Rose, J.M., Hutchins, D.A., 2008. Interactive effects of increased $p\mathrm{CO_2}$, temperature and irradiance on the marine coccolithophore *Emiliania huxleyi* (Prymnesiophyceae). European Journal of Phycology 43, 87–98.

Fent, K., Weston, A.A., Caminada, D., 2006. Ecotoxicology of human pharmaceuticals. Aquatic Toxicology 76, 122–159.

Ferrari, B., Mons, R., Vollat, B., Fraysse, B., Paxeus, N., Lo Giudice, R., Pollio, A., Garric, J., 2004. Environmental risk assessment of six human pharmaceuticals, are the current environmental risk assessment procedures sufficient for the protection of the aquatic environment? Environmental Toxicology and Chemistry 23, 1344–1354.

Fine, M., Tchernov, D., 2007. Scleractinian coral species survive and recover from decalcification. Science 315, 1811.

Fleming, L.E., Kirkpatrick, B., Backer, L.C., Bean, J.A., Wanner, A., Dalpra, D., Tamer, R., Zaias, J., Cheng, Y.S., Pierce, R., Naar, J., Abraham, W., Clark, R., Zhou, Y., Henry, M.S., Johnson, D., Van De Bogart, G., Bossart, G.D., Harrington, M., Baden, D.G., 2005. Initial evaluation of the effects of aerosolized Florida red tide toxins Brevetoxins in persons with Asthma. Environmental Health Perspectives 1135, 650–657.

Frayer, L., 2011, Jan. 5. 754-Pound Tuna Sells for Record $396,000 in Tokyo. AOL News. http://www.aolnews.com/2011/01/05/754-pound-bluefin-tuna-sells-for-record-396-000-in-tokyo.

Froese, R., Pauly, D., 2010. Species Fact Sheet, *Thunnus thynnus* Linnaeus, 1758 from: www.fishbase.org http://www.fishbase.org/summary/SpeciesSummary.php?genusname=Thunnus&speciesname=thynnus.

Galuardi, B., Royer, F., Golet, W., Logan, J., Neilson, J., Lutcavage, M., 2010. Complex migration routes of Atlantic bluefin tuna (*Thunnus thynnus*) question current population structure paradigm. Canadian Journal of Fisheries and Aquatic Sciences 67, 966–976.

Gao, K.S., Zheng, Y.Q., 2010. Combined effects of ocean acidification and solar ultraviolet radiation on photosynthesis, growth, pigmentation and calcification of the coralline alga *Corallina sessilis* (Rhodophyta). Global Change Biology 16, 2388–2398.

Gao, K.S., Helbling, E.W., Häder, D.P., Hutchins, D.A., 2012a. Ocean acidification and marine primary producers under the sun: a review of interactions between $\mathrm{CO_2}$, warming, and solar radiation. Marine Ecology Progress Series 470, 167–189.

Gao, K.S., Xu, J.T., Gao, G., Li, Y.H., Hutchins, D.A., Huang, B.Q., Wang, L., Zheng, Y., Jin, P., Cai, X.N., Häder, D.P., Li, W., Xu, K., Liu, N.N., Riebesell, U., 2012b. Rising $\mathrm{CO_2}$ and increased light exposure synergistically reduce marine primary productivity. Nature Climate Change 2, 519–523.

Garrison, T., 2007. Oceanography: an Invitation to Marine Science, sixth ed. Thomson Brooks/Cole Pub Co, Belmont.

Gennings, C., Molot, L.A., Dillon, P., 2001. Enhanced photochemical loss of organic carbon in acidic waters. Biogeochemistry 52, 339–354.

Gonzalez, F.J., Peters, J.M., Cattley, R.C., 1998. Mechanism of action of the non-genotoxic peroxisome proliferators: role of the peroxisome proliferatoractivated receptor α. Journal of the National Cancer Institute 90, 1702–1709.

Granéli, W., Lindell, M., De Farria, B.M., De Assis Esteves, F., 1998. Photoproduction of dissolved inorganic carbon in temperate and tropical lakes-dependence on wavelength band and dissolved organic carbon concentration. Biogeochemistry 43, 175–195.

Greene, R.M., Lehrter, J.C., Hagy III, J.D., 2009. Multiple regression models for hindcasting and forecasting midsummer hypoxia in the Gulf of Mexico. Ecological Applications 19, 1161–1175.

Gren, I.-M., 2008. Costs and Benefits from Nutrient Reductions to the Baltic Sea. Report 5877. Swedish Environmental Protection Agency, Stockholm.

Grigorakis, K., Rigos, G., 2011. Aquaculture effects on environmental and public welfare – the case of Mediterranean mariculture. Chemosphere 85, 899–919.

Haldar, G.C., Mazid, M.A., Rahman, M.A., Amin, S.M.N., 2001. The present status of Hilsha (*Tenualusa ilisha*) fishery in Bangladesh. In: Blaber, S., Brewer, D., Milton, D., Baino, C. (Eds.), Proceedings of the International Terubok Conference. Sarawak Development Institute (SDI), 93000 Kuching, Sarawak, Malaysia, pp. 52–64.

Haldar, G.C., Rahman, M.A., 1998. Ecology of Hilsa, *Tenualosa ilisha* (Hamilton). In: Mazid, M.A., Blaber, S.J.M. (Eds.), Proceedings of BFRI/ACIAR/CSIRO Workshop on Hilsa Fisheries Research in Bangladesh Held on 3–4 March 1998 at Bangladesh Agricultural Research Council, Dhaka, Bangladesh, vol. 6. Bangladesh Fisheries Research Institute (BFRI), pp. 11–19.

Haldar, G.C., Rahman, M., Haroon, A.K.Y., 1992. Hilsa, *Tenualosa ilisha* (Ham.) fishery of Feni river with reference to the impacts of the flood control structures. Journal of Zoology 7, 51–56.

Halpern, B.S., Walbridge, S., Selkoe, K.A., Kappel, C.V., Micheli, F., D'Agrosa, C., Bruno, J.F., Casey, K.S., Ebert, C., Fox, H.E., 2008. A global map of human impact on marine ecosystems. Science 319, 948–952.

Harvell, C.D., Kim, K., Burkholder, J.M., Colwell, R.R., Epstein, P.R., Grimes, D.J., Hofmann, E.E., Lipp, E.K., Osterhaus, A.D.M.E., Overstreet, R.M., 1999. Emerging marine diseases-climate links and anthropogenic factors. Science 285, 1505–1510.

Hasan, A.B., Kabir, S., Reza, A.H.M.S., Zaman, A.H.M., Ahsan, M.N., Akbor, M.A., Rashid, M.A., Mamunur, M., 2013. Trace metals pollution in seawater and groundwater in the ship breaking area of Sitakund Upazilla, Chittagong, Bangladesh. Marine Pollution Bulletin 71, 317–324.

Hassan, K., 2010. Pollution of marine environment in Bangladesh by shipping and the preventive methods. In: Proceedings of International Conference on Environmental Aspects of Bangladesh ICEAB10, Sept. 2010, Japan.

Hessen, D.O., Andersen, T., Larsen, S., Skjelkvale, B.L., de Wit, H.A., 2009. Nitrogen deposition, catchment productivity, and climate as determinants of lake stoichiometry. Limnology and Oceanography 54, 2520–2528.

Heyman, W.D., Kjerfve, B., Graham, R.T., Rhodes, K.L., Garbutt, L., 2005. Spawning aggregations of *Lutjanus cyanopterus* Cuvier on the Belize Barrier Reef over a 6 year period. Journal of Fish Biology 67, 83–101.

Hirsch, R., Ternes, T., Haberer, K., Kratz, K.L., 1999. Occurrence of antibiotics in the aquatic environment. Science of the Total Environment 225, 109–118.

Hofmann, G.E., Barry, J.P., Edmunds, P.J., Gates, R.D., Hutchins, D.A., Klinger, T., Sewell, M.A., 2010. The effect of ocean acidification on calcifying organisms in marine ecosystems, an organism-to-ecosystem perspective. Annual Review of Ecology, Evolution, and Systematics 41, 127–147.

Holm, J.V., Rügge, K., Bjerg, P.L., Christensen, T.H., 1995. Occurrence and distribution of pharmaceutical organic compounds in the groundwater downgradient of a landfill Grindsted, Denmark. Environmental Science and Technology 29, 1415–1420.

Hossain, M.M., Islam, M.M., 2006. Ship Breaking Activities and its Impact on the Coastal Zone of Chittagong, Bangladesh: Towards Sustainable Management. YPSA (Young Power in Social Action) Publishers, Chittagong, Bangladesh.

Houghton, J.T., Ding, Y., Griggs, D.J., Noguer, M., van der Linden, P.J., Xiaosu, D., 2001. Climate Change 2001: the Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, pp. 1–944.

Howarth, R.W., 2008. Coastal nitrogen pollution: a review of sources and trends globally and regionally. Harmful Algae 8, 14–20.

Howarth, R., Chan, F., Conley, D.J., Garnier, J., Doney, S.C., Marino, R., Billen, G., 2011. Coupled biogeochemical cycles: eutrophication and hypoxia in temperate estuaries and coastal marine ecosystems. Frontiers in Ecology and the Environment 9, 18–26.

Huesemann, M.H., Skillman, A.D., Creclius, E.A., 2002. The inhibition of marine nitrification by ocean disposal of carbon dioxide. Marine Pollution Bulletin 44, 142–148.

Hughes, T.P., 1994. Catastrophes, phase-shifts, and large-scale degradation of a Caribbean coral reef. Science 265, 1547–1551.

Huisman, J.P., Pham Thi, N.N., Karl, D.M., Sommeijer, B., 2006. Reduced mixing generates oscillations and chaos in the oceanic deep chlorophyll maximum. Nature 439, 322–325.

Hutchings, J., 2000. Collapse and recovery of marine fisheries. Nature 406, 882–885.

ICCAT, 2003. Report of the Standing Committee on Research and Statistics 2002–2003. ICCAT, Madrid.

ICCAT, 2009. Report of the 2008 Atlantic Bluefin Tuna Stock Assessment Session, pp. 1–71 [PDF] Available: http://www.iccat.int/Documents/SCRS/DetRep/DET_BFT_EN.pdf.

ICCAT Scientific Committee, 2010. Executive Summary Bluefin Tuna BFT. Retrieved Feb 26, 2011, from ICCAT Stock Assessments http://www.iccat.int/Documents/SCRS/ExecSum/BFT_EN.pdf.

Imai, I., Kimura, S., 2008. Resistance of the fish-killing dinoflagellate *Cochlodinium polykrikoides* against algicidal bacteria isolated from the coastal sea of Japan. Harmful Algae 7, 360–367.

Imai, I., Yamaguchi, M., Hori, Y., 2006. Eutrophication and occurrences of harmful algal blooms in the Seto Inland Sea, Japan. Plankton and Benthos Research 1, 71–84.

Ishida, N., Mitamura, O., Nakayama, M., 2006. Seasonal variation in biomass and photosynthetic activity of epilithic algae on a rock at the upper littoral area in the north basin of Lake Biwa, Japan. Limnology 7, 175–183.

Islam, K.L., Hossain, M.M., 1986. Effect of ship scrapping activities on the soil and sea environment in the coastal area of Chittagong, Bangladesh. Marine Pollution Bulletin 17, 462–463.

Islam, S., Alam, A.K.M.R., Islam, S., 2010. Analysis of metal in wastewater collected from three pharmaceutical industries located in Tongi area of Gazipur district. Bangladesh Journal of Scientific and Industrial Research 453, 277–282.

Jackson, J.B.C., Kirby, M.X., Berger, W.H., Bjorndal, K.A., Botsford, L.W., Bourque, B.J., Bradbury, R.H., Cooke, R., Erlandson, J., Estes, J.A., Hughes, T.P., Kidwell, S., Lange, C.B., Lenihan, H.S., Pandolfi, J.M., Peterson, C.H., Steneck, R.S., Tegner, M.J., Warner, R.R., 2001. Historical overfishing and the recent collapse of coastal ecosystems. Science 293, 629–638.

Jiang, C., Zhu, L., Hu, X., Cheng, J., Xie, M., 2011. Reasons and control of eutrophication. In: Ansari, A.A., Gill, S.S., Lanza, G.R., Rast, W. (Eds.), Eutrophication: Causes, Consequences and Control. Springer, New York, pp. 325–340.

Jobling, S., Coey, S., Whitmore, J.G., Kime, D.E., Van Look, K.J.W., McAllister, B.G., Beresford, N., Henshaw, A.C., Brighty, G., Tyler, C.R., 2002. Wild intersex roach (*Rutilus rutilus*) have reduced fertility. Biology of Reproduction 67, 515–524.

Jones, O., Voulvoulis, N., Lester, J., 2001. Human pharmaceuticals in the aquatic environment a review. Environmental Technology 22, 1383–1394.

Karlsson, J., Bystrom, P., Ask, J., Ask, P., Persson, L., Jansson, M., 2009. Light limitation of nutrient poor lake ecosystems. Nature 460, 506–580.

Keeling, R.E., Körtzinger, A., Gruber, N., 2010. Ocean deoxygenation in a warming world. Annual Review of Marine Science 2, 199–229.

Khan, M.A.A., Khan, Y.S.A., 2003. Trace metals in littoral sediments from the north coast of the Bay of Bengal along the ship breaking areas, Chittagong, Bangladesh. Journal of Biological Sciences 311, 1050–1057.

Kimura, S., Kato, Y., Kitagawa, T., Yamaoka, N., 2010. Impacts of environmental variability and global warming scenario on Pacific bluefin tuna (*Thunnus orientalis*) spawning grounds and recruitment habitat. Progress in Oceanography 86, 39–44.

Kitagawa, T., Kato, Y., Miller, M.J., Sasai, Y., Sasaki, H., Kimura, S., 2010. The restricted spawning area and season of Pacific bluefin tuna facilitate use of nursery areas: a modeling approach to larval and juvenile dispersal processes. Journal of Experimental Marine Biology and Ecology 393, 23–31.

Kloas, W., Urbatzka, R., Opitz, R., Würtz, S., Behrends, T., Hermelink, B., Hofmann, F., Jagnytsch, O., Kroupova, H., Lorenz, C., 2009. Endocrine disruption in aquatic vertebrates. Annals of the New York Academy of Sciences 1163, 187–200.

Köhler, S., Buffam, I., Jonsson, A., Bishop, K., 2002. Photochemical and microbial processing of stream and soil water dissolved organic matter in a boreal forested catchment in northern Sweden. Aquatic Sciences 64, 269–281.

Kopáček, J., Brzáková, M., Hejzlar, J., Nedoma, J., Porcal, P., Vrba, J., 2004. Nutrient cycling in a strongly acidified mesotrophic lake. Limnology and Oceanography 49, 1202–1213.

Kroeker, K.J., Kordas, R.L., Crim, R.N., Singh, G.G., 2010. Meta-analysis reveals negative yet variable effects of ocean acidification on marine organisms. Ecology Letters 13, 1419–1434.

Kuffner, I.B., Andersson, A.J., Jokiel, P.L., Rodgers, K.S., Mackenzie, F.T., 2008. Decreased abundance of crustose coralline algae due to ocean acidification. Nature Geosciences 1, 114–117.

Kurihara, H., 2008. Effects of CO_2-driven ocean acidification on the early developmental stages of invertebrates. Marine Ecology Progress Series 373, 275–284.

Langdon, C., Atkinson, M.J., 2005. Effect of elevated pCO_2 on photosynthesis and calcification of corals and interactions with seasonal change in temperature/irradiance and nutrient enrichment. Journal of Geophysical Research 110C9, C09S07.

Larsen, S., Andersen, T.O.M., Hessen, D.O., 2011. Climate change predicted to cause severe increase of organic carbon in lakes. Global Change Biology 17, 1186–1192.

Letscher, R.T., Hansell, D.A., Kadko, D., Bates, N.R., 2013. Dissolved organic nitrogen dynamics in the Arctic Ocean. Marine Chemistry 148, 1–9.

Lotze, H.K., Lenihan, H.S., Bourque, B.J., Bradbury, R.H., Cooke, R.G., Kay, M.C., Kidwell, S.M., Kirby, M.X., Peterson, C.H., Jackson, J.B.C., 2006. Depletion, degradation, and recovery potential of estuaries and coastal seas. Science 312, 1806–1809.

Luckas, B., Dahlmann, J., Erler, K., Gerdts, G., Wasmund, N., Hummert, C., Hansen, P., 2005. Overview of key phytoplankton toxins and their recent occurrence in the North and Baltic Seas. Environmental Toxicology 20, 1–17.

Ma, X., Green, S.A., 2004. Photochemical transformation of dissolved organic carbon in Lake Superior-an in-situ experiment. Journal of Great Lakes Research 30 (Suppl. 1), 97–112.

Mackenzie, F.T., 1995. Global climate change: climatically important biogenic gases and feedbacks. In: Woodwell, G., Mackenzie, F.T. (Eds.), Biotic Feedbacks in the Global Climatic System: Will the Warming Feed the Warming? Oxford Univ Press, New York, pp. 22–46.

MacKenzie, B.R., Mariani, P., 2012. Spawning of Bluefin Tuna in the Black Sea: historical evidence, environmental constraints and population plasticity. PLoS ONE 77, e39998.

MacKenzie, B.R., Mosegaard, H., Rosenberg, A.A., 2009. Impending collapse of bluefin tuna in the northeast Atlantic and Mediterranean. Conservation Letters 21, 26–35.

Maier, C., Hegeman, J., Weinbauer, M.G., Gattuso, J.P., 2009. Calcification of the cold-water coral *lophelia pertusa* under ambient and reduced pH. Biogeosciences Discussions 6, 1671–1680.

Mapstone, B., August 2008. Acid Oceans in the Spotlight, fourth ed. Antarctic Climate and Ecosystem News.

Marion, G., Furtado, J., Proaño, L., Corridoni, L., Musalli, M.A., Blanca, M., 2010. Overfishing and the case of the Atlantic Bluefin Tuna. In: 3rd UPC International Seminar on Sustainable Technology Development, 11th–18th June 2010, pp. 1–15.

Matear, R.J., Hirst, A.C., 2003. Long-term changes in dissolved oxygen concentrations in the ocean caused by protracted global warming. Global Biogeochemical Cycles 17, 1125.

McCarthy, M.J., Lavrentyev, P.J., Yang, L.Y., Zhang, L., Chen, Y.W., Qin, B.Q., Gardner, W.S., 2007. Nitrogen dynamics and microbial food web structure during a summer cyanobacterial bloom in a subtropical, shallow, well-mixed, eutrophic lake Lake Taihu, China. Hydrobiologia 581, 195–207.

McGuirk, R., Jun 14, 2012. Australia Creates World's Largest Marine Reserve Network, Limits Fishing, Oil, Gas Exploration. The Associated Press.

Meryl, W., 1996. The transition in the contribution of living aquatic resources to food security, food, agriculture, and the environment discussion. In: Paper 13 International Food Policy Research Institute, Washington D.C., pp. 27–28.

Millero, F., 2007. The marine inorganic carbon cycle. Chemical Review 107, 308–341.

Minella, M., Rogora, M., Vione, D., Maurino, V., Minero, C., 2011. A model approach to assess the long-term trends of indirect photochemistry in lake water: the case of Lake Maggiore NW Italy. Science of the Total Environment 409, 3463–3471.

Mitra, A., Barua, P., Zaman, S., Banerjee, K., 2012. Analysis of trace metals in commercially important crustaceans collected from UNESCO protected world heritage site of Indian Sundarbans. Turkish Journal of Fisheries and Aquatic Sciences 12, 53–66.

Moore, S.K., Vera, L., Trainer, V.L., Mantua, N.J., Parker, M.S., Laws, E.A., Backer, L.C., Fleming, L.E., 2008. Impacts of climate variability and future climate change on harmful algal blooms and human health. Environmental Health 7 (Suppl. 2), S4.

Morita, M., Suwa, R., Iguchi, A., Nakamura, M., Shimada, K., Sakai, K., Suzuki, A., 2010. Ocean acidification reduces sperm flagellar motility in broadcast spawning reef invertebrates. Zygote 18, 103–107.

Mostofa, K.M.G., Liu, C.Q., 2012. Conversion of '100 Tablets in a Bottle' into a Paper or Plastic Sheet Among Chinese Pharmaceuticals Companies. Report Submitted to 'State Administration of Foreign Experts Affairs (SAFEA)', Beijing, China.

Mostofa, K.M.G., Sakugawa, H., 2009. Spatial and temporal variations and factors controlling the concentrations of hydrogen peroxide and organic peroxides in rivers. Environmental Chemistry 6, 524–534.

Mostofa, K.M.G., Wu, F.C., Liu, C.Q., Vione, D., Yoshioka, T., Sakugawa, H., Tanoue, E., 2011. Photochemical, microbial and metal complexation behavior of fluorescent dissolved organic matter in the aquatic environments (Invited review). Geochemical Journal 45, 235–254.

Mostofa, K.M.G., Liu, C.Q., Gao, K., Vione, D., Ogawa, H., 2012. Challenges and solutions to marine ecosystems (Invited Speaker). In: Proceedings of BIT's 2nd Annual World Congress of Marine Biotechnology WCMB-2012, September 19–23, Dalian, China.

Mostofa, K.M.G., Liu, C.Q., Mottaleb, A., Wan, G.J., Ogawa, H., Vione, D., Yoshioka, T., Wu, F.C., 2013a. Dissolved organic matter in natural waters. In: Mostofa, K.M.G., Yoshioka, T., Mottaleb, A., Vione, D. (Eds.), Photobiogeochemistry of Organic Matter: Principles and Practices in Water Environment. Springer, New York, pp. 1–137.

Mostofa, K.M.G., Liu, C.Q., Pan, X.L., Yoshioka, T., Vione, D., Minakata, D., Gao, K., Sakugawa, H., Komissarov, G.G., 2013b. Photosynthesis in nature: a new look. In: Mostofa, K.M.G., Yoshioka, T., Mottaleb, A., Vione, D. (Eds.), Photobiogeochemistry of Organic Matter: Principles and Practices in Water Environment. Springer, New York, pp. 561–686.

Mostofa, K.M.G., Liu, C.Q., Pan, X.L., Vione, D., Hayakawa, K., Yoshioka, T., Komissarov, G.G., 2013c. Chlorophylls and their degradation in Nature. In: Mostofa, K.M.G., Yoshioka, T., Mottaleb, A., Vione, D. (Eds.), Photobiogeochemistry of Organic Matter: Principles and Practices in Water Environment. Springer, New York, pp. 687–768.

Mostofa, K.M.G., Liu, C.Q., Li, S., Mottaleb, A., 2013d. Impacts of global warming on biogeochemical cycles in natural waters. In: Mostofa, K.M.G., Yoshioka, T., Mottaleb, A., Vione, D. (Eds.), Photobiogeochemistry of Organic Matter: Principles and Practices in Water Environment. Springer, New York, pp. 851–914.

Moy, A.D., Howard, W.R., Bray, S.G., Trull, T.W., 2009. Reduced calcification in modern Southern Ocean planktonic foraminifera. Nature Geosciences 2, 276–280.

Muhling, B.A., Lamkin, J.T., Quattro, J.M., Smith, R.H., Roberts, M.A., Roffer, M.A., Ramírez, K., 2011a. Collection of larval bluefin tuna *Thunnus thynnus* outside documented western Atlantic spawning grounds. Bulletin of Marine Science 87, 687–694.

Muhling, B.A., Lee, S., Lamkin, J.T., Liu, Y., 2011b. Predicting the effects of climate change on bluefin tuna (*Thunnus thynnus*) spawning habitat in the Gulf of Mexico. ICES Journal of Marine Science 68, 1051–1062.

Myers, R.A., Worm, B., 2003. Rapid worldwide depletion of predatory fish communities. Nature 423, 280–283.

Nakamura, M., Ohki, S., Suzuki, A., Sakai, K., 2011. Coral larvae under ocean acidification, survival, metabolism, and metamorphosis. PLoS ONE 6, e14521.

Nassef, M., Matsumoto, S., Seki, M., Khalil, F., Kang, I.J., Shimasaki, Y., Oshima, Y., Honjo, T., 2010. Acute effects of triclosan, diclofenac and carbamazepine on feeding performance of Japanese medaka fish *Oryzias latipes*. Chemosphere 80, 1095–1100.

NCSG, 2011. S & P Monthly Reports of N. Cotzias Shipping Group. URL: http://www.cotzias.gr.

Neşer, G., Kontas, A., Ünsalan, D., Altay, O., Enis Darılmaz, E., Uluturhan, E., Kucuksezgin, F., Tekoğul, N., Yercan, F., 2012a. Polycyclic aromatic and aliphatic hydrocarbons pollution at the coast of Aliağa Turkey ship recycling zone. Marine Pollution Bulletin 64, 1055–1059.

Neşer, G., Kontas, A., Ünsalan, D., Uluturhan, E., Altay, O., Enis Darılmaz, E., Kucuksezgin, F., Tekoğul, N., Yercan, F., 2012b. Heavy metals contamination levels at the Coast of Aliağa Turkey ship recycling zone. Marine Pollution Bulletin 64, 882–887.

NMFS (National Marine Fisheries Service), 2004. Coral Reefs: Critical Biodiversity and Fishery Resources. www.nmfs.noaa.gov/prot_res/PR/coralhome.html.

Nurul Amin, S.M., Ara, R., Zafar, M., 2006. Conservation of marine and coastal shrimp resources and sustainable aquaculture. Research Journal of Fisheries and Hydrobiology 11, 18–22.

Oaks, J.L., Gilbert, M., Virami, M.Z., Watson, R.T., Meteyer, C.U., Rideout, B.A., Shivaprasad, H.L., Ahmed, S., Chaudhry, M.J.I., Arshad, M., Mahmood, S., Ali, A., Khan, A.A., 2004. Diclofenac residues as the cause of vulture population decline in Pakistan. Nature 427, 630–633.

Ollikainen, M., Honkatukia, J., 2001. Towards efficient pollution control in the Baltic Sea: an anatomy of current failure with suggestions for change. AMBIO 304, 245–253.

Orlando, E.F., Guillette, L.J., 2007. Sexual dimorphic responses in wildlife exposed to endocrine disrupting chemicals. Environmental Research 104, 163–173.

Orr, J.C., Fabry, V.J., Aumont, O., Bopp, L., Doney, S.C., Feely, R.A., Gnanadesikan, A., Gruber, N., Ishida, A., Joos, F., Key, R.M., Lindsay, K., Maier-Reimer, E., Matear, R., Monfray, P., Mouchet, A., Najjar, R.G., Plattner, G.-K., Rodgers, K.B., Sabine, C.L., Sarmiento, J.L., Schlitzer, R., Slater, R.D., Totterdell, I.J., Weirig, M.-F., Yamanaka, Y., Yool, A., 2005. Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. Nature 437, 681–686.

Pace, M.L., Cole, J.J., Carpenter, S.R., Kitchell, J.F., 1999. Trophic cascades revealed in diverse ecosystems. Trends in Ecology and Evolution 14, 483–488.

Paerl, H.W., Ustach, J.F., 1982. Blue-green algal scums: an explanation for their occurrence during freshwater blooms. Limnology and Oceanography 272, 212–217.

Paine, R.T., 1980. Food webs: linkage, interactions strength and community infrastructure. Journal of Animal Ecology 49, 667–685.

Panter, G.H., Hutchinson, T.H., Hurd, K.S., Sherren, A., Stanley, R.D., Tyler, C.R., 2004. Successful detection of anti-androgenic and aromatase inhibitors in pre-spawning adult fathead minnows *Pimephales promelas* using easily measured end points of sexual development. Aquatic Toxicology 70, 11–21.

Pasha, M., Mahmood, A.H., Rahman, I., Hasnat, A., 2012. Assessment of ship breaking and recycling industries in Bangladesh – An effective step towards the achievement of environmental sustainability. In: International Conference on Agricultural, Environment and Biological Sciences. ICAEBS'2012, May 26–27, 2012, Phuket.

Pauly, D., Christensen, V., Guénette, S., Pitcher, T.J., Sumaila, U.R., Walters, C.J., Watson, R., Zeller, D., 2002. Towards sustainability in world fisheries. Nature 418, 689–695.

Pelletier, D., Claudet, J., Ferraris, J., Benedetti-Cecchi, L., Garcia-Charton, J.A., 2008. Models and indicators for assessing conservation and fisheries-related effects of marine protected areas. Canadian Journal of Fisheries and Aquatic Sciences 65, 765–779.

Phlips, E.J., Badylak, S., Youn, S., Kelley, K., 2004. The occurrence of potentially toxic dinoflagellates and diatoms in a subtropical lagoon, the Indian River Lagoon, Florida, USA. Harmful Algae 3, 39–49.

Pinnegar, J.K., Polunin, N.V.C., Francour, P., Badalamenti, F., Chemello, R., Harmelin-Vivien, M.-L., Hereu, B., Milazzo, M., Zabala, M., D'Anna, G., Pipitone, C., 2000. Trophic cascades in fisheries and protected-area management of benthic marine ecosystems. Environmental Conservation 27, 179–200.

Platt, T., Fuentes-Yaco, C., Frank, K.T., 2003. Marine ecology: spring algal bloom and larval fish survival. Nature 423, 398–399.

Politi, Y., Arad, T., Klein, E., Weiner, S., Addadi, L., 2004. Sea urchin spine calcite forms via a transient amorphous calcium carbonate phase. Science 306, 1161–1164.

Prince, E.K., Myers, T.L., Kubanek, J., 2008. Effects of harmful algal blooms on competitors: allelopathic mechanisms of the red tide. Limnology and Oceanography 53, 531–541.

Pro, J., Ortiz, J.A., Boleas, S., Fernandez, C., Carbonell, G., Tarazona, J.V., 2003. Effect assessment of antimicrobial pharmaceuticals on the aquatic plant *Lemna minor*. Bulletin of Environmental Contamination and Toxicology 70, 290–295.

Ramirez, A.J., Brain, R.A., Usenko, S., Mottaleb, M.A., O'Donnell, J.G., Stahl, L.L., Wathen, J.B., Snyder, B.D., Pitt, J.L., Perez-Hurtado, P., Dobbins, L.L., Brooks, B.W., Chambliss, C.K., 2009. Occurrence of pharmaceuticals and personal care products in fish, results of a national pilot study in the United States. Environmental Toxicology and Chemistry 28, 2587–2597.

Randall, J.E., 1967. Food habits of reef fishes of the West Indies. Studies Tropical Oceanography 5, 665–847.

Reddy, M.S., Basha, S., Joshi, H.V., Ramachandraiah, G., 2005. Seasonal distribution and contamination levels of total PHCs, PAHs and heavy metals in coastal waters of the Alang–Sosiya ship scrapping yard, Gulf of Cambay, India. Chemosphere 61, 1587–1593.

Reddy, M.S., Mehta, B., Dave, S., Joshi, M., Karthikeyan, L., Sarma, V.K.S., Basha, S., Ramachandraiah, G., Bhatt, P., 2007. Bioaccumulation of heavy metals in some commercial fishes and crabs of the Gulf of Cambay. Current Science 92, 1489–1491.

Remington, S., Krusche, A., Richey, J., 2011. Effects of DOM photochemistry on bacterial metabolism and CO_2 evasion during falling water in a humic and a whitewater river in the Brazilian Amazon. Biogeochemistry 105, 185–200.

Riccioni, G., Landi, M., Ferrara, G., Milano, I., Cariani, A., Zane, L., Sella, M., Barbujani, G., Tinti, F., 2010. Spatio-temporal population structuring and genetic diversity retention in depleted Atlantic Bluefin tuna of the Mediterranean Sea. Proceedings of the National Academy of Sciences of the United States of America 107, 2102–2107.

Richardson, S.D., Ternes, T.A., 2011. Water analysis: emerging contaminants and current issues. Analytical Chemistry 83, 4614–4648.

Rico, A., Satapornvanit, K., Haque, M.M., Min, J., Nguyen, P.T., Telfer, T.C., van den Brink, P.J., 2012. Use of chemicals and biological products in Asian aquaculture and their potential environmental risks: a critical review. Reviews in Aquaculture 4, 75–93.

Riebesell, U., 2004. Effects of CO_2 enrichment on marine phytoplankton. Journal of Oceanography 60, 719–729.

Riebesell, U., Zondervan, I., Rost, B., Tortell, P.D., Zeebe, R.E., Morel, F.M.M., 2000. Reduced calcification of marine plankton in response to increased atmospheric CO_2. Nature 407, 364–367.

Riegl, B., Purkis, S.J., Keck, J., Rowlands, G.P., 2009. Monitored and modeled coral population dynamics and the refuge concept. Marine Pollution Bulletin 58, 24–38.

Roig, B., 2008. KNAPPE-knowledge and Need Assessment of Pharmaceutical Products in Environmental Waters. Final Report. European Union, 6th Framework Program, Brussels.

Rooker, J.R., Secor, D.H., De Metrio, G., Schloesser, R., Block, B.A., Neilson, J.D., 2008. Natal homing and connectivity in Atlantic bluefin tuna populations. Science 322, 742–744.

Rotschild, B., Ault, J., Philippe, G., Maurice, H., 1994. Decline of the Chesapeake Bay oyster population: a century of habitat destruction and overfishing. Marine Ecology Progress Series 111, 29–39.

Runnalls, T.J., Hala, D.N., Sumpter, J.P., 2007. Preliminary studies into the effects of the human pharmaceutical clofibric acid on sperm parameters in adult fathead minnow. Aquatic Toxicology 84, 111–118.

Sala, E., Ballesteros, W., Starr, R.M., 2001. Rapid decline of Nassau grouper spawning aggregations in Belize: fishery management and conservation needs. Fisheries 26, 23–30.

Santos, L.H.M.L.M., Araújo, A.N., Fachini, A., Pena, A., Delerue-Matos, C., Montenegro, M.C.B.S.M., 2010. Ecotoxicological aspects related to the presence of pharmaceuticals in the aquatic environment. Journal of Hazardous Materials 175, 45–95.

Sarraf, M., Stuer-Lauridsen, F., Dyoulgerov, M., Bloch, R., Wingfield, S., Watkinson, R., 2010. The Ship Breaking and Recycling Industry in Bangladesh and Pakistan. The World Bank. Report No 58275-SAS.

Shapiro, J., 1973. Blue-green algae, why they become dominant. Science 179, 382–384.

Shurin, J.B., Borer, E.T., Seabloom, E.W., Anderson, K., Blanchette, C.A., Broitman, B., Cooper, S.D., Halpern, B.S., 2002. A cross-ecosystem comparison of the strength of trophic cascades. Ecology Letters 5, 785–791.

Shved, N., Berishvili, G., Baroiller, J.F., Segner, H., Reinecke, M., 2008. Environmentally relevant concentrations of 17α-ethinylestradiol (EE2) interfere with the growth hormone (GH)/insulin-like growth factor (IGF)-I system in developing bony fish. Toxicological Sciences 106, 93–102.

Soni, A., 1997. Ecology of Intertidal Macrofauna and Literature Review for Marine Biota. Gujarat Ecology Commission, Ecological Restoration and Planning for Alang–Sosiya Ship-breaking Yard, Gujarat.

Southard, G.M., Fries, L.T., Barkoh, A., 2010. *Prymnesium parvum*: the Texas experience. Journal of the American Water Resources Association 46, 14–23.

Srinivasan, U.T., Cheung, W.L., Watson, R., Sumaila, U.R., 2010. Food security implications of global marine catch losses due to overfishing. Journal of Bioeconomics 12, 183–200.

Stedmon, C.A., Markager, S., Tranvik, L., Kronberg, L., Slätis, T., Martinsen, W., 2007a. Photochemical production of ammonium and transformation of dissolved organic matter in the Baltic Sea. Marine Chemistry 104, 227–240.

Stedmon, C.A., Thomas, D.N., Granskog, M., Kaartokallio, H., Papaditriou, S., Kuosa, H., 2007b. Characteristics of dissolved organic matter in Baltic coastal sea ice: allochthonous or autochthonous origins? Environmental Science and Technology 41, 7273–7279.

Steele, J.H., Schumacher, M., 2000. Ecosystem structure before fishing. Fisheries Research 44, 201–205.

Sulzberger, E., Durisch-Kaiser, E., 2009. Chemical characterization of dissolved organic matter DOM: a prerequisite for understanding UV-induced changes of DOM absorption properties and bioavailability. Aquatic Sciences 71, 104–126.

Sumpter, J.P., 2005. Endocrine disrupters in the aquatic environment: an overview. Acta hydrochimica et hydrobiologica 33, 9–16.

Tatters, A.O., Fu, F.X., Hutchins, D.A., 2012. High CO_2 and silicate limitation synergistically increase the toxicity of *Pseudo-nitzschia fraudulenta*. Plos One 7, e32116.

Teijon, G., Candela, L., Tamoh, K., Molina-Díaz, A., Fernández-Alba, A.R., 2010. Occurrence of emerging contaminants, priority substances (2008/105/CE) and heavy metals in treated wastewater and groundwater at Depurbaix facility (Barcelona, Spain). Science of the Total Environment 408, 3584–3595.

Teo, S.L.H., Block, B.A., 2010. Comparative influence of ocean conditions on yellowfin and Atlantic bluefin tuna catch from longlines in the Gulf of Mexico. PLoS ONE 5, e10756.

Ternes, T., 2004. Assessment of Technologies for the Removal of Pharmaceuticals and Personal Care Products in Sewage and Drinking Water Facilities to Improve the Indirect Potable Water Reuse. POSEIDON Project, Final Report. EU-FP7, Brussels.

Thomulka, K.W., McGee, D.J., 1993. Detection of biohazardous materials in water by measuring bioluminescence reduction with the marine organism *Vibrio harveyi*. Journal of Environmental Science and Health. Part A: Environmental Science and Engineering and Toxicology 28, 2153–2166.

Tranvik, L.J., Olofsson, H., Bertilsson, S., 1999. Photochemical effects on bacterial degradation of dissolved organic matter in lake water. In: Bell, C.R., Brylinsky, M., Johnson-Green, P. (Eds.), Microbial Biosystems, New Frontiers Proceedings of the 8th International Symposium on Microbial Ecology Atlantic Canada Society for Microbial Ecology, Halifax, Canada, 1999.

Trivedi, J.M., 1997. Microbiological Studies. Gujarat Ecology Commission, Ecological Restoration and Planning for Alang–Sosiya Ship-Breaking Yard, Gujarat.

UNDP, 1985. Bay of Bengal Programme: Marine Fisheries Resources Management. A Review of the Biology and Fisheries of Hilsa Ilisha in the Upper Bay of Bengal. BOBP/WP/37, pp. 1–58.

UNESCO, 2004. Impacts and Challenges of a Large Coastal Industry. Alang-Sosiya Ship-breaking Yard, Gujarat, India. In: Coastal Region and Small Island Papers 17. UNESCO, Paris, pp. 1–65.

UNFPA, 2011. The State of World Population 2011. United Nations Population Fund, New York, USA. www.unfpa.org.

Vähätalo, A.V., Zepp, R.G., 2005. Photochemical mineralization of dissolved organic nitrogen to ammonium in the Baltic Sea. Environmental Science and Technology 39, 6985–6992.

Vähätalo, A.V., Salonen, K., Münster, U., Järvinen, M., Wetzel, R.G., 2003. Photochemical transformation of allochthonous organic matter provides bioavailable nutrients in a humic lake. Archiv für Hydrobiologie 156, 287–314.

van de Merwe, J.P., Chan, A.K.Y., Lei, E.N.Y., Yau, M.S., Lam, M.H.W., Wu, R.S.S., 2011. Bioaccumulation and maternal transfer of PBDE 47 in the marine medaka *Oryzias melastigma* following dietary exposure. Aquatic Toxicology 103, 199–204.

Vidal-Dorsch, D.E., Bay, S.M., Maruya, K., Snyder, S.A., Trenholm, R.A., Vanderford, B.J., 2012. Contaminants of emerging concern in municipal wastewater effluents and marine receiving water. Environmental Toxicology and Chemistry 31, 2674–2682.

Villeneuve, D.L., Ankley, G.T., Makynen, E.A., Blake, L.S., Greene, K.J., Higley, E.B., Newsted, J.L., Giesy, J.P., Hecker, M., 2007. Comparison of fathead minnow ovary explant and H295R cell-based steroidogenesis assays for identifying endocrine-active chemicals. Ecotoxicology and Environmental Safety 68, 20–32.

Vione, D., Lauri, V., Minero, C., Maurino, V., Malandrino, M., Carlotti, M.E., Olariu, R.I., Arsene, C., 2009. Photostability and photolability of dissolved organic matter upon irradiation of natural water samples under simulated sunlight. Aquatic Sciences 71, 34–45.

Waldbusser, G.G., Bergschneider, H., Green, M.A., 2010. Size-dependent pH effect on calcification in post-larval hard clam *Mercenaria* spp. Marine Ecology Progress Series 417, 171–182.

Westneat, M., 2009. Encyclopedia of Life, *Thunnus thynnus* Linnaeus, 1758 Northern Bluefin Tuna. http//www.eol.org/pages/223943.

WGBFAS Report, 2012. Baltic Fisheries Assessment Working Group. ICES, pp. 101–150.

Wilkinson, C., 2000. Status of Coral Reefs of the World: 2004, pp. 473–491 (Chapter 18).

Worm, B., Lotze, H.K., Hillebrand, H., Sommer, U., 2002. Consumer versus resource control of species diversity and ecosystem functioning. Nature 417, 848–851.

Worm, B., Hilborn, R., Baum, J.K., Branch, T.A., Collie, J.S., Costello, C., 2009. Rebuilding global fisheries. Science 325, 578–585.

Worrall, F., Burt, T.P., 2007. Trends in DOC concentration in Great Britain. Journal of Hydrology 346, 81–92.

Xiao, M., Wu, F.C., Zhang, R., Wang, L., Li, X., Huang, R., 2011. Temporal and spatial variations of low-molecular-weight organic acids in Dianchi Lake, China. Journal of Environmental Science 23, 1249–1256.

Yamamoto-Kawai, M., McLaughlin, F.A., Carmack, E.C., Nishino, S., Shimada, K., 2009. Aragonite undersaturation in the Arctic Ocean: effects of ocean acidification and sea ice melt. Science 326, 1098–1100.

Yamashita, N., Yasojima, M., Miyajima, K., Suzuki, Y., Tanaka, H., 2006. Effects of antibacterial agents, levofloxacin and clarithromycin, on aquatic organisms. Water Science and Technology 53, 65–72.

Yan, T., Zhou, M.-J., 2004. Environmental and health effects associated with harmful algal bloom and marine algal toxins in China. Biomedical and Environmental Sciences 17, 165–176.

Yates, B.S., Rogers, W.J., 2011. Atrazine selects for ichthyotoxic *Prymnesium parvum*, a possible explanation for golden algae blooms in lakes of Texas, USA. Ecotoxicology 20, 2003–2010.

Zeebe, R.E., Wolf-Gladrow, D.A., 2001. CO_2 in Seawater: Equilibrium, Kinetics and Isotopes. In: Elsevier Oceanography Series, vol. 65, p. 346.

Zepp, R.G., Erickson, D.J., Paul, N.D., Sulzberger, B., 2011. Effects of solar UV radiation and climate change on biogeochemical cycling: interactions and feedbacks. Photochemical and Photobiological Sciences 10, 261–279.

Zhang, Y., van Dijk, M.A., Liu, M., Zhu, G., Qin, B., 2009. The contribution of phytoplankton degradation to chromophoric dissolved organic matter (CDOM) in eutrophic shallow lakes: field and experimental evidence. Water Research 43, 4685–4697.

Zondervan, I., 2007. The effects of light, macronutrients, trace metals and CO_2 on the production of calcium carbonate and organic carbon in coccolithophores—a review. Deep Sea Research Part II: Topical Studies in Oceanography 54, 521–537.