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Anthropogenic threats to coastal and marine biodiversity: A review

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ABSTRACT

Healthy oceans provide a wide range of goods and services essential for human life. Provision of food and medicines, detoxification of pollutants and recycling of nutrients are of value for human use. These goods and services are 'for free' but require intact marine ecosystems. Coastal and marine biodiversity and their supporting ecosystems are now subject to a multitude of threats. The intensity and scale of anthropogenic impacts in the world's ocean have increased dramatically during the industrial age and these impacts are combining to accelerate the loss and fragmentation of important coastal marine habitats. The present review focuses on types and impacts of anthropogenic threats to coastal and marine biodiversity with respect to diseases, overexploitation, extinction, genetic and behavioural degradation of taxa, global climate change, habitat destruction or loss, habitat degradation and fragmentation, non-indigenous species, coastal and marine pollution, altered salinity and altered sedimentation.

INTRODUCTION

Biodiversity is defined as the variability among living organisms from all sources, including, 'inter alia', terrestrial, marine, and other aquatic ecosystems, and the ecological complexes of which they are part. This includes diversity within species, between species and of ecosystems (Hawksworth, 1996).

Coastal waters constitute the interface of inland and marine environments and are some of the most productive waters. Coral reefs, soft-bottom continental shelves and upwelling continental shelves are extremely productive than the open oceans and the deep sea. The ocean's biological diversity provides immense benefits to all of human society. Knowledge about these resources is still meagre; however, trends in the best studied species and ecosystems indicate that these resources and their benefits are threatened by human activities globally (Hourigan, 1998).

GOODS AND SERVICES PROVIDED BY THE MARINE ENVIRONMENT

Marine ecosystems provide a wide variety of goods and services, including vital food resources for millions of people. A large and increasing proportion of our population lives close to the coast; thus the loss of services such as flood control and waste detoxification can have disastrous consequences (Worm et al., 2006; Kettunen, 2007).

Coastal areas also provide critical ecological services such as nutrient cycling, flood control, shoreline stability, beach replenishment and genetic resources (Scavia et al., 2002; Pan et al., 2013). Marine and coastal areas support a rich assortment of aquatic biological diversity that contributes to the economic, cultural, nutritional, social, recreational and spiritual betterment of human populations (www.fao.org/biodiversity).

Marine environment provides three types ecosystem services: provisional services, regulating and maintenance services and cultural services (Table 1) (Katsanevakis et al., 2014).

THREATS TO COASTAL AND MARINE BIODIVERSITY

Any direct or indirect human activity that threatens the

Table 1. Goods and services provided by the marine environment.

Category	Marine goods and services	Description	Examples
Production services	Food provision	Provision of Biomass for human consumption	Fishing activities and aquaculture
	Water storage and provision	Provision of water for human consumption and other uses	Coastal lakes, deltaic aquifers, desalination plants, industrial cooling processes, and coastal aquaculture
	Biotic material and biofuels	Provision of biotic elements for medicinal, ornamental, commercial or industrial purposes	Drugs, cosmetics, corals, shells, fishmeal, algal or plant fertilisers, and biomass to produce energy or biogas from decomposing material.
Regulating and maintenance services	Water purification	Removal of wastes and pollutants	Treatment of human waste, bioremediation; remineralisation; and decomposition
	Air quality regulation	Regulation of air pollutants in the lower atmosphere	-
	Coastal protection	Natural protection of the coastal zone against erosion from waves, storms or sea level rise	By biogenic and geologic structures to create protective buffer zones
	Climate regulation	The ocean acts as a sink for green house and climate active gasses	Inorganic carbon is dissolved into the seawater and used by marine organisms
	Weather regulation	Influence on the local weather conditions	Influence of coastal vegetation, wetlands, air moisture, saturation point and cloud formation
	Ocean nourishment	Natural cycling processes for availability of nutrients in seawater	Production of organic matter
	Life cycle maintenance	Healthy and diverse reproduction of species	Maintenance of key habitats for nurseries, spawning areas or migratory routes
	Biological regulation	Biological control of pests	Control of pathogens, vector borne human diseases and invasive species
Cultural services	Symbolic and aesthetic values	Exaltation of senses and emotions by seascapes, habitats or species	Values put on coastal, natural and cultural sites.
	Recreation and tourism	Opportunities for relaxation and entertainment	Coastal and offshore activities
	Cognitive effects	Inspiration for arts and applications, material for research and education, Information and awareness	Architectural designs inspired by marine shells, medical applications, test organisms for biological experiments and respect for nature

planet's biological diversity in the form of genes, populations, species, ecosystems, or other levels of biological organization is considered a threat to survival. Modern human actions threaten biological diversity on a worldwide scale (Sechrest and Brooks, 2002; Imtiyaz et al., 2011). Changes and loss in marine biodiversity are driven by anthropogenic factors in addition to natural forces (Relini, 2012).

The continued growth of human population and of per capita consumption has resulted in unsustainable exploitation of Earth's biological diversity, exacerbated by other anthropogenic environmental impacts (Hourigan, 1998; Pan et al., 2013).

The most serious and direct threats to coastal and marine biodiversity are the conversion of coastal habitats into man-made land uses (SEP, 2013). Indirect threats to marine biodiversity would be in the form of pollution and sedimentation (Hutomo and Moosa, 2005). Indiscriminate fishing, quarrying, dredging, deforestation, industrialization and other anthropogenic activities are the main threats causing considerable damage to marine environments and consequently to the associated flora and fauna (Joshi et al., 2015).

Sechrest and Brooks (2002) proposed that the major global threats to coastal and marine biodiversity include diseases, overexploitation, extinction, genetic or behavioural degradation of taxa, global climate change, habitat destruction or loss, habitat degradation and fragmentation, introduced species, coastal and marine pollution, altered salinity and altered sedimentation.

Diseases

Viral pathogens can significantly affect primary production in the sea and can reduce primary productivity by as much as 78 percent (Wommack and Collwell, 2000).

The virulent disease outbreaks can drive host populations below a threshold from which they cannot recover for example, Caribbean-wide die-off of the long spined sea urchin, *Diadema antillarum*. The most extreme case of disease impact is extinction, for example, extinction of the gastropod limpet; *Lottia alveus* in the western Atlantic ocean (Lessios, 2016).

Crain et al. (2009) reported that marine diseases may be increasing for some species due to human activities. For example, Caribbean urchin die-off, various coral diseases, lobster declines in the north Atlantic and marine mammal disease (Glenn and Pugh, 2006). Humans activities which promote disease outbreaks includes aquaculture with its artificially dense populations; shipping and ballast water transport (which facilitate disease vector transport), warming and other environmental changes (that enhance disease effects), input of terrestrial disease agents (Lafferty et al., 2004) and various synergistic stressors that weaken populations' disease resistance (Bruno et al., 2007).

Overexploitation

Humans extract biological organisms from nature for food, energy and other resources. Some of the most widespread exploitation is in the form of fishing and most marine fisheries have experienced drastic collapses in target species (Sechrest and Brooks, 2002). Overexploitation is the leading threat to vulnerable marine species and a major threat to marine ecosystems (Halpern et al., 2008).

Overfishing

Overfishing can be defined as a level of fishing which puts at risk values endorsed either by the fishing management agency, by the nation in whose waters fishing takes place, or within widely accepted international agreements. Overfishing with by-catch problems impacts the marine biodiversity through commercial fishing, recreational fishing, illegal unregulated or unreported and ghost fishing (Brown and Macfadyen, 2007; Nevill, 2008). Overharvest has led to population depletions and in some cases, local and even global extinctions of species (Kappel, 2005). Worm et al. (2006) predicted that most of the current fisheries will collapse in the next 50 years if management strategies are not altered.

Lewison and Crowder (2003) reported that the non-target species have been profoundly impacted by non-selective fisheries. Destructive fishing practices, like bottom trawling and dynamite fishing, are detrimental to both physical and biogenic habitats and the species that depend upon them (Crain et al., 2009).

Extinction

The most obvious loss of biodiversity is the extinction of unique taxa. Extinction occurs when no more individuals of a taxonomic group survive, either within a specified part of their range or forever lost across their entire range. Marine taxa have had comparatively little scientific attention paid to them, though by all calculations they contain a significant amount of species at risk of extinction in the foreseeable future (Sechrest and Brooks, 2002).

The increasing risk of extinction in the sea is widely acknowledged, and the conservation of marine biodiversity has become a high priority for researchers and managers alike (Reynolds et al., 2005; Jones et al., 2007). The pressures of fishing have given rise to species depletion: commercial extinction (SeaWeb, 2016).

Genetic or behavioural degradation of taxa

There are two main mechanisms of genetic and behavioural degradation, the outright loss of populations and alteration of populations as a result of human activity. Alteration of behaviours in response to human activity also lessens natural diversity (Sechrest and Brooks, 2002).

When populations of a species become depleted, the genetic variation is reduced, which compromises the species' ability to adapt to new environmental changes and stresses. Due to interdependencies among species, the demise of one can lead to the decrease or demise of others (SeaWeb, 2016).

Global climate change

Jackson et al. (2001) reported that effects of climate change constitute a major concern for coastal ecosystems in the long run. Climate change forces species to shift their ranges and disrupts ecological communities (Lemoine and Böhning-Gaese, 2003). Relini (2012) proposed that climate change due to oceanic temperatures, acidity and patterns of water movement, largely caused by increasing atmospheric carbon dioxide, and impacts from damage to the ozone layer.

Climate change is reflected in alterations in atmospheric, hydrological and biogeochemical cycles. These changes are associated with volcanic activity, changes in atmospheric chemistry, tidal changes, glaciations and melting of ice caps. Human activities that affect global climate change include the production of air pollution from sources such as fossil fuel combustion and burning of forests (Sechrest and Brooks, 2002).

Craig (2012) recorded that climate change is likely to significantly affect marine biodiversity in a number of ways. The core impacts of climate change on marine biodiversity are caused by:

- Increase in ocean temperatures
- Patterns of ocean currents
- Sea-level rise
- Increasing atmospheric CO_2 levels and ocean acidification
- Excessive nutrient enrichment
- Ozone depletion and increased UV radiation fluxes
- Regime shifts

Increase in ocean temperatures

IPCC (2007) reported that human-generated greenhouse gases have already led to an average increase in ocean and air temperatures of 0.4–0.8°C. According to Gitay et al. (2002), the mean surface temperature has increased by 0.6 ± 0.2°C during the 20th century.

An increase in surface water temperature is likely to affect most metabolic rates of marine organisms and be translated into significant changes in biological processes and biodiversity (Hall, 2002). Hiscock et al. (2004) proposed that effects of temperature increase on coastal organisms have an indirect influence on populations, acting on reproductive processes like development of gonads, release of propagules, survival and settlement of larval stages.

For shallow coastal waters thermal stratification combined with nutrient enrichment can lead to the occurrence of hypoxia resulting in excessive decomposing of organic matter, stratification and the development of hypoxia and anoxia (Pan et al., 2013). Slight changes in climatic patterns could have major effects, while any large local, regional or global change could have cataclysmic effects. Already, delicate oceanic coral reef ecosystems have declined recently as ocean temperatures have increased (Nevill, 2008).

As a result of this increasing temperature, marine ecosystems are also changing and causing temperature-sensitive marine species to migrate pole ward (Craig, 2012). Ocean temperature is a major determinant of marine biodiversity and that change in ocean temperature may ultimately rearrange the global distribution of life in the ocean (Tittensor et al., 2011). Increase in ocean temperature has caused a major threat to Loggerhead Turtle, Coral reefs and ecological balance of the marine and polar communities (Imtiyaz et al., 2011).

Crain et al. (2009) has noted that warming temperatures can impact marine systems at numerous levels like:

- Organism - due to changes in morphology, behaviour, and physiology.
- Population - due to altered transport processes effecting recruitment and dispersal.
- Community - due to altered species interactions.

Patterns of ocean currents

Seawater circulates in surface currents and in three-dimensional, globe-spanning, interconnected currents below the surface. Prevailing winds drive the surface currents which account for 13 to 25% of all ocean water movement. Climate change, wind patterns and sea temperatures, alters the ocean’s patterns of currents (Craig, 2012).

Kraynak and Tetrault (2003) documented that ocean currents are important to marine biodiversity for upwellings. Upwellings occur when deep nutrient-rich water rises up to replace the water carried away from the coast. Upwellings support plankton blooms and high concentrations of marine plants and animals, including commercially important species of fish.

Changes in ocean currents can convert these regions of high productivity to hypoxic zones or dead zones. Changes in wind patterns increases upwellings of nutrients creating a boom-and-bust cycle in which decaying plankton blooms consumed most of the oxygen in the water (ENN Staff, 2009).

Sea-level rise

Climate change-driven sea level rise occurs for two main reasons: thermal expansion and melting land-based ice (IPCC, 2007). Sea-level rise causes multiple impacts on highly productive–but also highly vulnerable–estuaries. It will have greatest impacts on intertidal and coastal ecosystems that have narrow windows of tolerance to flooding frequency or depth (Craig, 2012).

Rising temperatures impact marine organisms directly, but also cause waters to expand and ice caps to melt, driving sea-levels to rise at a rate of at least 2 mm/yr (Scavia et al., 2002). Galbraith et al. (2002) estimates between 20 and 70% of the coastal habitats in North American bays will be lost due to sea level rise.

Paul (2011) reported that melting of the world's major ice sheets and smaller mountain glaciers are also making a significant contribution to global sea level rise, as much as 12 cm by the end of the century. Long-term sea-level rise predictions are difficult but initial sea-level rise will primarily affect marine biodiversity in low-lying coastal areas, especially because sea-level rise appears to be accelerating (Gillis, 2012).

With about a 3°C increase in global average temperature, 30% of the world's coastal wetlands will be lost and barrier islands, mangrove forests, and near-shore coral reefs are similarly vulnerable (IPCC, 2007). Destruction or decline of these coastal ecosystems of high biodiversity will decrease coastal and marine biodiversity (Craig, 2012).

Increasing atmospheric CO_2 levels and ocean acidification

Increased carbon dioxide (CO_2) from the burning of fossil fuels and other human activities continues to affect our atmosphere (Sabine et al., 2004; IPCC, 2007).

The excessive atmospheric CO_2 is up taken by the world's oceans to maintain the balance of the carbonate buffer system. In this naturally-occurring process, atmospheric CO_2 readily dissolves into seawater and reacts with water to produce carbonic acid (H_2CO_3). The carbonic acid dissociates into H^+ and bicarbonate (HCO_3^-) ions. Bicarbonate further dissociates into more H^+ and carbonate ($CO_3^=$) ions. However, the recent uptake of CO_2 is too rapid for the supply of $CO_3^=$ ions, and therefore, H^+ and bicarbonate levels are increasing, while carbonate levels are decreasing, with the ultimate result of an increased acidity of ocean waters at a global scale, a phenomenon termed as 'ocean acidification' (Pan et al., 2013).

As CO_2 emissions continue to rise, ocean acidification is rapidly becoming a critical issue with the potential to affect many species and their ecosystems associated with human food resources (UNEP, 2010). The global ocean average pH was 8.2 but due to industrialisation oceans have absorbed increased amounts of CO_2 emissions and there has been a decrease in pH of 0.1 which represents a 30% increase in seawater's acidity. This may affect the abundance, health, physiology, biochemical properties and behaviour of marine organisms, as adults and/or in their juvenile form (Doney et al., 2009).

Impacts of ocean acidification:

- Elevated CO_2 negatively impact shelled organisms like marine bivalves (Guinotte and Fabry, 2008).
- Impacts on calcifying and photosynthesizing marine organisms and associated species (Crain et al., 2009).
- Affects orientation, balance mechanisms and behaviour in adult fin fish (Munday et al., 2010).
- Impacts in young clownfish by affecting changes in their prey, and loss or damage to their habitats (Comeau et al., 2009).
- Causes reduced shell calcification in juveniles; alteration in their body shape and size, causing serious consequences for their survival into adulthood in marine molluscs and crustaceans (Kurihara et al., 2007).

Excessive nutrient enrichment (Eutrophication and Hypoxia)

Addition of inorganic or organic N and P carried from land through river runoff or sewage inputs is known as Nutrient enrichment. It is mostly a phenomenon that has impacts on coastal waters of developed countries (Pan et al., 2013).

Howarth et al. (2000) noted that eutrophication leads to a cycle of enhanced algal blooms followed by algal death, decomposition and oxygen depletion, is a widespread problem in coastal waters. Addition of fixed N and P triggers increased primary production, decrease in water clarity, alteration of food chains and the occurrence of harmful algal blooms with increased frequency (Martin and LeGresley 2008).

Impacts of excessive nutrient enrichment:

- Changes in species composition (Boesch, 2002)
- Shifts in competitive hierarchies due to addition of limiting nutrients (Emery et al., 2001)
- Promotes invasion by non-native species (Williams and Smith, 2007).
- Hypoxic conditions created by microbial decomposition of blooming algae (Crain et al., 2009)
- Changes in growth, metabolism, and mortality of marine organisms, with declining of sensitivity (Gray et al., 2002).
- Compressed habitats, loss of key fauna, and diversion of energy from higher trophic levels to microbial pathways as organisms die and decompose (Diaz and Rosenberg, 2008).

Ozone depletion and increased UV radiation fluxes

McKenzie et al. (2010) noted that in recent years, increase in atmospheric greenhouse gases has caused depletion in stratospheric ozone which has resulted in increased flux of ultraviolet radiation to the Earth’s surface.

The anthropogenic emissions of greenhouse gases that tend to cause a temperature increase at the Earth’s surface also produce a decrease in stratospheric temperatures which may serve to increase ozone loss in Polar regions. This results in a greater change in ultraviolet radiation fluxes in Polar and high-latitude regions, which are more susceptible to the formation of an “ozone hole” during spring (Pan et al., 2013).

According to Hader et al. (2010), increased ultraviolet radiation represents a relatively new problem to marine organisms and it acts as an environmental stressor for corals, zooplankton and fish.

Regime shifts

Pan et al. (2013) reported that regime shifts arise when a combination of climatic, biological and physical changes lead to persistent new sets of ecosystemic characteristics that represent deviations or shifts from the historic record.

Changes in precipitation frequency and intensity, ocean acidification, water temperature increase, changing wind patterns, hydrology fluctuations and alterations, combined with anthropogenic pollution by nutrients and toxins, all can affect water quality in estuarine and coastal waters (Gitay et al., 2002).

It has been demonstrated that for the past 20 to 30 years El Niño-Southern Oscillation (ENSO) events have increased their frequency, persistence and intensity which affect the coastal regions (Pan et al., 2013). Climate change is impacting marine biodiversity through its own effects on marine ecosystems and synergistic interactions with existing stressors, such as habitat destruction, overfishing, and marine pollution (Craig, 2012).

Habitat destruction or loss

Emergent structures, such as rocky outcrops, boulder shoals, epibenthic reef formations, vegetation as well as other topographic features provide heterogeneity and structural complexity in marine benthic environments.

These structures provide refuge from predation and competition, as well as physical and chemical stresses, or may represent important food resources and critical nursery or spawning habitat. In addition, they modify the hydrodynamic flow regime near the sea floor, with potentially significant ecological effects on food availability, growth, larval and/or juvenile recruitment and sedimentation (Turner et al., 1999).

One of the most devastating threats to biodiversity is the outright loss of habitat due to human activity. Once removed, a natural habitat is often permanently lost, although natural or artificial restoration of some habitats is possible over time (Craig, 2012).

Crain et al. (2009) reported that many coastal habitats have been completely lost due to direct removal or degradation and eventual loss from the cumulative effects of various stressors. Some examples of marine habitat loss include:

- Coastal wetlands drained and converted to upland habitat with the addition of dredge spoils (Lotze et al., 2006).
- Oyster reefs overharvested to the point where they cannot be replenished (Kirby, 2004).
- Intertidal and shallow subtidal habitats converted to jetties and hardened shoreline (Crain et al.; 2009).
- Mangroves removed to make way for shrimp-farm ponds (Alongi, 2008).

A combination of melting ice caps and thermal expansion of water in the oceans causes many coastal areas and estuaries will be flooded by the sea, while an increase in extreme weather patterns will increase erosion and flooding. The fundamental patterns of ocean circulation will be changed, leading to widespread disruption of both ocean and terrestrial ecosystems (Imtiyaz et al., 2011).

Nevill (2008) reported that habitat damage to marine ecosystem is largely caused by fishing gear (for example, bottom trawling), coastal development, destruction of coral reefs and mangroves, natural freshwater flows, coastal foreshores, coastal wetlands and estuaries which all support coastal marine ecosystems.

Factors contributing to habitat loss are overconsumption, overpopulation, land use change, deforestation, pollution (air pollution, water pollution, soil contamination) and global warming or climate change (Hogan, 2010; Relini, 2012). Coastal urbanization, the dredging, filling and isolation of salt-marshes, eutrophication and decreasing water quality, are among the human activities that produce dramatic changes in marine coastal areas (Hall, 2002). Airoldi et al. (2008) have proposed three major categories of habitat loss:

- Loss of native resident species,
- Loss of food resources,
- Loss of environmental complexity and ecosystem functions.

Fishing activities, such as trawling and dredging for fish and shellfish, have the capability of altering, removing or destroying the complex, three-dimensional physical structure of benthic habitats by the direct removal of biological (For example, sponges, hydroids, bryozoans, amphipod tubes, shell aggregates and sea grass) and topographic (For example, sand depressions and boulders) features (Turner et al., 1999).

Habitat degradation and fragmentation

Habitat destruction and fragmentation is a process that describes the emergences of discontinuities (fragmentation) or the loss (destruction) of the environment inhabited by an organism. Marine ecosystems are experiencing high rates of habitat loss and degradation, and these processes are considered as the most critical threat to marine biodiversity (Gray, 1997; Imtiyaz et al., 2011).

Degradation of habitats occurs when some aspect of the natural environment is removed or altered. Alteration can include addition of pollutants, heavy human or livestock usage, extraction of resources, activities or management techniques that disrupt natural cycles or disturbance regimes. Habitat fragmentation has also increased in ecosystems as a result of human alteration and destruction of habitat. Fragmentation of habitat can result in decreased populations and range size for many species (Sechrest and Brooks, 2002).

Pan et al. (2013) noted that habitat fragmentation in sedimentation, ultimately resulted in a loss of > 50% of sea grass beds (*Posidonia oceanica*), a decline in macroalgal cover (*Cystoseira* spp.) and a loss in associated faunal assemblages, which impacted negatively on the goods and services provided for local human population.

Introduced species

Introduced/Non-indigenous species are the species introduced outside of their natural range and beyond their natural dispersal potential. Invasive species are a subset of established introduced species and have an adverse effect on biological diversity, ecosystem functioning, socio-economic values and/or human health in invaded regions (Torchin et al., 2003; Pan et al., 2013).

The vectors of non-intentional introduction are shipping; aquaculture, aquarium trade etc. are direct transport. These are facilitators to the establishment of introduced populations and only some of the established species cause large changes in native biodiversity. Species that are successful invaders into new areas are generally ones that can tolerate a broad range of environmental conditions, competition, predation and other ecological interactions, and have intrinsic biological characteristics including high reproductive capability, broad diet and high dispersal rates. The increased fragmentation, degradation, and destruction of habitats, along with other threats, will certainly open more niches for non-native species introductions. The result could drastically lessen biodiversity, resulting in a taxonomically and ecologically homogeneous planet (Sechrest and Brooks, 2002).

Pyšek and Richardson (2010) reported that marine biological invasions are increasingly altering coastal biota, generating changes in the chemical and/or physical properties of an ecosystem, ecosystem functioning and ultimately result in adverse effects on economy and human health. Coastal marine habitats are some of the most invaded habitats globally due to the concentration of activities that promote invasion, such as shipping, aquaculture, fisheries, and aquarium trade. Estuaries have been particularly hard hit by invasive species (Williams and Grosholz, 2008; Crain et al., 2009).

Invasive species have transformed marine habitats around the world. The most harmful of these invaders displace native species, change community structure and food webs, and alter fundamental processes, such as nutrient cycling and sedimentation. Alien invasives have damaged economies by diminishing fisheries, fouling ships' hulls, and clogging intake pipes (Molnar et al., 2008). Once alien species become established in marine habitats, it can be nearly impossible to eliminate them (Thresher and Kuris, 2004; Craig, 2012).

Vilà et al. (2010) noted that in marine ecosystems, alien marine species may become invasive and displace native species, cause the loss of native genotypes, modify habitats, change community structure, affect food web properties and ecosystem processes, impede the provision of ecosystem services, impact human health, and cause substantial economic losses. Katsanevakis et al. (2013) documented that rapid globalisation and increasing trends of trade, travel, and transport in recent decades have accelerated marine biological invasions by increasing rates of new introductions through various pathways, such as shipping, navigational canals, aquaculture, and the aquarium trade.

Alien marine species are harmful to native biodiversity in a number of ways, for example, as competitors, predators, parasites, or by spreading disease (Imtiyaz et al., 2011). Bax et al. (2003) recorded examples of rapidly proliferating alien species like:

- North Pacific sea star, *Asterias amurensis* in Port Phillip Bay.
- Invasive green algae, *Caulerpa taxifolia* has spread to the Adriatic Sea, and over most of the Mediterranean. Invasive comb jelly, *Mnemiopsis leidyi* in the Black Sea has collapsed the coastal fisheries worth many millions of dollars annually.
- Invasive crab, *Carcinus maenas* a European species now found in Australia, Japan, South Africa and both coasts of North America.
- New Zealand screw shell, *Maoricolpus roseus* introduced to Tasmania from New Zealand and has spread across the continental shelf.

Ballast water is capable of transporting viral and bacterial pathogens and the resistant cysts of toxic dinoflagellates along with invasive alien marine species that are intermediate hosts for parasites affecting humans (Ruiz et al., 2000).

Alien marine species also have positive impacts like improvement of aesthetic values, creation of new economic activities and increased employment in invasive alien marine species management projects and programs (Bax et al., 2003).

Coastal and marine pollution

Contamination of the natural environment in the form of liquids, solids, gases, or even forms of electromagnetic radiation input into air, water, or land' is known as pollution. Input of organic and inorganic substances into the environment by humans has become a growing threat to biodiversity.

According to Sechrest and Brooks (2002), pollution can be of acute or chronic type.

Acute pollution:

- Occurs with a single incident causing environmental disasters
- For example, oil spills, refinery and shipping accidents and nuclear accidents.
- Initial effects cause massive biodiversity loss.
- Long lasting effects is the prolonged ecological impact of radioactive material.

Chronic pollution:

- Caused with the addition of substances to the environment over a continuous time period.
- Sources include industrial emissions, aerosol release from biomass burning, agricultural runoff, pesticides, erosion, and automobile emissions.
- Immediate effects of chronic pollution may be small.
- Sustained rates and accumulation of chronic pollution can be more devastating than acute environmental disasters.

Pollution including nutrients, sediments, plastic litter, hazardous and radioactive substances; discarded fishing gear, microbial pollution, and trace chemicals such as carcinogens, endocrine-disruptors, and info-disruptors is a major threat to marine biodiversity (Nevill, 2008; SeaWeb, 2016). Coastal ecosystems are polluted by numerous human-generated materials that enter the marine environment through land-based runoff or marine dumping, oil pollution, heavy metals and plastics (Crain et al., 2009; Craig, 2012).

Land-based runoff or marine dumping

Many pollutants of major concern received by marine environment through land-based runoff or marine dumping are persistent organic pollutants (POPs) and inorganic pollutants.

Persistent organic pollutants (POPs):

- POPs are the compounds synthesized by humans in industrial processes.
- Organic chemicals which resist degradation and accumulate in the environment.
- Persists and accumulates in the tissues of organisms and is subsequently biomagnified through food webs.
- Becomes more concentrated and detrimental at higher trophic levels.
- Due to semi-volatile nature and long half-lives, POPs accumulate at high latitudes.
- Effects of POPs include cancers, deformations and reproductive failure due to disruption of sex hormones in marine organisms.

Examples of POPs includes:

- Organohalogenated compounds (for example, chlorinated pesticides like DDT)
- Petroleum compounds and their derivatives [for example, polycyclic aromatic hydrocarbons (PAHs)]
- Polyhalogenated biphenyls [e.g., polychlorinated biphenyls (PCBs)]
- Fire retardants like polybrominated diphenyl ethers (PBDEs)
- Pharmaceuticals
- Personal care products (PPCPs)

(Islam and Tanaka, 2004; Crain et al., 2009; Craig, 2012)

Oil pollution

Oil pollution has increased since the middle of the 20th century when oil shipping and associated spills increased in frequency. Millions of tons of oil enter the marine environment from numerous sources in addition to spills, including ballast water, maintenance of refineries, and small-scale land-based dumping "down-the drain" (Crain et al., 2009; Imtiyaz et al., 2011).

Impacts of oil pollution: Effects of oil on fish, marine mammals, and seabirds include:

- Physical abnormalities, blindness, cancer and mortality.
- Poisoning due to internal damage from oil ingestion.
- Animals become “sleepy” and drown due to hypothermia.
- Oil creates a sticky substance in water called ‘mousse’, which stuck to the fur or feather of sea animals. As a result, birds are unable to fly and die due to starvation.
- Affect filter feeders by concentrating in the flesh of these animals.
- Death of clams, mussels, and oysters due to quick accumulation of oils and toxins.
- Kill eggs and sperms of corals if occurred during coral spawning.

Heavy metals

Islam and Tanaka (2004) reported that heavy metals like mercury, cadmium, silver, nickel, selenium, lead, copper, chromium, arsenic, and zinc enter coastal waters directly through dumping, atmospheric deposition, or sewage, which also brings organic pollutants, trace elements, and pharmaceuticals.

Heavy metals interfere with metabolic pathways and bioaccumulate in tissues, having severe impacts on higher trophic levels such as marine mammals, leading to immune suppression and related diseases (Crain et al., 2009).

Plastics

Plastics derived from offshore dumping and poor waste disposal on land constitute the largest portion of marine litter on beaches and in open waters (Crain et al., 2009). Floating plastic waste accounts for 80 percent or more of marine debris. Debris in oceans and seas is an aesthetic problem; it incurs considerable costs and can have severe impacts on marine organisms and habitats (Pawar et al., 2016).

Plastic pollution also affects marine biodiversity. Various marine animals can become physically entangled in larger forms of plastic debris, leading to injury, dismemberment, and death (Derraik, 2002; Crain et al., 2009; Craig, 2012).

Altered salinity

Jacobs et al. (2002) noted that human activities like tidal restrictions, inlet channelization, altered drainage patterns, freshwater diversions, desalinization plants, and global warming–related changes such as melting ice caps and shifts in water circulation or precipitation patterns alter salinity regimes in coastal-water bodies.

Anthropogenic activities cause decrease in salinity which impact marine invertebrates (Alutoin et al., 2001). Altered salinity regimes become a significant stressor when levels shift from normal tidal or seasonal patterns or exceed the natural range of variation for extended periods of time. Since salinity is a physiological factor, it can cause immediate mortality or sub lethal stress at the organism level, leading to shifts in community and ecosystem structure (Crain et al., 2009).

Altered sedimentation

Coastal marine habitats depend on a dynamic balance of sediment input and export to function properly, and human activities can threaten these systems by both increasing and decreasing sediment delivery. Damming and diverting freshwater or tidal influence can reduce important sediment delivery to coastal wetlands (Hutomo and Moosa, 2005).

Increase in sedimentation rates is a major problem in coastal waters worldwide and can exceed two times background sedimentation rates. Sedimentation disproportionally impacts coastal estuaries, where increasing sediment loads lead to burial of benthic communities and increasing water turbidity, reducing light penetration and leading to numerous associated negative effects (Crain et al., 2009).

CONCLUSION

Coastal and marine biodiversity is declining very rapidly due to increasing human-population pressure on coastlines and brings multiple human uses and threats to the coastal marine environment. Anthropogenic threats have precipitated a global disaster for coastal and marine biodiversity. Focus should be made on sustainable use of marine resources by public awareness of marine and coastal ecosystems, their productivity, biodiversity, value to humanity, and their fragility or exhaustibility has increased greatly.

Comprehensive, multi-sector, multi-objective management provides an essential framework for effective coastal conservation. It is of utmost importance that the general public, the scientific community, policy makers, and politicians and decision makers establish close relationships among each other and attain a common objective of environmental policy reinforcement and education. There is a need to more fully understand the effects of anthropogenic threats on various marine organisms at different stages of the lifecycle including the ecosystem level impacts.

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