IMPACTS OF PLASTIC POLLUTION ON THE SUSTAINABILITY OF SEAFOOD VALUE CHAIN AND HUMAN HEALTH

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Abstract

The study evaluated the impacts of plastic pollution on the sustainability of seafood value chain. The world aquaculture production in 2016 stood at 80.0 million tons of food fish, gradually declined by 0.3 million tons to 79.7 million tons in 2017, and rose to 81.4 million tons in 2018. Global aquaculture production maintained relatively steady increase from 2011 to 2018. Plastic pollution can afflict oceans, land, and waterways. It is estimated that about 1.1 to 8.8 million metric tons of plastic waste enters the world ocean from coastal communities every year. Living organisms, mostly marine animals, can be injured either by the mechanical effects, such as the entanglement in plastic objects and problems related to the ingestion of plastic wastes, or via exposure to chemicals in plastics that interfere with their body physiology. Also, humans are affected by plastic pollution, by disruption of various hormonal mechanisms, etc. The mainstream plastic wastes accumulations in the environment have adversely affected both terrestrial and aquatic wildlife and wildlife habitat (habitation); with humans utterly affected by the growing rate of plastic pollution. More than 5 trillion pieces and fragments of plastic wastes are distributed in the world oceans worldwide. If the plastic pollution problem is not solved, by 2050, there possibly will be more plastic wastes in the world oceans, rivers, lakes, etc. than fishes and other aquatic organisms; this puts the sustainability of seafood value chain in threat. There are three main pathways by which plastic debris always affect wildlife; entanglement, ingestion, interaction. Entanglement in plastic debris is responsible for the deaths (both reported and unreported) of many aquatic organisms, such as fish, seals, and turtles, as well as birds. These marine animals get caught up in the plastic debris and end up suffocating/drowning. Greenpeace International (2018) stated that in a 2006 report called *Plastic Debris in the World's Oceans*, it was estimated that over 267 different species of animals have suffered entanglement and plastic debris ingestion. It was estimated that at least 400,000 aquatic mammals perish annually as a result of plastic pollution in oceans. Interaction includes the contact with plastic debris (with exclusion of entanglement) including abrasions, use as substrate, collisions, and obstructions. Many marine animals, especially Whales and Sea turtles, are affected by the pollution caused by plastics through ingestion. Large quantities of plastic wastes have been found in stomachs of beached whales. A pilot whale was found almost dead in June 2018, and later died, in a water canal at Southern Thailand close to the border with Malaysia after it swallowed more than 80 pieces of plastic bags which weighed up to 3Ib. Some species of sea turtle are jelly fish consumers, but regularly mistake plastic bags for their natural prey, jelly fish. This plastic debris may kill the sea turtle by the obstruction of its oesophagus. Deep sea animal species have been found with quantities of plastics in their stomachs. Microplastics ingestions have been indicated to occur for various organisms.

Keywords: Plastic Pollution, Plastic Waste, Seafood Sustainability, Marine Animals

1. Introduction

Plastic pollution has remained one of the glitches at the epicenter of the challenges plaguing the universe status quo. More than estimated eighty million tons of plastic related wastes are released into the sea annually. Roughly 5 trillion fragments of plastic trash are dispersed and scattered in all the water bodies globally. Although plastics are known to be low-cost, resilient, and long-lasting, the resultant high levels of plastic waste generation by humans (Hammer *et al.*, 2012) have made its use a universal concern. A research report by Richard Thompson (2004) at the University of Plymouth, UK, revealed a large quantity of micro-debris occurring at the seashores and oceans in Antarctica, the Europe, Australia, Africa, and the Americas (Lytle, 2015). The use and acceptability of plastics and the resultant waste accumulation and environmental degradation have shown a mean increase, in spite of the numerous movements and mobilizations countering the random usage and acceptability of plastic packaging materials and the related ecological contamination and pollution. A recent research study conducted in 2017 reported that over 83 percent of the tap water samples collected around the world was polluted with plastic pollutants (Mary *et al.*, 2017; Chris and Dan, 2017). It was the principal research study and finding focusing on pollution of world drinking water by plastic debris and indicated that with a 94 percent contamination rate, the samples from the United States' tap water were the most contaminated, followed by India and Lebanon. The United Kingdom, Germany, and France in Europe recorded the least rate of contamination, although 72 percent, which is still high (Chris & Dan, 2017). The finding suggests that individuals may be consuming 3,000 to 4,000 plastic debris and micro-particles from tap water annually alone.

In mid-June 2018, a pilot whale was seen in a waterway at Southern part of Thailand, close to the Malaysian border, battling with life and subsequently died after ingesting more than an estimated 80 pieces of plastic components and bags amounting to about 3Ib. Specialists submitted that the plasticparts and bags might have possibly prohibited the pilot whale from ingesting food, hence leading to a lack of consciousness and death. By 2050, if the challenges of plastic wastes are not addressed, we will possibly have more plastic debris in universal lakes, rivers, seas, oceans, etc. than aquatic organisms, particularly fishes, posing adanger to the marine environment and human health. Plastic wastes have the propensity to expose animals to poison, which may unsympathetically affect man's seafood supplies (Daniel, 2004). Plastic pollution was shown to be extremely damaging to big aquatic creatures, as defined in the favorite book "*Introduction to Marine Biology*" as constituting the "distinct greatest threat" to marine mammals (Karleskint *et al.*, 2009). Some aquatic species, like seafood, were seen to be contaminated with vast quantities of plastic debris in their gastrointestinal tract. Once this happens, the marine animals usually starve, as the plastic debris blocks their digestive and gastrointestinal tracts (Daniel, 2004). Sometimes, aquatic animals become entangled in plastic wastes like discarded fishing nets, getting hurt or killed in the encounter.

With the recent unabated increase in the quantities of plastic wastes released to water bodies globally, the sustainability of the world's aquatic animals' value chain is under threat. Altogether, Seafood constitutes part of a healthy and nutrient-dense diet and notably a rich source of essential nutrients, like vitamins and minerals, for man; fish is known to be a rich source of omega-3 fatty acid, which promotes heart performance and health. In an aquatic ecosystem, the very high accrual of plastic debris may have a substantial effect on the sustainability of the seafood value chain, which, customarily, mayaffect public health and food safety. Recent research on demographics of several species of seafood has indicated that a universal implosion of species of shellfish before the year 2048 is likely. The astronomicalcollapse of this kind would take place due to increasing plastic pollution and excessive fishing activities, intimidating marine ecologies (Juliet, 2006). Around February 2007, a claim made by the National Fisheries Institute showed that the perceived degenerations in a population of fish were correlated to naturally occurring instabilities and those state-of-the-art technologies would in time lessen any effect humankind has on aquatic life, including its increasing release of plastic wastes and pollutants.

Plastics themselves contribute to approximately 12 percent of discarded waste — almost every human releases at least two plastic related wastes per day. With the world population clocking 7.7 billion in 2019, the average plastic wastes generation is estimated at 15.4 billion pieces per day. Many categories of plastics are in existence depending on their originators and polymerization techniques (Barnes *et al.*, 2009). Contingent on their chemistry, plastics, together with resins, have variable chemical and physical properties associated with pollutant adsorption and absorption. Due to salty environments and the cooling impact of the ocean, degeneration and decay of polymeric compounds take far longer. These are contributory factors to the doggedness of plastic wastes in specific ecosystems (Barnes *et al.*, 2009). Recent research studies reported that plastic debris in the seas degrade more rapidly than was once believed, owing to their contact with rain, sun, microorganisms, and other ecological conditions, leading to the discharge of toxic compounds like phthalates and bisphenol A. Nonetheless, due to the increased bulk of plastic wastes in the ocean, decomposition has slowed down.

This research will give concise, logical, and scientific-based information on the direct impacts of plastic pollution on seafood value chain and public health. The study will aim at ascertaining and quantifying the potential effects of plastic pollutions and its associated chemical components – bisphenol A (BPA), phthalates, etc. – on lifespan of seafood and human health, with more focus on health consequences of consuming plastic contaminated seafood, such as tilapia, shrimp, crabs, etc. using rat model and, if possible, human model.

The research focused on the impacts of plastic pollution on seafood value chain sustainability and public health nutrition.

2.1. Seafood in present world

Seafood is any kind of sea life considered as food by man, importantly including fish and shellfish. Shellfish include species of crustaceans (e.g. crabs, shrimp, and lobster), molluscs (e.g. bivalve molluscs for instance clams, oysters, and mussels and cephalopods for example octopus and squid), and echinoderms (e.g. sea urchins). In history, marine mammals like cetaceans (whales & dolphins) and seals have been consumed as diet, although it happens to a reduced degree in recent times. Comestible sea plants such as seaweeds and microalgae are commonly consumed as marine vegetables round the globe, particularly in Asia. In parts of North America, though not largely in the United Kingdom, the word "seafood" is inclusive of freshwater creatures consumed by man; all consumable aquatic life could be referred to as "seafood" for the purpose of wholeness.

The harvest of wild or undomesticated seafood is customarily referred to as sea hunting or fishing, whereas the husbandry and farming of seafood is recognized as aquaculture or fish farming (if fish). Seafood is colloquially distinguished from meat, though it's still animal in nature and exempted from vegetarian food, as ascertained by groups such as the Vegetarian Society subsequent to misperception surrounding pescetarianism. Seafood is a significant source of animal proteins in numerous diets around the ecosphere, principally in maritime areas.

Most seafood yield is eaten by humans, nevertheless a substantial amount is used as fish feed to cultivate other fish and rear livestock. Some seafoods (called kelp) are used as a fertilizer for other plants. In such ways, they are used to make additional food for human consumption. Similarly, food products such as spirulina tablets and fish oil are seafoods' extracts. Some seafood is fed to aquarium fish, and also used to feed home pets like cats. A minor proportion is used in medicine, or is in the industries for nonfood purposes (e.g. leather).

2.1.1. Development in Seafood harvesting, cultivation, processing, and consuming

The harvesting, handling, processing, and consumption of seafoods are prehistoric practices with archaeological evidence dating back into the Paleolithic (Inman, 2007). Discoveries in a ocean cave at Pinnacle Point, South Africa, show *Homo sapiens* (modern humans) harvested aquatic life as early as over 165,000 years ago, whereas the Neanderthals, an extinct species of human contemporary with earliest *Homo sapiens*, seem to have been consuming seafood at locations alongside the Mediterranean coastline commencing about the same time (Human Evolution National Geographic News, 2011). Isotopic examination of the skeletal remnants of Tianyuan man, a forty thousand (40,000) year old anatomically modern human from the eastern Asia, has shown he habitually ate freshwater fish (Yaowu *et al.*, 2009). Archaeology features and geographies like shell middens, thrown-away fish bones and cave landscapes indicate that seafoods were vital for the survival and were consumed in substantial amounts. In this period, most individuals subsisted on a hunter-gatherer lifestyle and were, of inevitability, continuously on the move. Nevertheless, where there are early instances of permanent settlements like those at Lepenski Vir, they are nearly always connected with fishing as the main source of diet.

The olden river Nile was filled with fish. Fresh and dried fishes were staple food for many of the populace. The early Egyptians had tools and methods for fishing and these are illustrated in drawings, tomb scenes, and papyrus documents. Certain depictions hint that fishing was pursued as a pastime.

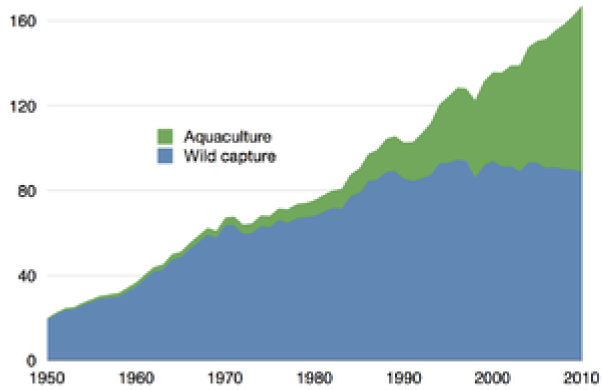


Figure 1: Global fisheries harvest, wild capture against aquaculture production, (million tonnes) 1950–2010 (FAO, 2012)

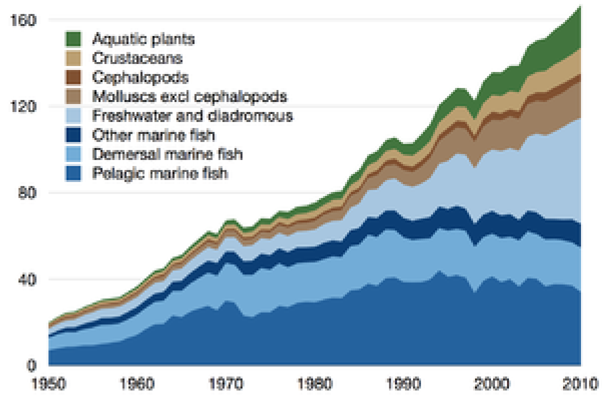


Figure 2: Global fisheries harvest, both farmed and wild, in million tonnes, 1950–2010 (FAO, 2012)

Fishing acts are rarely epitomized in ancient Greek beliefs, an image of the little social status of fishing. Nevertheless, Oppian of Corycus, a renowned Greek author, penned a foremost treatise on ocean fishing, the *Halieutika* or *Halieulica*, composed amid 177 and 180. This is the initial such work to have continued to the modern-day. The eating of fish varied in agreement with the affluence and locality of the household. In the islands of Greek and on the coastline, seafoods (octopus, shellfish, and squid) were common. The seafoods were consumed locally but often conveyed inland. Anchovies and sardines were steady fare for the people of Athens. They were sometimes sold very fresh, but further regularly salted. A stele of the late third century BCE from the Akraiphia (small Boeotian city), on Lake Copais, offers a list of prices of fish. The cheapest of all was *skaren* (parrotfish) while Atlantic blue fin tuna was as times three as expensive. Common saltwater fish were red mullet, ray, yellowfin tuna, sturgeon, or swordfish, a delicacy which was consumed salted. Lake Copais was well-known in Greece for its eels, celebrated by the heroes. Other freshwater fish were carp, pike-fish, and the little appreciated catfish.

Pictorial indication of fishing by the Romans come from mosaics. At a time, the goatfish was taken to be the epitome of superfluity, above all perhaps because its scales reveal a bright red coloration when it passes away out of water. For this single reason, these fish were sometimes left to die leisurely on the table. There was a recipe where this takes place *in garo*, in the sauce. At the commencement of the Imperial age, nonetheless, this tradition abruptly ended, that's why *mullus* in the banquet of Trimalchio could be presented as the *parvenu* characteristic, who windbags his guests with an obsolete exhibition of dying fish.

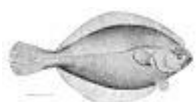
In the times of medieval, seafood was less admired than meats, and regularly seen as simply an alternative to meat during fast days. However, seafood was the lifeblood of many coastal inhabitants. Kippers prepared from herring fished in the North Sea might be found in markets as far as Constantinople. While great amounts of fish were consumed fresh, a large percentage was salted, dried, and smoked. Stockfish, cod that was riven down the interior, affixed to a pole and dried out, was common, although its preparation is time-consuming, and was meant for beating the dried fish using a mallet before soaked in water. A wide variety of mollusks including mussels, oysters, and scallops were consumed by coastline and river-dwelling inhabitants. Freshwater crayfish were perceived as a desired substitute to meat in the course of fish days. When compared to meat, fish was more costly for inland residents, particularly in Central Europe, and hence not a choice for many.

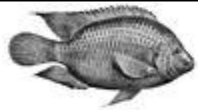
Recent information of the reproductive cycles of marine species have led to the improvement of hatcheries and enhanced techniques of aquaculture and fish farming. Improved understanding of the risks of consumption of raw and improperly cooked shellfish and fish has led to enhanced preservation techniques, methods and processing.

2.1.2. Kinds of seafood round the world

The next table is built on the International Standard Statistical Classification of Aquatic Animals and Plants, ISSCAAP, classification used by the UN FAO for the collecting and compiling of fishery statistics (FAO, 2012). The production information have been extracted from the UN FAO Fish Stat database (FAO, 2012), and include both caught from the wild fisheries and aquaculture production.

Table 1: Kinds of seafood round the world

Group	Subgroup	Explanation	2010 production 000 tonnes
fish	Fish are marine vertebrates which lack limbs with figures, use gills to respire, and have heads sheltered by cartilage skulls. Total for fish:		106,639
	 marine pelagic	Pelagic fish live & feed close to the surface or in the seawater column of the ocean, but not on the ocean bottom. The main groups of seafood can be separated into larger predator fish (mahi-mahi, mackerel, salmon, sharks, tuna, billfish,) and smaller forage fish (herring, anchovies, menhaden, sardines, sprats). The smaller forage fish nourishes on plankton, and can accrue toxic substances to an extent. The larger predator fish nourish on the forage fish, and accrue toxic substances to a much higher extent than the forage fish.	33,974
	 marine demersal	Demersal fish dwell and nourish on/near the ocean bottom (Walrond, 2009). Some groups of seafood are flatfish, cod, stingrays, and grouper. Demersal fish nourish mostly on crustaceans on the ocean floor, and are more sedentary when compared to the pelagic fish.	23,806
	 diadromous	Diadromous fish are fishes that migrate between the ocean and the fresh water. Some groups of seafood are shad, salmon, lampreys, and eels.	5,348

		freshwater	Freshwater fish dwell in ponds, rivers, lakes, and reservoirs. Some groups of seafood are carp, bass, tilapia, trout, and catfish. In general, freshwater fish offer themselves to fish farming more freely than the sea fish, and the greater part of the tonnage described here speaks of farmed fish.	43,511
molluscs	Molluscs are invertebrates with very soft bodies that aren't segmented like crustaceans. Gastropods and bivalves are sheltered by a calcareous shell that grows proportionately with the mollusc growth. Cephalopods are not sheltered by a shell. Total for molluscs:			20,797
		bivalves	Bivalves, at times called clams, have a shielding shell in two main hinged parts. A valve is the name for the protecting shell of the bivalve. The bivalve plainly means having *two shells*. Vital seafood bivalves include scallops, mussels, oysters, and cockles. Majority of them are filter feeders that bury themselves in deposit on the seabed wherever they are safe from predator. Others lie on the floor of sea or attach to rocks or other rigid exteriors. Bivalves have been a part of the diet of coastal communities. Oysters were cultivated in fishponds by the Romans. Mariculture has in recent times become a significant source of bivalves for food.	12,585
		gastropods	Marine gastropods, called sea snails, are univalves meaning they have a single piece protecting shell. Gastropod plainly means *stomach-foot*, as they appear to creep on their stomachs. Common groups of seafood are conch, limpets, abalone, whelks and periwinkles.	526
		cephalopods	Cephalopods are not sheltered by shell. Cephalopod plainly means *head-foots*, as they have appendages which appear to shoot out from their head. They have superb vision and very high intelligence. Cephalopods drive themselves with a water jet, laying down "smoke screens" using ink. Typical examples are squid, octopus, cuttlefish. They are consumed in various nations. Depending on the particular species, their arms and at times other body parts are equipped in numerous ways. Octopus must be cooked appropriately to get rid of smell, slime, and ink residue. In Mediterranean nations and in the UK squid are often referred to as calamari (Merriam-Webster's Online Dictionary, 2019). Cuttlefish is consumed less than squid, although it is common in Italy and dried, shredded cuttlefish is a food in Eastern Asia.	3,653 plus
		other	Molluscs not included above	4,033
crustacean	Crustaceans (meaning *crust*; from Latin *crusta*) are invertebrates with body segmentation protected by hard crusts called exoskeletons or shells, commonly made of chitin and designed slightly like a knight's armour. Their shells do not develop, and must occasionally be shed or moulted. Generally two legs or limbs point out from each of the segments. Most commercial crustaceans are decapods, i.e. they have ten legs, with compound eyes set on stalks. Their exoskeletons turn pink or red when boiled. Total for crustaceans:			11,827 plus
		shrimps	Shrimp & prawns, are little, slim, stalk-eyed and ten-legged crustaceans with elongated spiny rostrums. They are common, and can be seen near the seafloor of most estuaries and coasts, and in rivers and lakes. They play vital roles in food	6,917

			chain. There are numerous species, and customarily there's a species adapted to any specific habitat. Small crustacean resembling a shrimp tends to be known as one (Rudloe and Rudloe, 2009).	
		crabs	Crabs are stalk-eyed ten-legged crustaceans, typically walk sideward, and have clutching claws as their front pair of limbs. They have short antennae, small abdomens, and a short carapace which is wide and flat.	1,679
		lobsters	Spiny lobsters and clawed lobsters are stalk-eyed crustaceans with long abdomens and ten legs. The clawed lobsters have great asymmetrical claws for its anterior pair of limbs, one for cutting, the other for crushing. The spiny lobster lacks large claws, but has a elongated, spiny antennae as well as a spiny carapace. Lobsters are bigger than most crabs or shrimp.	281
		krill	Krill are like young shrimps, but have exterior gills and more than ten legs for swimming, plus nourishing and grooming legs. They are seen in seas round the globe where they sieve feed in huge pelagic swarms (Steven & Yoshinari, 1997). Like shrimp, krills are an essential part of the aquatic food chain, transforming phytoplankton into a form bigger animals can guzzle. Each year, bigger animals consume half the projected biomass of krill about 600 million tonnes (Steven & Yoshinari, 1997). Humans eat krill in Russia and Japan, but most often the krill harvest is used to produce fish feed and for oil extraction. Krill oil has omega-3 fatty acids, equally to fish oil.	215
		other	Other crustaceans not covered	1,359 plus
other aquatic animals		Total for other aquatic animals:		1409+
	 	aquatic mammals	Aquatic mammals form diverse group of over 128 species that bank on the sea for their existence (Pompa *et al.*, 2011). Currently, whale meat is harvested from legal, non-commercial expeditions (BBC News, 2010). About a thousand long-finned experimental whales are still killed yearly (Nguyen, 2010). Japan has recommenced hunting for whales, which they call "research whaling" (The Japan Times Online, 2008). In present Japan, two distinct cuts of whale meat are generally well-known: the belly meat and the more cherished tail or fluke meat. Fluke meat sell for over $200 per kilogram, nearly three times the rate of belly meat (Palmer, 2010). Fin whales are mainly preferred as they are believed to yield the finest quality fluke meat. In Taiji in Japan and some parts of Scandinavia, the Faroe Islands, dolphins are conventionally regarded as food, and are slaughtered in drive hunts or harpoon (Matsutani, 2009). Ringed seals are important food source for the residents of Nunavut (Eskimo Art, 2009), and are also hunted and consumed in the Alaska. The meat of sea mammals could be high in mercury; may pose health hazards to humans when consumed (Johnston, 2009). The UN FAO record only the informed numbers of marine mammals harvested, not the tonnage. A 2010 report by FAO indicated	?

			that 12,000 dolphins, 2500 whales, and 182,000 seals.	
		aquatic reptiles	Sea turtle has long valued as food in several parts of the globe. Most fifth century BC Chinese texts describe sea turtles as exotic delicacies (Schafer, 1962). Sea turtles are fished worldwide, though in most countries it is unlawful to hunt some species (CITES, 2006). Many coastline communities round the ecosphere depend on sea turtles as source of daily protein, often collecting sea turtle eggs, as well as keeping caught sea turtles alive on their backs till wanted for consumption (Settle, 1995). Some species of sea turtle are now struggling to avoid extinction, and some are unsympathetically endangered (IUCN 2012). The UN FAO reports that over 1,418,975 crocodiles were harvested in 2010 alone, but the tonnage was not record.	296 plus
		echinoderms	Echinoderms are invertebrates without head, seen on the floor of the sea in all seas and at all depths. Echinoderms are not seen in fresh water. They typically have a five-pointed radial symmetry, move, breathe as well as perceive with their tube feet, which is retractable. They are enclosed with a calcareous and spiky skin. Echinoderms used as seafood include sea urchins, sea cucumbers, and sometimes starfish. Wild sea cucumbers are gathered by divers and in China they are cultivated commercially in artificial fishponds (Ess, 2009). The female and male gonads of sea urchins, regularly termed sea urchin roe or corals (Rogers-Bennett,2007), are delicacies in many parts of the world (Alan, 2014; Lawrence, 2007)	373 plus
		jellyfish	Jellyfish is gelatinous and soft, with a form shaped like bell or umbrella which throbs for locomotion. They have a long, trailing appendages with stings for prey capturing. They are seen free-swimming in the water column in all seas, and are sometimes found in freshwater. They must be dried within hours to avoid spoilage. They are considered a delicacy in Japan. Traditional processing methods are done by a jellyfish master. It involves a 20 to 40 day multiple-phase procedure starting with doing away with the mucous membranes and gonads. The oral arms and umbrella are then cured with a mixture of table salt and alum, and compacted. Processing lessens odor, liquefaction, the growing of spoilage organisms, as well as makes the jellyfish drier and more acidic, generating a crisp & crunchy feeling. Only scyphozoan jellyfish have its place to the order Rhizostomeae are fished for food; over 12 of the nearly 85 species. Majority of the harvest are done in southeast Asia.	404 plus
		other	Marine animals that are not included above, such as sea squirts *(pictured)*, spoon worms, ducks, lancelets & frogs.	336
marine			Total for marine plants & microphytes:	19,893

plants and microphytes	 	seaweed	Seaweed is a loose informal term which lacks a formal definition. Generally, the term is applied to the bigger, macroscopic forms of algae, as opposite to microalga. Examples of groups of seaweed are the multicellular brown, red, and green algae. Eatable seaweeds typically contain high quantities of fibre and, in dissimilarity to land-dwelling plants, contain complete protein. They are used broadly as food in coastline cuisines round the globe. Seaweed has been an integral part of regimens in China, parts of Korea, and Japan ever since prehistoric era. Seaweed is also eaten in various traditional European civilizations, in northern and western Ireland, Iceland and western Norway, Wales, the Atlantic coast of France, and some coastal parts of South West England, as well as Nova Scotia & Newfoundland.	
		microphytes	Microphytes are miniscule organisms, and can be bacterial fungal, or algal. Microalgae are type of aquatic plant, which includes species consumed by animals and humans. Some species of marine bacteria can be used as seafood; e.g. spirulina, a kind of cyanobacteria.	
			Total production (thousand tonnes)	**168,447**

2.1.3. Processing of seafood

Fish is a extremely perishable product: the "fishy" odor of lifeless fish is due to the rapid breakdown of amino acids into biogenic amines and ammonia (Narain and Nunes, 2007). Live diet fish are regularly conveyed in tanks at great expense for an international market which prefers its seafood slaughtered immediately before cooking. This process initially was initiated by Lindeye. Supply of live fish without water is being explored in recent times. While certain seafood restaurants retain live fish in aquaria for exhibition purposes or for traditional philosophies, most of live fish are retained for dining consumers. The live food fish profession in Hong Kong, for instance, is projected to have encouraged the importations of live food fish to over 15,000 tonnes in 2000. Global sales in same year were valued at US$400 million (The World Resources Institute, 2007).

If the cold chain is not adhered to properly, food products commonly decay and become unsafe before the date of validity in print on the package. As the possible harm for a consumer when consuming rotten fish is considerably larger than for instance with dairy products, the U.S. Food & Drug Administration (FDA) has announced regulation in the USA necessitating the use of a time temperature indicator on some fresh cool seafood products (FAO, 2012).

Freshly harvested fishes are highly perishable food products that must be eaten promptly, preserved, or discarded; it can be preserved for only a short period. In various countries, fresh fish is deboned and exhibited for sale on a cradle of crushed ice or frozen. Fresh fish is most usually found near water bodies, but the introduction of refrigerated truck and train transportation made fresh fish widely available in inland.

Extensive preservation of fish is achieved in a many ways. The ancient and still most broadly used techniques are salting and drying. Desiccation, a complete drying technique, is generally used to preserve fish like cod. Salting and partial drying is well known for preserving fish such as mackerel and herring. Fish such as tuna, salmon, and herring are heated and canned. Most fish are boned prior to the canning, but certain small fish (e.g. sardines) are only decapitated and eviscerated prior to canning.

2.2. Consumption of seafood

Seafood is greatly consumed all around the world; it offers the global prime source of very high-quality protein and oil: 14–16% of the animal protein consumed globally; over a billion people depend on seafood as their chief source of animal protein (Tidwell and Allan, 2001). Fish is amongst the most public food allergens.

Iceland, Portugal, and Japan are the utmost consumers of seafood per capita in the world. The UK Food Standards Agency (UK FSA) endorses that at least two portions of seafood ought to be consumed per week, one of which have to be rich in oil. There are more than 100 different types of seafood obtainable around the UK coastline. Fish rich in oil such as herring or mackerel are rich in long chain Omega-3 fatty acids (oils). These oils are in every cell of the body of human, and are vital for the biological functions of human such as brain functionality.

Whitefish such as cod and haddock are very low in calories and fat which, combined with oily fish rich in Omega-3 such as trout, sardines, fresh tuna, mackerel, and salmon, can help to protect against coronary heart disease, and aiding to develop strong teeth and bones. Shellfish are chiefly rich in zinc, which is necessary for healthy skin, fertility, and muscles. Casanova allegedly ate 50 oysters per day (Slovenko, 2001; McMurray and Ingber, 2007).

2.2.1. Seafood taste and texture

As at 2017, over 33,000 known species of fish and several more aquatic invertebrate species have been designated (Fish Base, 2017). Bromophenols, produced by aquatic algae, gives aquatic animals a taste and smell that is lacking from freshwater invertebrates and fish. In similar way, a chemical compound named dimethylsulfoniopropionate (DMSP) found in green and red algae is transmitted to animals in the aquatic food chain. When hydrolysed, dimethyl sulfide (DMS) is produced, and is frequently released during preparation of food when fresh fish and shellfish are heat treated. In minor quantities, it produces a definite smell; one links with the marine, but which in greater quantities gives the impression of a rotten seaweed & old fish. Another molecule called TMAO is in fishes and offers them a distinctive smell. It also occurs in freshwater species, but more numerous in the cells of an animal living deeper in the sea, so that fish in the deeper parts of the marine has a more robust taste than species living in shallow parts of water. Eggs from seaweed have sex pheromones named dictyopterenes, which are destined to interest the sperm. These pheromones are also seen in edible seaweeds, which add to their aroma. Nonetheless, only a lesser number of species are generally eaten by humans.

Table 2: Common species used as seafood

	Mild flavor	Moderate flavor	Full flavor
Delicate texture	basa, rainbow trout, hardshell clam, blue crab, peekytoe crab, flounder, hake, scup, eastern oyster, Pacific oyster smelt, spanner crab, cuttlefish	anchovy, orange roughy, Atlantic Ocean perch, herring, lingcod, moi, Lake Victoria perch, European oyster, sea urchin, yellow perch	Atlantic mackerel
Medium texture	European sea bass, hybrid striped bass, black seabass, bream, cod, rockfish, pink salmon, snapper, wolffish, hardshell clam, surf clam, drum, haddock, hoki, Alaska pollock, tilapia, turbot, walleye, lake whitefish, cockle, Jonah crab, snow crab, crayfish, Chinese white shrimp, bay scallop	sablefish, Atlantic salmon, pink shrimp, king crab, blue mussel, greenshell mussel, coho salmon, skate, dungeness crab	chum salmon, escolar, c hinook salmon, American shad

Firm texture	gulf shrimp, Pacific white shrimp, squid, grouper, halibut, monkfish, pompano, Arctic char, carp, catfish, dory, yellowtail, Abalone, conch, stone crab,Dover sole, sturgeon, tilefish, wahoo, American lobster, spiny lobster, freshwater shrimp, octopus, black tiger shrimp	kingklip, mahimahi, opah, barr amundi, cusk, dogfish, mako shark, swordfish, geoduck clam, squat lobster,albacore tuna, yellowfin tuna, rock shrimp, sea scallop	Chilean sea bass, cobia, barracuda, croaker , eel, blue marlin, blue fin tuna, mullet, sockeye salmon

2.2.2. Nutritional compositions and health benefits of seafood

Fish can make up as part of a nutritious diet and is a good source of minerals and vitamins; oily fish is rich in omega-3 fatty acid, which may benefit heart health (NHS, 2015). From freshwater and saltwater fish to the deep water shellfish, seafood is a cherished delicacy. Seafood is nutrient-dense, functions as a good source of protein, minerals, and vitamins, in addition to being rich in omega-3 fatty acids and aids in the reduction of common diseases.

Here are the Top ten (10) from Health benefits of seafood

- **Good for joints –** Regular consumption of seafood has been demonstrated to lessen the arthritis symptoms. Research has revealed that regular consumption of omega-3 fatty acids can reduce morning stiffness and ease tender joints in subjects with rheumatoid arthritis.

- **Provision of essential nutrients** – Although the facts depend on the seafood type you consume, seafood is well-known for being a natural source of vitamin D, minerals, vitamins, B-complex vitamins, and vitamin B. B-complex vitamins such as B1, B3, biotin, B12, etc., carry out various different functions, prompting energy production, metabolism, concentration, and beauty. Some kinds of fish, like salmon, are rich source of vitamin A, hence helping to safeguard vision and enhance the immune and reproductive system’s abilities. One more vitamin found in a number of seafood – regularly the fatty skin of tuna, salmon, and others – is vitamin D that supports healthy bone growth and development, boosts immune system efficiency, and aids calcium absorption, as well as cell growth and development.
- **Promoting heart health –** While seafood is nutritive enough to be high in protein and low in saturated fats, its ultimate health benefit lies in its ample source of omega-3 fatty acids. Whereas quite a lot of studies have been done on the health benefits of the omega-3 fatty acids, they are most remarkably well-known for their benefits in cardiovascular health. In actual fact, they can meaningfully reduce the risk of cardiovascular diseases such as strokes, arrhythmias, and heart attacks from arising. Although many desire to obtain their omega-3 fatty acids with capsules, it’s more advisable when got from the actual consumption of seafood.

- **Maintenance of eyesight –** A study in 2014 published in the *Investigative Ophthalmology and Visual Science Journal* submits that individuals who eat omega-3 fatty acids in seafood are least likely to suffer from age-linked macular relapse, a disease that can result in vision loss. Fish and shellfish consumption can also improve night vision. Regular consumption of oil-rich fish can help keep the eyes healthy and bright.

- **Glowing skin –** Consistent consumption of seafood aids skin moisture retention. The skin’s natural glow is influenced more by diet. The omega-3 fatty acids in seafood shield the skin against the UV rays from the sun. Current research has found narrow discoveries signifying fish oil can aid in reducing the pervasiveness of acne.

- **Brainpower enhancement –** Seafood omega-3s might lower the risk of developing Alzheimer's disease. A sufficient intake of EPA and DHA found in omega-3 fatty acids promote good brain growth and development in babies and children. Recent research suggests prolong intake of omega-3 fatty acids could boost cognitive function in aging females.

- **Reduce depression –** Latest research has revealed an association between the intake of omega-3 fatty acids and danger of depression and has found that consumption of omega-3 fatty acids may not only reduce the risk of depression but has the prospective to treat depression as well.

- **Pregnancy benefits –** Research indicate that consumption of more fish has helpful benefits on birth weight as it improves fetal growth and development. The consumption of seafood also aid in decreasing preterm delivery and is vital for central nervous system development.

- **Improves immune function –** Increased consumption of omega-3 can lessen the symptoms of asthma and some allergies. Selenium is an effective antioxidant found in seafood that is well-known to improve the human immune system.

- **Lots of choices –** There are a wide variant of seafood to select from. Even though one of the utmost deterrents to seafood is that "sea taste", there are numerous different healthy techniques to prepare a meal to aid dispense with that fishy feeling and unwanted taste.

2.2.3. Health hazards related to seafood

Some fish contain mercury and other harm substances. Fish and shellfish have a usual propensity to accumulate mercury in their bodies, habitually in the form of methyl mercury, a very highly toxic and organic compound of mercury. Types of fish high on the food chain, such as king mackerel, albacore tuna, swordfish, tilefish, and shark contain higher mercury concentrations than others. This is due to mercury is deposited in the fish muscle tissues, and when a predacious fish prey on another fish, it takes up the whole body load of mercury in the consumed fish. As fish accumulate methyl mercury more efficiently than they depurate it, fish-tissue concentrations rise over time. Thus species of fish that are high on the food chain accumulate body loads of mercury that could be ten times larger than the species they eat. This process is named "Biomagnification". The first incidence of widespread mercury toxicity in humans happened this way in Minamata, Japan, and is now called Minamata disease.

Food Allergy & Anaphylaxis Network stated that shellfish are among the common food allergens (Food Allergy & Anaphylaxis Network, 2007). A common miscalculation is a cross-reactivity between iodinated radiocontrast agents and seafood (Boehm, 2008).

For individuals (males and females) not of childbearing age, it is unclear that exposure to mercury from distinctive levels of fish consumption has any antagonistic health effects. In opposite, fish consumption has substantial benefits for decreasing the risk of death from cardiac disease, the leading cause of death. Accordingly, mercury exposure from fish consumption should not be a main concern to individuals (males and females) not of childbearing age. The benefits of fish consumption can be maximized by eating a wide variety of different seafood.

Mercury may possibly have subtle impacts on the development of infants' nervous systems. Consequently, pregnant women, those who are breastfeeding, women who may become pregnant, and very young children ought to avoid 4 varieties of fish that are very high in mercury: swordfish, king mackerel, shark, as well as golden bass. Other fish can still be consumed to make sure that infants obtain the benefits of DHA for the development of brain. Light tuna has comparatively low mercury levels, and other fish, such as wild and cultivated salmon and shrimp, have very low mercury levels.

Polychlorinated biphenyls (PCBs) and dioxins can amass in foods, like fish. The levels of these chemicals seen in fish, including cultivated fish, are very low and related to levels in dairy products and meats. Likened with the health benefits of fish consumption, the health risks of levels of these compounds are very low and ought not to influence individual choices about fish consumption. Compared with fish bought from store, freshwater fish caught locally may have higher levels of these chemicals, therefore local advisories ought to be consulted for advice.

Generally, the health benefits of consumption of fish significantly outweigh the likely risks, particularly when guiding principles are used to lessen the minor chance of being affected by the risks.

Focus on mercury in fish:

Fish and shellfish accrue mercury in their bodies, frequently in the form of methylmercury, a very toxic organomercury compound. Fish products have been revealed to have variable amounts of heavy metals, predominantly mercury and fat-soluble pollutants from marine pollution. Species of fish that live long in addition to being high on the food chain, such as swordfish, king mackerel, marlin, tuna, shark, and tilefish have higher bioaccumulation of mercury than others. Mercury is well-known to bioaccumulate in humans, so its bioaccumulation in seafood transmits into humans, where it can cause mercury poisoning. Mercury is dangerous to both humans and the natural ecosystems as it is a metal well-known to be extremely toxic, mainly due to its capability to harm the central nervous system. In human-controlled ecologies of fish, customarily done for market production of required seafood species, mercury noticeably increases through the food chain by way of fish eating small plankton, as well as via non-food sources, for instance underwater sediment. The occurrence of mercury in fish may be a specific health concern for women who are pregnant or intending to become pregnant, young children, and nursing mothers.

Biomagnification of mercury in fish:

The intake of fish is undoubtedly the most substantial source of ingesting-related mercury exposure in animals and humans. Mercury and its organic form, methyl mercury, are present in very small concentrations in saltwater. Nevertheless, they are absorbed, typically as methyl mercury, by algae at the beginning of the food chain. The algae is then consumed by fish and other higher organisms in the food chain. Fish absorb methyl mercury efficiently, but eliminate it very slowly. The Methyl mercury is *insoluble and as a result not excreted. Instead, it accrues, mainly in the viscera, though also in the tissue of muscle. This leads to the bioaccumulation of mercury, as it builds up in the adipose tissue in successive trophic levels: larger fish, zooplankton, small nekton, and so on. The older that such fish, the more mercury they might have bioaccumulated. Anything that consumes these fish in the food chain also ingests the high level of mercury the fish have accumulated. The process elucidates why predacious fish such as sharks and swordfish or birds like eagles and osprey have higher accumulations of mercury in their tissue than might be possible by direct contact alone. Species on the food chain can accumulate mercury in the body up to ten times greater than the species they eat. The process is known as biomagnification. For instance, herring has mercury levels at about 0.1 parts per million, whereas shark has mercury levels higher than 1 ppm.*

2.2.4. Improper labelling

A 2013 research by Oceana found that one in every three of seafood sampled from the US was inaccurately labelled. Tuna and snapper were mainly predisposed to mislabelling, and seafood replacement was the most public type of deception (Oceana, 2013). These deceptive practices can damage both the consumers' wallet as well as pose health risks. A different type of inaccurate labelling is short-weighting (Fish Watch, 2018), where overglazing or soaking practices can misleadingly increase the actual weight of the fish. The detection of agents of water retention assists in identifying the fraud and its source.

2.3. Sustainability of seafood

Sustainable seafood is a seafood that is caught or farmed in ways that reflect the lasting vitality of harvested species and the welfare of the oceans, and the incomes of fisheries-dependent societies. It was first upheld via the sustainable seafood movement which started in the 1990s. Investigation into trends in population of several species of seafood is indicating a universal collapse of seafood species by the year 2048. Such a collapse takes place due to overfishing and pollution, menacing oceanic ecosystems, according to information from some researchers (Boston, 2007).

A major global scientific research published in the journal *Science* in November 2006 found that around one in every three of all fishing stocks globally have declined to less than 10% of their maximum observed abundance, and that if the current trends continue all fish stocks globally will collapse in fifty years (BBC News, 2006). Around July 2009, Boris Worm of Dalhousie University, the author of the 2006 research article in *Science*, co-authored an edition on the state of the world's fisheries in conjunction with Ray Hilborn of the University of Washington, a critic of the original study, at Seattle. The new edition found that via good fisheries managing techniques even dwindled fish stocks could be revitalized and made commercially viable yet again (The New York Times,2009).

The FAO State of World Fisheries & Aquaculture in 2004 report projected that in 2003, of the key fish stocks or resources which evaluation information is accessible, roughly 20% were depleted, over exploited, or recovering from depletion (7%, 16%, and 1% respectively) and required rebuilding (The State of World Fisheries and Aquaculture, 2004).

The National Fisheries Institute, a well-known representative trade advocacy group of the US seafood industry, disagrees. They maintained that presently perceived decline in the population of fish is due to natural variations and that improved technologies will in time alleviate any impact human is having on marine life (MSNBC, 2007).

2.4. Seafood in religion

For the utmost part Islamic nutritional laws allow the consumption of seafood, although the Hanbali prohibit eels, the Shafi prohibit crocodiles and frogs, and the Hanafi outlaw bottom feeders such as carp and shellfish. The Jewish laws of Kashrut prohibit the consumption of eels and shellfish (Yoreh, 2012). In the Old Testament in the bible, the Mosaic Covenant permitted the Israelites to consume finfish, but eels and shellfish were an atrocity and not permitted. In prehistoric and middle age times, the Catholic Church prohibited the practice of consuming eggs, meat, and dairy products for the period of Lent. Thomas Aquinas debated that these "afford more pleasure as diet than fish, and more nourishment to the body of human, so that from their intake there marks a greater excess obtainable for seminal matter, which when plentiful grow into a great inducement to lust." In the US, the Catholic doctrine of abstaining from meat on Fridays for the period of Lent has promoted the Friday fish fry (Walkup, 2003), and parishes regularly sponsor a fish fry for the period of Lent. In mostly Roman Catholic populated areas, restaurants can change their menus in the course of Lent by adding seafood stuffs to their menu (Carlino, 1990).

2.5. Sustainable seafood

Sustainable seafood is a seafood that is farmed or caught using methods that reflect the long-term vivacity of harvested species and the health of the oceans, in addition to the livelihoods of fisheries-dependent societies. It was first endorsed via the movement for sustainable seafood which started in 1990s. The operation focused on environmentally destructive fishing and overfishing methods. Through many initiatives, the movement raised concerns and increased awareness over the manner our seafood is harvested.

2.5.1. Significance of the Sustainable Seafood Movement

Presently, aquatic environments are in colossal pressure. Their glitches predominantly arise through anthropogenic sources, such as ecological destruction and overfishing. However, study put forward that fisheries are capable of stabilizing or recovering their populations when responsible regulations and management are put in place (Bassan, 2011). Regrettably, most seafood is gotten through reckless fishing practices that continue the modification of some aquatic ecosystem, resulting in record dwindling stocks (Bassan, 2011). For instance, over 85 percent of the global fisheries are fished at or more than their maximum limit of sustainability (Bassan, 2011). Putting into consideration the growing world population and the pressure it has, and still continue to exert on Earth's resources, a better sustainable fishing method is required if humans desire to make use of its natural richness.

2.5.2. Sustainable Seafood Movement

Sustainable Seafood Movement is a resourceful initiative born out of the realization that world aquatic ecosystems were being damaged, hurt, and overexploited (Cooke *et al.*, 2011). It started in the 1990s and was propelled by social marketing via campaigns for Ecolabel and awareness (Roheim, 2009). By means of social marketing, the cooperation between industry and environmental non-governmental organizations (NGOs) allowed for the user to make well-informed selections, possibly contributing to the marine biodiversity conservation (Cooke *et al.*, 2011).

2.5.3. Ecolabeling programs

Ecolabeling programs assess the production process using environmental standards set by independent third party. If the process accomplishes the specific requirements, the marketer or producer may acquire the license to use ecolabel for its marketing. This allows the buyer to identify that the product was made sustainably (Roheim, 2009). Labeling is not only an active regulatory tool in cheering consumers to make ecofriendly choices, but it also affords a financial advantage to the producers. In 1996 the MSC (Marine Stewardship Council) effected the first certification program (Cooke *et al.*, 2011). Since then, they have not made only a discrete effort to conserve the health of ecosystems, but have also added to more financial success for the producers. For example, as soon as the American Albacore Fishing Association (AAFA) had its tuna certified to standard of the Marine Stewardship Council, they were able to acquire premium prices for their products (Green Futures, 2010). For the lesser fishing society in Bonita, California, certification permitted them to trade direct, as opposed to relying on the unsteadiness on the dock (Green Futures, 2010). They make a profit of $2,260 better than $1,700 per tonne (Green Futures, 2010). More organizations and companies are currently opting in to use environmentally sustainable production, ecolabeling for instance, to gain a larger market share and greater profits.

2.5.4. Awareness campaigns

Awareness campaigns focus on teaching the community and inspiring them to buying products that reflect the vitality of aquatic species (Roheim, 2009). They do it by boycotting certain products and species as well as by seafood guides. Seafood guides list the species that are acceptable to eat and which are not based on their ecological impact (Roheim, 2009). Guides are normally constructed into three groupings, some by the likeness of a traffic light's colours: yellow, red, and green (Roheim, 2009). These rankings are dependent on how the seafood reacts to fishing abundance, gear impact, pressure, management, and by catch. Yellow represents a good alternative, red is item to shun, and green is the top choice (Roheim, 2009). Many organizations, like the Monterey Bay Aquarium, developed their own seafood guides or seafood wallet cards for public distribution (Cooke *et al.,* 2011).

In September 2016, a collaboration of Oceana, Skytruth, and Google introduced Global Fishing Watch, a website aimed to assist citizens of the world in monitoring activities of fishing (Google, 2016; Oceana, 2016).

2.5.5. Fishing Methods

There are a variety of fishing methods used all over the world today. Each one has its impact on the environment that varies on intensity. Table 3 lists fishing method along with its environmental impacts.

Table 3: Fishing Methods

Method	Type of fish	Equipment uses	Environmental Impact
Pole/troll	Bottom dwellers to open ocean swimmers	Fishing rod/pole and bait	Reduced chance of by catch. Low environmental impact.
Purse seining	Schooling fish	Large net is used to border fish. The bottom of the net is drawn close to push the fish towards the middle	Greater chance of by catch
Gillnetting	Sardines, cod, salmon	Uses a structure of nets with weights and floats. The nets are moored to the sea floor and allowed to stay afloat at the surface	Animals can not perceive the net and therefore, they swim into it and are snarled. Colossal risk of by catch.
Traps and pots	Lobsters, shrimp, crab	Wire or wooden cages anchored to the ocean floor; fishing weirs	Lower chance of by catch. The traps retain the fish alive.
Trolling	Salmon, tuna, mahi-mahi	Line towed at the back of the boat	Relieves by catch
Longline	Pelagic fish	Fishing line thrown out from the boat.	Fishermen use weights to

fishing		May range from 1 to 50 miles.	descend their lines, decreasing the risk of by catch. Very high possibility of by catch.
Harpooning	Large pelagic fish	Harpoon	No possibility of by catch. Fishermen have to visualize target.
Trawls & d redges	Pollock, shrimp, cod, flounder	Use of huge fishing nets that can either drag in the middle of the surface or the floor or on the bottommost of the sea floor.	Can destroy the sea floor. Huge number of by catch.

2.5.6. National Oceanic and Atmospheric Administration (NOAA)

The National Oceanic & Atmospheric Administration (NOAA) is a state government agency which has authority over marine fisheries, management, and conservation. It has formed Fish Watch to assist in guiding disturbed consumers to sustainable seafood selections. The fisheries in the US are watched over by the Ten National Standards of Magnuson–Stevens Fishery Conservation & Management Act. Hence, the National Standards are guarding the fish population and abolishing overfishing. Alongside with the Magnuson-Stevens Act, United State fisheries are also controlled under the Endangered Species Act & Marine Mammal Act (MAFAC, 2007).

The National Oceanic & Atmospheric Administration fisheries service has begun using aquaculture to make sustainable seafood. Aquaculture is shellfish or fish farming. The aquaculture fisheries hatch the eggs of the fish and nurture the fish until they grow to market size. By use of aquaculture the wild fish will repopulate without overfishing threat. Aquaculture fish have a range of uses including: pharmaceutical, food, and nutritional. Two different types of aquaculture exist; fresh water and marine aquaculture. Marine aquaculture farms the species of fish that live in the sea while fresh water aquaculture farms the species of fish that live in the freshwater. The National Oceanic & Atmospheric Administration is focusing on an alternate seafood sources to aid repopulate and protect the ocean's environments.

2.5.7. The Marine Stewardship Council

An international non-profit organization called the MSC (Marine Stewardship Council) is working to preserve the oceans. Its mission is to make a joint use of certified fisheries and ecolabeling to make societies aware of how essential it is to conserve our oceans. The two major ways the MSC controls the regulation of sustainable seafood is by making standards for ecolabeling and certified fisheries. The MSC works with scientists, seafood companies, fisheries, conservation groups, and the community to promote environmental friendly seafood choices.

The certified fisheries are adjudged on the three standards provided by the MSC. However, the Marine Stewardship Council does not certify the fisheries. The fisheries are certified by third party system to eliminate any bias. The MSC standards were made to maintain healthy ecosystems and reduce overfishing. The three standards include:

- Environmental Impact. Every one of the fisheries is adjudged by the extent of the impact they have on the ocean environments. The fishery might not use any method of fishing that destroys the function, structure, diversity, or productivity of the ecosystem.
- Maintaining Sustainable Fish Stocks. The fishery might not excessively exploit any of its resources.

- Effective Management. Not only does the fishery follow the other two MSC standards, they also follow all national, international, and local laws.

Once a fishery is reviewed and certified, its certification is valid for 5 years. Within that 5 years period, the fishery will be inspected and gauged to the MSC environmental standards. The fishery will have to under the approval process again after the 5 years period passed.

The second means the Marine Stewardship Council regulates seafood to the people is by use of ecolabelling. The ecolabel on products of seafood assures that the seafood is a certified fishery and come from a sustainable source. The ecolabel are found around the globe. The consumer feels good about purchasing seafood with MSC ecolabel.

The fishery must obtain the MSC Fisheries certification before the MSC ecolabel is placed on a seafood product. In addition, all businesses in the supply chain that take proprietorship of the product including manufacturers, pack houses, retailers, catering organizations, restaurants, traders, distributors, and wholesalers must obtain the Marine Stewardship Council Chain of Custody Certification.

2.5.8. The Marine Stewardship Council Criticisms

Critics criticize the MSC for certifying particular fisheries that may be injurious to the environment, in distress, or where there is a dearth of information available (Williams, 2015). For instance, the Antarctic tooth fish fishery located in the Ross Sea was conferred an MSC label, regardless of a lack of rudimentary information on the stock itself (Smith, 2015). A Marine Policy research that analyzed the MSC fisheries stocks found that over 31 percent of the stocks were overfished, and 11 percent did not have appropriate information available (Froese and Proelss, 2012). A Greenpeace oceans campaigner, Richard Page, stated that consumers are being cheated. Consumers think they are buying sustainable fish and can consume them with a clean conscience (Smith, 2015).

3.5.9. The Friend of the Sea

The Friend of the Sea is a current project of the World Sustainability Organization, a worldwide trademark registered by humanitarian and environmental conservation mission. The Friend of the Sea was founded by Dr. Paolo Bay who initiated the movement for sustainable seafood in Europe. The International Organization for Standardization audit the certified fisheries. The criteria for becoming a certified fishery is:

- No habitat devastation
- Social accountability
- No endangered species by catch
- The fish stock might not be overexploited
- The Reduction of carbon footprint
- Must obey all regulations and laws

The Friend of the Sea also plays a part in the aquaculture farms certification. The setting up of aquaculture helps lessen the number of species caught in the wild. The criteria of aquaculture include:

- Must adhere to all waste water guidelines
- Must use antibiotics only if it is required
- A very low escapes percentage
- Social accountability

- No environmental impact where the farm is located
- Reduction of the carbon footprint
- No growth hormones, no genetically modified organisms

In 2004, aquaculture accounted for 32 percent of the total fish production. Aquaculture is gradually becoming more popular with over 8 percent rise per year in the past 30 years.

2.5.10. The sustainable seafood advisory lists and certification

The sustainable seafood advisory lists & certification are programs designed for increasing the consumer awareness of the sustainability of their seafood buying choices and the environmental impacts. The Marine Conservation Society and the California-based Seafood Watch's fish online are some of the well-known guides. Marine Stewardship Council's scheme for consumer seafood products is one of the well-known certification programs. Other programs are regional guides, like that produced by the AMCS (Australian Marine Conservation Society). In North America, Canada in particular, Sea Choice makes recommendations and assessments using the system of traffic light, while the recommendation of restaurants is carried out by Vancouver Aquarium's Ocean Wise.

The lists of advisory and guides

- The Blue Ocean Institute Seafood Guide in New York City.
- Royal Forest & Bird Protection Society (RFBPS) of New Zealand, Best Fish Guide
- The USAudubon Society's National Seafood Wallet Card (ASNSW)
- India’s In Season Fish A sustainable seafood guide
- Fish online website & Good Fish Guide (UK & Northeast Atlantic)
- Marine Conservation Society (MCS)
- The Monterey Bay Aquarium Seafood Watch
- The Seafood Guide established by Good Fish Foundation (goedevis.nl) & WWF Europe
- Greenpeace: International Seafood Red list
- The Environmental Justice Foundation Consumer Guide To Prawns
- Australian Marine Conservation Society makes Australia's Sustainable Seafood Guide, a consumer guide used to advise the consumers about endangered fish species.
- Monterey Fish Market Seafood advisory list in West Coast, USA
- Initiative of Sustainable Seafood Canada; (Sea Choice) Canada’s Seafood Guide

Labelling and certification

- Sustainable Fishery Advocates runs the FishWise program aimed at labeling seafood by retailers.
- The Marine Stewardship Council lists certified products on its website and provides a consumer seafood products’ certification program
- Friends of the Sea, an independent organization, developed certification structures for products from aquaculture and sustainable fisheries. The certification structures also contain standards for the carbon footprint reduction and social accountability.
- A Vancouver Aquarium conservation program, Ocean Wise, certify restaurants and publish a dining guide.

Consumer health

- The US Oceana's Campaign to Stop Seafood Contamination

2.6. Fish and seafood as food

Several fish species are eaten as food in almost all regions round the globe. Fish is a significant source of protein and other essential nutrients for humans. In fishery and culinary contexts, *fish* include shellfish, like echinoderms, molluscs, and crustaceans. English language does not make a distinction between fish as an animal & the food made from it, as is applicable to cow vs. beef or pig vs. pork. Also English has the word seafood used for fish found in the oceans and seas, and other aquatic life used as food.

Ever since 1961, the mean annual growth in world apparent food fish consumption (3.2%) has overtaken population growth (1.6%) and surpassed meat consumption from all land-dwelling animals, combined (2.8%) and individually (ovine, pig, bovine, other), with the exception of poultry (4.9%). In per capita basis, consumption of food fish has grown from 9.0 kg in the year 1961 to 20.3 kg in 2016, at mean rate of about 1.5% per year (FAO, 2018).The increase in consumption is driven not only by production increase, but also by combination of several factors, including urbanization, growing demand, wastage, rising incomes, better utilization, and linked with population growth, among others (FAO, 2018).

Europe, Japan and the US all together accounted for 47% of the world's total consumption of food fish in 1961 but later reduced to about 20 percent in 2015. Of the world total of 149 million tons in 2015, Asian countries consumed over two-thirds; record 106 million tons at 24.0 kg per capita (FAO, 2018). Africa and Oceania recorded the lowest share of consumption. The shift is due to the outcome of structural modifications in the sector and, particularly, the growing role of Asian countries in production of fish, and a significant margin between the rates of economic growth of the world's mature fish markets and the ones of various increasingly essential emerging markets round the world, mainly in Asia (FAO, 2018).

2.6.1. Species

Over 32,000 fish species have been described (FishBase, 2012), making fish species the most varied group of vertebrates. Additionally, there are several shellfish species. Nevertheless, only a lesser number of species are normally consumed by humans.

Table 4.: Common species of fish & shellfish used for food

	Mild flavor	Moderate flavor	Full flavour
Delicate texture	Basa, rainbow trout, hardshell clam,flounder, hake, scup, smelt, blue crab, peekytoe crab, eastern oyster, Pacific oyster, spanner crab, cuttlefish	lingcod, moi, orange roughy, Anchovy, herring, Atlantic Ocean perch, European oyster, sea urchin, Lake Victoria perch, yellow perch	Atlantic mackerel
Medium texture	European sea bass, Black sea bass, hybrid striped bass, hoki, Alaska pollock, rockfish, bream, cod, drum, haddock, pink salmon, snapper, tilapia, wolffish, hardshell clam, turbot, walleye, lake whitefish, surf clam, cockle, bay scallop, Chinese white shrimp, snow crab, crayfish, Jonah crab	Atlantic salmon, coho salmon, Sablefish, skate, dungeness crab, greenshell mussel, pink shrimp, king crab, blue mussel	American shad, Escolar, chum salmon, chinook salmon
Firm	Dory, grouper, halibut, monkfish, Arctic	Kingklip, mahimahi, opah,	Chilean sea

texture	char, carp, catfish, pompano, Dover sole, abalone, conch, stone crab, sturgeon, tilefish, wahoo, yellowtail, American lobster, spiny lobster, gulf shrimp, Pacific white shrimp, squid, octopus, black tiger shrimp, freshwater shrimp	Barramundi, cusk, dogfish, mako shark, swordfish, geoduck clam, squat lobster, albacore tuna, yellowfin tuna, rock shrimp, sea scallop	bass, cobia,Barracuda, croaker, sockeye salmon, bluefin tuna, eel, blue marlin, mullet

Source: Peterson, James & editors of Seafood Business (2009)

2.6.2. Preparation of Fish

There are variety of ways fish can be prepared; can be uncooked (raw) (*e.g.,* sashimi), cured by marinating (*e.g.,* ceviche), smoking (*e.g.,* smoked salmon), pickling (*e.g.,* pickled herring), steaming, grilling, frying (*e.g.,* fish and chips), poaching (*e.g.,* court-bouillon), or baking. Many of the techniques for preservation used in many cultures have become redundant but are still done for their resultant texture and taste when consumed.

2.6.3. The nutritional value of Fish

Internationally, fish and fish products on the average provide only about 34 calories per capita each day. Nonetheless more than as source of energy, the nutritional contribution of fish is substantial in terms of easily digested animal proteins, high-quality, and particularly in combating micronutrient deficiencies (FAO, 2018). A ration of 150g of fish provides 50 to 60% of an adult's daily requirement of protein. Fish proteins are important in the diet of some countries that are densely populated, where the total intake of protein is low, and are mainly essential in diets of Small Island Developing States (SIDS) (FAO, 2018).

Table 5.: A **comparison of the nutrients in 100 g of oily fish and whitefish**

Nutrient	Whitefish Alaska pollock	Oily fish Atlantic herring
Energy (kcal)	111	203
Protein (g)	23	23
Fat (g)	1	12
Cholesterol (mg)	86	77
Vitamin B-12 (µg)	4	13
Phosphorus (mg)	267	303
Selenium (µg)	44	47
Omega-3 (mg)	509	2014

United States Department of Agriculture (September 2011).

In 1992, the Intermediate Technology Publications wrote that Fish offers a good source of high protein quality and has many vitamins and minerals. It can be classed as oily fish, shellfish, or whitefish. Whitefish, like seer and haddock, have very little fat, commonly less than 1 percent, while oily fish, like sardines, have between 10 to 25 percent. Due to its high fat content, the oily fish have a variety of fat-soluble vitamins, A, D, E, K, as well as essential fatty acids, which are all essential for healthy functioning of the human body (Fellows and Hampton, 1992)

2.6.4. The health benefits of Fish

Fish is amongst the top healthiest diets on the earth. Studies over the past decades have revealed that the nutrients and minerals content of fish, and the omega-3 fatty acids in pelagic fishes in particular, are friendly to the heart and can help improve the development of brain and reproduction. It's dense with essential nutrients, like vitamin D and protein. Also, Fish is a rich source of omega-3 fatty acids, shown to be extremely essential for human brain and body.

Here are eleven health benefits of fish consumption that are proven by series of research.

1. High in essential nutrients

Fish is filled with lots of nutrients that are lacking in most individuals. These include high-quality protein, and various vitamins and minerals, notably iodine. Fatty species are at times considered the healthiest. This is because fatty fish, including sardines, tuna, salmon, mackerel, and trout, are higher in fat soluble nutrients. This includes vitamin D, a fat-soluble nutrient lacking in many individuals. Fatty fish boast omega-3 fatty acids that are essential for optimal function of the human body and brain, as well as strongly linked to reduced risk of various diseases. To meet one's omega-3 requirements, one should consume fatty fish at least once or twice per week as recommended. For a vegan, better opt for omega-3 supplements produced from microalgae.

2. Reduces risk of strokes and heart attacks

Strokes and heart attacks are two most popular causes of untimely death in the world. Fish is one of the heart-healthy foods. Predictably, various great observational studies indicate that individuals who consume fish frequently have a lower risk of strokes, heart attacks, and death from related heart and nerve diseases. In one study involving more than 40,000 men in the US, those who frequently ate at least one servings of fish a week had a 15 percent lower risk of developing heart diseases. Researchers believe that fatty fish are more beneficial for heart health because of their high content of omega-3 fatty acid.

3. Have nutrients essential for development

The omega-3 fat docosahexaenoic acid (DHA) is particularly significant for the development of brain and eye. Omega-3 fatty acids are vital for human development and growth. For this reason and more, it's often recommended that pregnant and lactating women consume sufficient omega-3 fatty acids. Though, some fish species are high in mercury, which has been linked to problems of brain development. Consequently, pregnant women should only consume fish low in mercury, like sardines, trout, and salmon, and not more than 340 grams a week. They ought to shun raw, uncooked, and improperly cooked fish as it may contain microbes that can hurt the fetus.

4. Enhance brain health

Brain function regularly declines as one ages. Whereas mild mental decline is usual, severe neurodegenerative ailments such as Alzheimer's disease are also in existence. Many observational studies show that humans who consume more fish have slower mental decline rates. Studies also indicate that individuals who consume fish weekly have more gray matter — brain's main functional tissue — in the brain parts that regulate and control memory and emotion.

5. Depression prevention and treatment

Depression is a common psychological condition characterized by decreased energy, low mood, sadness, and loss of interest in activities and life. Though it is not talked about as much as heart disease or obesity. Depression is presently one of the world's major health complications. Studies have shown that individuals who consume fish frequently less likely to be depressed. Many controlled trials also show that omega-3 fatty acids can fight depression and significantly raise the efficiency of antidepressant medications. Fish consumption and omega-3 fatty acids can also help other mental conditions, like bipolar disorder.

6. A good source of vitamin D

Fish and fish products are amongst the best vitamin D dietary sources. In the body, vitamin D acts as a steroid hormone; over 41.6 percent of the population of the US is either low or deficient in it. Fatty fish like salmon & herring have the highest amounts of vitamin D. A single 113 g serving of cooked salmon has around 100% of the recommended vitamin D intake. Some fish oils, like cod liver oil, are also very rich in vitamin D, providing over 200 percent of the Daily Value per 15 ml; a single tablespoon. If one doesn't get much sun and doesn't consume fatty fish frequently, one may consider intake of a vitamin D supplement.

7. May reduce risk of autoimmune diseases

Autoimmune diseases like type 1 diabetes arise when the immune system erroneously attacks and damages healthy tissues of the human body. Many studies have linked fish oil or omega-3 consumption to a decreased risk of type 1 diabetes in infants and children, and a kind of autoimmune diabetes in adults. Vitamin D and omega-3 fatty acids in fish and fish oils could be responsible. Many experts held that fish consumption may also reduce the risk of multiple sclerosis and rheumatoid arthritis, although the existing evidence is weak.

8. Can assist in preventing asthma in children

Asthma is a known disease characterized by a chronic inflammation of airways. The rate of this disease has increased dramatically since the past decades. Research indicates that regular fish intake is associated to a 24 percent reduced risk of asthma in children, however no significant effect has been reported in adults.

9. May prevent age-related ocular degeneration

Age-linked macular degeneration (AMD) is the leading cause of blindness and vision impairment that typically affects older adults. Various evidence put forward that omega-3 fatty acids and fish may protect against AMD. In a study, frequent fish consumption was linked to a 42 percent lower risk of age-related macular degeneration in women. A different study found that fatty fish consumption once a week was associated to a 53 percent reduced risk of neovascular AMD.

10. Fish may improve quality of sleep

Sleep disorders and related impairments have become very common globally. Increased exposure to blue light could play a part, but some scientists believe that the deficiency of vitamin D could also play a part. In a 6-month research in 95 middle-aged men, a diet with salmon 3 times a week led to marked improvements in sleep and daily functioning. The research scholars suspected that this was due to the vitamin D content.

11. Delicious and ease of preparation

Fish is delightful and easy to cook. For this and more reasons, it should be pretty easy to integrate it into your food. Consuming fish one or two times every week is presumed sufficient to for its benefits. If possible, choose catch fish from the wild rather than cultivated. Wild fish are likely to have more omega-3 fatty acids. Salmon can be fried, boiled, baked, or seared. It combines well with a many vegetables and grains.

2.6.5. The health hazards of fish consumption

Fish is the one of the most common food to interrupt the airway and cause choking. Choking due to fish consumption was answerable for nearly 4,500 reported incidences in the UK in 1998 (Accident Statistics, 1998).

2.6.5.1. Seafood allergens

A seafood (fish) allergy is a hyperactive sensitivity to an allergen which may be present in fish, particularly in shellfish. This may lead to hyper reactiveness of the immune system, leading to severe physical symptoms (National Institutes of Health, 2005). Some individuals who have food allergy also suffer seafood allergy (Allergy Facts and Figures, 2019). Allergic reactions may result from consumption of seafood, or by inhaling vapors from cooking or preparing seafood (Canadian Food Inspection Agency. 2009). Anaphylaxis is the utmost severe seafood allergy reaction; which is an emergency demanding immediate attention. Epinephrine can be used to treat anaphylaxis.

2.6.5.2. Biotoxins in fish

Some fish species, especially the puffer fugu used for sushi, as well as some types of shellfish, can result in serious poisoning if improperly prepared. These fish always use these poisons as a defense mechanism against predators. Particularly, fugu consumed in Japan has lethal dose of tetrodotoxin in its inner organs. Ciguatera poisoning can arise from consumption of bigger fish from the warm tropical waters, like barracuda, grouper, red snapper, and sea bass. Scombroid poisoning can be caused from consuming large oily fish which have stayed around for a long time before freezing or refrigeration. This includes scombroids like mackerel and tuna, but may also include non-scombroids like amberjack and mahi-mahi. The poison is tasteless and has no odour (Swift and Swift, 1993).

Lots of fish consume algae and other organisms that have biotoxins; defensive materials against predators. Biotoxins accumulated in fish and shellfish include saxitoxins, ciguatoxin, brevetoxins, domoic acid, and okadaic acid. With the exception of ciguatoxine, high quantities of these toxins are found only in shellfish. Both ciguatoxine and domoic acid can be lethal to humans; others will only cause dizzyness, diarrhea, and a short-term feeling of claustrophobia.

As shellfish are filter feeders, they accrue toxins made by microscopic algae, like diatoms and dinoflagellates, and cyanobacteria. There are four syndromes known as shellfish poisoning which may appear in sea mammals, humans, as well as birds from the intake of toxic shellfish. They are primarily associated with bivalve molluscs, like oysters, mussels, clams, and scallops (Silver, 2006). Fish, just like anchovies can also accumulate toxins like domoic acid. If suspected, medical attention has to be sought.

The toxins that are responsible for most fish and shellfish poisonings, including scombroid and ciguatera poisoning, are resistant to heat to the point where conventional cooking and preparatory methods do not get rid of them.

2.6.5.3 Toxic metals in fish

Fish and fish products contain varying quantities of heavy and toxic metals. Insoluble substances often show negligible toxicity; toxicity is a function of solubility. Organometallic compounds like dimethyl mercury and tetraethyl lead can be very toxic. According to the US FDA, the risk posed by mercury due to consumption of seafood (shellfish and fish) is not a health concern to many individuals. However, some seafood contains enough mercury to hurt unborn babies or young children's developing nervous system. Three recommendations made by the FDA for young children and child-bearing women are:

1. Check indigenous advisories regarding the fish safety (seafood) caught by friends and relatives in local rivers, coastal areas, and lakes. If advice is unavailable, consume up to 6 ounces (an average meal) per week of fish caught from local water bodies, but don't eat any other fish in same week.
2. Consume up to 2 average meals (12 ounces; 6 ounces per meal) per week of many fish and shellfish lower in mercury. Four of the most frequently consumed fish which are low in mercury include canned light tuna, pollock, catfish, and salmon. Albacore (white tuna), another commonly consumed fish, contains more mercury than the canned light tuna. Therefore, when selecting your two fish and shellfish meals, you may consume up to one average meal (6 ounces) of albacore tuna per week.
3. Do not consume shark, king mackerel, swordfish, or tilefish as they have high accumulations of mercury.

These three recommendations are also recommended when fish and shellfish are fed to young children, though in smaller portions.

2.6.5.4. Persistent organic pollutants in seafood

If fish and shellfish live in contaminated waters, they tend to accumulate other toxic chemicals, especially fat-soluble pollutants containing bromine or chlorine, PCBs or dioxins. Fish to be consumed have to be caught in uncontaminated water. Certain organizations such as Environmental Defense Fund, Seafood Watch, RIKILT, IMARES provide information on fish species that do not accumulate high metals/toxins.

2.6.5.5. Parasites in fish

Parasites in fish are common and a natural occurrence. Although not a health concern in carefully prepared fish, parasites are a health concern when consumers consume lightly preserved or raw fish such as gravlax, sushi, sashimi, and ceviche. The popularity of such lightly preserved or raw fish delicacies makes it imperative for consumers to know this risk. Raw fish have to be frozen to an inner temperature of −4 °F (−20 °C) for a minimum of 7 days to eliminate parasites. Home freezers could not be sufficiently cold to kill parasites.

Customarily, fish that live part of or all their lives in freshwater were seen as unfitting for sashimi due to the likelihood of parasitic infections. Parasites from freshwater fish are severe problem in most regions of the world, Southeast Asia in particular. Fish that expend part of their lifespan in freshwater or brackish water, like salmon, are a particular health problem. A study done in Seattle, Washington revealed that 100 percent of wild salmon contained roundworm larvae able to infect individuals. In the same study aquacultured salmon did not contain any roundworm larvae (Deardorff and Kent, 1989).

Parasite infection due to consumption of raw fish is uncommon in the developed world; less than 40 cases each year in the United States, and includes mostly three kinds of parasites: Anisakis (a nematode/roundworm), Diphyllobothrium (a cestode/tapeworm), and *Clonorchis sinensis* (a trematode/fluke). Anisakis' infection risk is mostly higher in fishes living in a river like mackerel (*saba*) or salmon (*sake*) in Salmonidae. Such parasitic infections can largely be avoided by preserving in salt, vinegar, boiling, or burning, or overnight freezing. It is common in Japan to consume raw ikura and salmon, but these foods are frozen all night prior to consumption to prevent parasite infections, particularly anisakis.

2.6.6. Vegetarianism

Table 6: Nutritional composition of fish compared to meat 110 grams (4 oz or 0.25 lb)

Source	protein	calories	carbs	fat
Fish	20–25 g	110–140	0 g	1–5 g
chicken breast	28 g	160	0 g	7 g
Lamb	30 g	250	0 g	14 g
steak (beef top round)	36 g	210	0 g	7 g
steak (beef T-bone)	25 g	450	0 g	35 g

As fish is flesh of animal, the Vegetarian Society showed that vegetarian diets cannot have fish. The neologism "Pescetarians" encompasses those who consume fish and other kinds of seafood, but not birds and mammals (The Merriam-Webster dictionary, 2019). Pescatarians may eat fish based exclusively upon the knowledge that the fish are not farmed in the factory as land animals are; that is, their problem is the capitalist-industrial meat production, not the animal foods consumption themselves. Some consume fish with the rationalization that fish have a lesser amount of sophisticated nervous systems than terrestrial and amphibious animals. Others may decide to consume wild fish alone based upon the absence of confinement, whilst deciding to not eat farmed fish.

A 1999 meta-study joined data from five different studies from western nations. The meta-study indicated mortality ratios, where lesser numbers indicated less death incidences, for vegetarians to be 0.84, infrequent meat consumers to be 0.84, pescetarians to be 0.82. Vegans and regular meat consumers shared highest mortality ratio of 1.00. Nevertheless, the fewer mortality was due largely to the comparatively lower smoking prevalence in these vegetarian cohorts (Timothy *et al.*, 1999).

2.7. Plastic pollution in this contemporary

Plastic pollution is the buildup of plastic particles, such as plastic bottles, plastic bags, and much more, in the global environment that adversely affects wildlife habitat, wildlife, and humans (Laura, 2018). Based on size plastics pollutants are categorized into macro-, meso-, or micro debris (Hammer *et al.*, 2012). Plastics are durable and inexpensive, and consequently plastic production levels by humans are high (Hester and Harrison, 2011). Nevertheless, the chemical structure of some plastics makes them resistant to various natural degradation processes and therefore they degrade slowly (Le Guern, 2018). These two factors have together led to a very high incidence of plastic pollution in the world.

Plastic pollution can affect oceans, land, and waterways. It is reported that 1.1 to 8.8 million metric tonnes (MT) of plastic waste go into the ocean from coastal communities per year (Jambeck *et al.*, 2015). Living organisms, marine animals in particular, can be hurt by problems related to the ingestion of plastic waste, or mechanical effects, like entanglement in plastic materials, or through exposure to chemical additives within plastics that impair their physiology. Plastic pollution also affect humans, usually through disruption of many hormonal mechanisms.

As at 2018, about 380 million tonnes of plastic is produced worldwide per year. From the 1950s up to 2018, more than 7.8 billion tons of plastics have been produced globally. An estimated 12% has been incinerated and 9 percent recycled (The Economist, 2018). In the UK, more than 5 million tonnes of plastic are used up per year, of which only an estimated 25% is recycled, with the remainder ending up in landfills. This large quantity of plastic waste invariably enters the environment, with research suggesting that the bodies of 90 percent of seabirds may contain plastic debris (Nomadic, 2016; Mathieu-Denoncourt *et al.*, 2014). In some regions there have been substantial efforts to lessen plastic pollution by promoting plastic recycling and reducing consumption of plastic (Walker and Xanthos, 2018). Many researchers suggest that by 2050 there may be more plastic wastes than fish in the world oceans by weight (Sutter, 2016).

2.7.1. Types of plastic debris

Three main forms of plastics contributing to plastic pollution are macro-, mega- and micro-plastics. Micro- and mega plastics have amassed in highest concentrations in the Northern Hemisphere, concentrated in water fronts and urban centers. Plastic are commonly seen off the coastline of many islands due to currents carrying the debris. Both macro- and mega-plastics are found in footwear, packaging, and other domestic items discarded in landfills or washed off of ships. Fishing-related items are most likely to be seen around remote islands (Walker *et al.*, 1997; Barnes *et al.*, 2009). They may also be referred to as macro-, meso-, and micro debris.

Plastic debris (plastics) is categorized as primary or secondary debris (plastics). Primary plastics are the plastics (debris) in their original form as at the time of collection. Instances of these include cigarette butts, microbeads, and bottle caps (Pettipas *et al.*, 2016). Conversely, secondary debris (plastics) make up the smaller plastics that have generated from primary plastics degradation (Driedger *et al.*, 2015).

2.7.1.1. Microdebris (Microplastics)

Microdebris are pieces of plastic between the size of 2 mm and 5 mm (Barnes *et al.*, 2009). Plastic debris starting off as meso- or macrodebris could disintegrate into microdebris through collisions and degradation that cause it to breakdown into smaller pieces. Microdebris are commonly known as nurdles (Hammer *et al.*, 2012). Nurdles are usually recycled to produce new plastic items, however they end up easily released into the environment in the course of production due to their small size. They regularly end up in the marine waters through streams and rivers (Hammer *et al.*, 2012). Microdebris that come from cosmetic and cleaning products are also regarded as scrubbers. Because scrubbers and microdebris are too tiny in size, filter-feeding organisms frequently eat them (Hammer *et al.*, 2012).

Primary microplastics, a kind of microdebris, called Nurdles enter the marine through spills from land based sources or during transportation. These microplastics accumulate in the oceans resulting to the buildup of Persistent Bio-accumulating Toxins like PCB's and DDT which are naturally hydrophobic and can result to adverse health effects.

A study by Richard Thompson in 2004, from the University of Plymouth, UK, reported a great quantity of microdebris on the waters and beaches in the Americas, Australia, Europe, Africa, and Antarctica (Le Guern, 2018). Thompson and his associates reported that plastic pellets from both industrial and domestic sources were being degraded into much smaller pieces of plastic, some with a diameter smaller than the hair of human (Le Guern, 2018). If not swallowed, this microdebris stays afloat as opposed to being immersed into the marine environment. Richard Thompson predicts there could be 300,000 plastic items per km^2 of ocean surface as well as 100,000 plastic particles per km^2 of seabed (Le Guern, 2018). International pellet watch sampled polythene pellets from 30 beaches in 17 countries and then analyzed the samples for organic micro-pollutants. It was seen that pellets in beaches in Vietnam, southern Africa, and America contained pesticides compounds suggesting a high usage of pesticides in the areas (Otaga, 2009).

2.7.1.2. Macrodebris

Macrodebris are plastic debris larger than 20 mm. These include plastic items like plastic grocery bags (Hammer *et al.,* 2012). Macrodebris are regularly found in marine waters, and could have a severe impact on the native marine organisms. Fishing nets are prime pollutants. Even after been abandoned, they continue to entrap aquatic organisms and other plastic debris. In the long run, these abandoned fishing nets become so difficult to take out from the marine as they become so heavy, having increased in weight ratcheting up to 6 tons (Hammer *et al.*, 2012).

2.7.2. The decomposition of plastics

Plastics wastes contribute to around 10% of discarded waste. Many categories of plastics exist depending on their various precursors and the polymerization method. Reliant on their chemical composition, resins and plastics have various properties related to contaminant adsorption and absorption. Polymer decomposition takes far longer due to the sea cooling effect and the saline environments. These are contributory factors to the plastic debris persistence in certain environments (Barnes *et al.*, 2009). Latest studies have demonstrated that plastics in the marine decompose more rapidly than was once believed, as a result of the exposure to sun, rain, and other environmental conditions, leading to the discharge of toxic chemicals like bisphenol A, pthalates, etc. However, because of the increasing volume of plastic wastes in the ocean, the rate of decomposition has gradually slowed down. The Marine Conservancy predicted the rates of decomposition of many plastic products. It is projected that a disposable nappy takes over 450 years, a foam plastic cup takes over 50 years, a plastic beverage holder takes over 400 years, and a fishing line takes over 600 years to degrade (le Guern, 2018).

2.7.3. Persistent organic pollutants

It is estimated that world production of plastics is approximately 380 million tons per year. Some researchers have argued that it is higher than that. Their large quantity has been seen to transport persistent organic pollutants, better known as POPs. POPs are linked to an increased algae distribution associated with red tides (Barnes *et al.*, 2009).

2.7.4. Effects of plastic debris on the environment

The plastic debris distribution is very highly variable due to some factors like coastline geography, urban areas, wind and ocean currents, and trade routes. The population of humans in some regions also plays large role in this distribution. Plastics are commonly found in encircled regions like the Caribbean. It functions as a means of distribution of most organisms to remote coastlines that are not their original environments. This may potentially grow the dispersal and variability of organisms in designated areas that are less in biological diversity. Plastics can be used as vectors for chemical pollutants like heavy metals and persistent organic pollutants (Barnes *et al.*, 2009).

2.7.5. Plastic pollution contributes to climate change

"Plastic and Climate", a new report, was published in 2019. According to the report, in the year 2019, plastic will contribute equivalent of 850 million tonnes of carbon dioxide (CO_2) – greenhouse gases – to the atmosphere. In present trend, yearly emissions will increase to 1.34 billion tonnes by 2030. By 2050 plastic may release 56 billion tonnes of Greenhouse gas emissions, around 14% of earth's remaining carbon budget (Center for International Environmental Law, 2019). Plastic will emit 260 billion tons by 2100, over 50% of the carbon budget. Those emissions are from transportation, incineration, production, but also there are effects on Phytoplankton (Executive Summary Plastic & Climate, 2019).

2.7.6. Effects of plastics on land and the soil

Chlorinated plastic can discharge harmful chemical compounds into the neighboring soil, which can seep into surrounding water sources or groundwater as well as the world ecosystem. This can result to severe harm to the species that take in the water.

Landfill areas have many types of plastics in them. In these landfills, there are several microorganisms which accelerate the biodegradation of plastic materials. These microorganisms include bacteria like *Pseudomonas*, a nylon-consuming bacteria, and Flavobacteria. These bacteria are known to breakdown nylon by the activity of the nylonase, an enzyme that degrade nylon. Breakdown of biodegradable plastics leads to the release of methane, a very potent greenhouse gas that contributes considerably to global warming (Biello, 2011).

2.7.7. Plastic pollution in our tap water

A study in 2017 found that 83 percent of tap water samples taken from around the world had plastic pollutants. This was reported to be the first study to focus on world pollution of drinking water with plastics, and indicated that with a rate of contamination of 94 percent, tap water in the US was the most polluted, Lebanon and India followed. European countries like Germany, the UK, and France had the lowest rate of contamination, although still as high as 72 percent. This shows that individuals may be ingesting between 3,000 and 4,000 plastic microparticles from tap water each year. The study found particles of size more than 2.5 microns, which is over 2500 times larger than 1 nanometer. Currently, it may not be clear if this contamination affects human health, however if the tap water is also found to have nano-particle pollutants, there may possibly be adverse effects on human (Damian Carrington Environment, 2017). However, plastic tap water contamination remains understudied, just as are the links of how contamination transfers between humans, water, air, and soil (Lui, 2017).

2.7.8. Impacts of plastic on world oceans

In 2012, it was projected that there was roughly 165 million tons of plastic contamination in the world's oceans. A type of plastic of concern in regards to plastic pollution in the ocean is nurdles. Nurdles, a type of microplastic, are industrially made plastic pellets used in the making of plastic products and are usually shipped through cargo ship. Billions of nurdles spill into world oceans per year, and it is estimated that worldwide, around 10 percent of beach litter are made up of nurdles. Plastics in oceans usually degrade within a year, although not entirely. During the process, toxic chemical compounds such as polystyrene and bisphenol A from some plastics may leach into waters. Nurdles and polystyrene pieces are the most well-known types of plastic pollution in the aquatic environment, and when combined with food containers and plastic bags make up the majority of ocean debris.

One study reported that the amount of plastic pieces (macroplastics, meso-plastics, small microplastics, and large microplastics) afloat at sea are more than 5 trillion (Eriksen, 2014). The littering of these plastics delivered into the marine waters is toxic to humans and marine life. The toxins that are constituents of plastic include phthalate, like diethylhexyl phthalate which is a very toxic carcinogen, lead, mercury, and cadmium. Plankton, fish, and humans, through the food chain, including seafood chain, ingest these very highly toxic chemicals and carcinogens. Consuming the fish containing these toxins may lead to an increase in immune disorders, cancer, and birth defects (Fernandez and Chatenoud, 1999).

The majority of the litter near the coast and in the ocean is made up of plastics which is a persistent prevalent source of marine pollution (Walker, 2018). According to Dr. Marcus E. of The 5 Gyres Institute, there are over 5.25 trillion particles of plastic pollutants weighing as much as 270,000 tons in 2016. These plastics are taken by the currents of the ocean and accumulate in large vortexes called ocean gyres. The majority of theocean gyres become pollution dumpsites filled with plastics.

Plastic pollution has contributed to Biomagnification.

> *Biomagnification, at times known as 'biological magnification' or 'bioamplification', is the growing concentration of a substance in organisms' tissues at successively higher levels in the food chain. This happens as organisms at a higher trophic levels consume significant numbers of contaminated organisms at a lower level; with increased eating, these concentrations can increase.*

2.7.9. Sources of ocean-based (sea-based) plastic pollution

Nearly 20 percent of plastic debris which pollutes the ocean waters, which translates to over 5.6 million tons, comes from sea-based (ocean-based) sources. An international treaty, MARPOL, imposes a complete and total ban on the disposal of plastics at-sea (Muhammad, 2017; Stephanie, 2017). Merchant ships expel sewage, used medical equipment, cargo, and other types of plastic-containing wastes into the ocean. In the US, the Marine Plastic Pollution Research & Control Act of 1987 (MPPRCA) prohibits the release of plastics in the ocean, including plastics from naval vessels (Derraik, 2002; Craig *et al.*, 1990). Naval and research vessels discharge waste and military equipment that are believed to be unnecessary. Pleasure crafts discharge fishing gear and other kinds of waste, both accidentally and through neglectful handling. The leading source of ocean-based plastic pollution is discarded fishing gear (both nets and traps), projected to be up to 90 percent of plastic debris in some regions.

Continental litter of plastic enters the ocean mainly by direct discharge into coastal waters or storm-water runoff, flowing into waterways (Cozar, 2014). Plastics in the ocean have been proven to be carried by the ocean currents which, in the long run, form into what is referred to as the Great Garbage Patches (Great Pacific Garbage Patch, 2017). Knowledge of the paths that plastics follow in ocean currents originates from accidental drops of containers from ship carriers. For instance, The Hansa Carrier in May 1990, sailing from Korea to the US, broke apart as a result of a storm, eventually resulting in thousands of shoes dumped; these dumped shoes ultimately started showing up on the United States western coast, and Hawaii (Christian *et al.*, 2017).

Ocean plastic pollution from land-based sources

Estimates for the role of land-based (terrestrial) plastic vary widely. While one research projected that a little over 80 percent of plastic wastes in marine water come from land (terrestrial) sources, responsible for 0.8 million tons (880,000 short tons; 790,000 long tons) every year (Hammer *et al.*, 2012). Jambeck *et al.* in 2015 estimated that 275 million tons (303,000,000 short tons; 271,000,000 long tons) of plastic wastes were generated in 192 coastline countries in 2010 alone, with 4.8 million tons to 12.7 million tons (14,000,000 short tons; 12,500,000 long tons) entering the ocean - a fraction of only up to 5% (Jambeck *et al.*, 2015).

In a research published by *Science* in 2015, Jambeck *et al.* projected that the ten leading emitters of marine plastic pollution globally are, from the least to the most, Bangladesh, Nigeria, Malaysia, Egypt, Thailand, Sri Lanka, Vietnam, Philippines, Indonesia, and China (Jambeck *et al.*, 2015). In a research published by *Environmental Science and Technology*, Schmidt *et al.* (2017) estimated that the Yellow River, Hai River, Yangtze, Indus, Nile, Ganges, Amur, Niger, the Mekong, and Pearl River transport 88–95% of the world plastics load into the sea (Christian *et al.*, 2017; Harald, 2017).

Another land source that has raised concern is landfills. Most plastic wastes in landfills are single-use plastic items like packaging. Discarding plastics in this manner results to accumulation (Barnes *et al.*, 2009). Though disposing of plastic debris in landfills has lesser risk of gas emission than discarding through incineration, the former has space related limitations. Another concern of plastic wastes disposal in landfills is that the liners performing as protective layers between the environment and the landfill can break, thus leaking and releasing toxins and polluting the nearby water and soil (North and Halden, 2013). Landfills sited near oceans regularly contribute to oceanic debris as its content is easily carried up and transported to the ocean by the action of wind or small waterways like streams and rivers. Oceanic debris can also result from streams of sewage water that has been inefficiently treated, which is in the long run transported to the ocean via rivers. Plastic items that have not been properly discarded can also be passed to oceans by storm waters (Hammer *et al.*, 2012).

2.7.10. The Pacific Ocean's plastic pollution

In the Pacific Gyre, precisely 20°N – 40°N latitude, enormous bodies with floating oceanic debris can be seen (United States Environmental Protection Agency, 2015). Models of ocean currents and wind patterns show that the plastic waste/debris in the northern Pacific is mostly dense in areas where the Subtropical Convergence Zone, 23°N – 37°N latitude, meets the southwest-northeast line, found at the north of the Hawaiian archipelago (United States Environmental Protection Agency, 2015).

In the Pacific Ocean, two massive accumulations exist: the eastern garbage patch and the western garbage patch, the latter off the Japan coast and the former between California and Hawaii. Both garbage patches are part of the great Pacific garbage patch; they are linked through a plastic debris section off the northern coastline of the Hawaiian Islands. It is estimated that both garbage patches have 100 million tonnes of debris (United States Environmental Protection Agency, 2015). The debris is not compact, and even though most of it is close to the pacific surface, it can be found more than 100 feet deep in the ocean (United States Environmental Protection Agency, 2015).

Lavers, J. L. and Bond, A. L., in a research published in April 2017, reported the highest plastic waste density anywhere in the world on uninhabited and remote Henderson Island in Southern Pacific due to the South Pacific Gyre. The beaches were reported to contain an approximated 37.7 million debris items together weighing 17.6 tons. In a research transect on the North Beach, every day 17 to 268 new debris items washed up on a section of 10 metre. The study noted that *Coenobita spinosus* (purple hermit crabs) build their homes and houses in plastic containers that washed up on beaches (Dani, 2017; Hunt, 2017).

2.7.11. Effects of plastic pollution on animals

It is known that plastic pollution has the likelihood be toxic to animals, adversely affecting human food supplies (Daniel, 2004), including seafood supply chain. Plastic pollution is highly detrimental to large aquatic mammals, as explained in the book the *Introduction to Marine Biology* as constituting the single greatest threat to marine lives (Karleskint *et al.*, 2009). Some marine species, like sea turtles, have been discovered to contain large quantities of plastics in their stomach (Daniel, 2004). As this occurs, the marine animal typically starves, as the plastic blocks its digestive tract (Daniel, 2004). Sometimes Marine mammals are entangled in plastic wastes like discarded nets, which can either kill or harm them (Daniel, 2004).

2.7.11.1. Entanglement

Entanglement in plastic waste is responsible for the deaths of lots of aquatic organisms, like turtles, birds, fish, and seals. These marine animals are caught up in the plastic debris and end up being suffocated, drowned, or killed by prolonged and exhaustive struggling. As they are incapable of untangling themselves, they also die from their lack of ability to escape their predators or from starvation (Hammer *et al.*, 2012). Being entangled also often leads in severe ulcers, bruises, and lacerations. In a report in 2006 called *Plastic Debris in the World's Oceans* (Greenpeace International, 2018), it was reported that at least 267 different marine animal species have suffered from and experienced entanglement and ingestion of plastic debris. More than 400,000 marine mammals perish every year as a result of plastic pollution in oceans (Daniel, 2004). Marine animals get trapped in discarded fishing equipment, like ghost nets. Fishing nets and ropes used to fish are usually made of synthetic materials like nylon and other polymeric materials, making fishing equipment more buoyant and durable. These aquatic organisms can also get caught in circular plastic materials used for packaging, and if the animal grows in size continuously, the plastic may cut into their flesh, causing severe injuries. Equipment such as discarded fishing nets can drag along the seabed, inflicting damage to coral reefs (Gregory, 2009).

2.7.11.2. Ingestion of plastics

2.7.11.2.1. Aquatic animals

Marine animals such as sea turtles are affected by plastic pollution. Some species are jelly fish consumers, and regularly mistake plastic bags for their prey. This plastic debris may kill the sea turtle by obstruction of the oesophagus (Gregory, 2009). Baby sea turtles are mostly vulnerable according to a study by Australian scientists in 2018 (Gabbatiss, 2018). So too are the whales. Large quantities of plastic wastes have been (repeatedly) found in the stomachs of whales (Gregory, 2009). Plastic debris began to appear in the sperm whale stomach since the 1970s, and has been well-known to be responsible for the death of many whales (Chua *et al.*, 2019). In June 2018, over 80 plastic bags were found in a pilot whale battling for life on the shores of Thailand (The Guardian, 2018). In March 2019, a lifeless Cuvier's beaked whale was washed up in an ocean in the Philippines with approximately 40 kg (88 lbs) of plastics in its stomach (BBC, 2019). In April 2019, after a dead sperm whale was discovered off of Sardinia with approximately 22 kg (48 lbs) of plastics in its stomach, a warning by the World Wildlife Foundation stated that plastic contaminant is one of the greatest dangerous threats to marine life, noting that five (5) whales have lost their lives due to plastic wastes within a two year period (Barry, 2019). More whales may possibly have died within this period without being reported or seen.

Some of the smallest plastic bits (micro-plastics) are being ingested by small fish, in part of the pelagic zone in ocean known as the *Mesopelagic zone,* that is 200 to 1000 meters below the sea surface, and totally dark. Much is not known about these fish, other than the fact that there are lots of them. They hide in the dark part of the ocean, dodging predators and then swimming to the surface of the sea at night to feed (Parker, 2014). Plastic debris found in these fish stomachs were collected at the time of *Malaspina's circumnavigation*, a research survey that studies the impact of global variation on the oceans (Fernandez-Armesto, 2006).

A research done by Scripps Institution of Oceanography indicated that the average plastic debris content in the stomachs of over 27 different species numbering 141 mesopelagic fish was 9.2%. Their estimation for the rate of ingestion of plastic debris by these fish in North Pacific was between 12000 & 24000 tons each year (Carson *et al.,* 2011). The lantern fish is the most widely known mesopelagic fish. It lives in the central ocean gyres, an enormous system of revolving ocean currents. Since lantern fish function as a primary source of food for the fish that consumers buy, including swordfish and tuna, the plastics debris they ingest become integral part of the food chain; disturbing. The lantern fish remains one of the major bait fish in the sea. It eats large quantities of plastic debris, which in turn make them not to be nutritious enough for other fish to prey on (Moore, 2014). Plastics have been seen in the stomachs of deep sea organisms (Taylor, 2017).

2.7.11.2.2. Birds

Plastics do not only affect animals living exclusively in the oceans. Seabirds are also seriously affected. It was estimated in 2004 that gulls in North Sea had an about thirty pieces of plastic debris in their stomachs. Seabirds regularly mistake waste floating on the surface of the sea as prey. Their food sources regularly has ingested plastic debris already, consequently transferring the plastic debris from prey to predator. Ingested debris can physically damage and obstruct a bird's digestive tract, impairing its ability to digest, leading to starvation, malnutrition, and, eventually, death. Toxic chemicals known as PCBs (polychlorinated biphenyls) also become accumulated on the plastics surface at the ocean. The accumulated PCBs are released when seabirds consume the plastics. These chemical compounds can accumulate in the body tissues and constitute severe lethal impacts on the immune system, reproductive ability, and hormone balance of a bird. Floating plastic wastes may produce infections, ulcers, and lead to death. Oceanic plastic pollution may even extend to birds that have never in their entire life been at the sea. Most parents may unintentionally feed their nestlings plastic debris, mistaking the plastic debris for food (Rodríguez *et al.*, 2012). Baby seabirds are the most vulnerable to the ingestion of plastic as they are not capable of vomiting up their food as the adult seabirds may do (Derraik, 2002).

After the early observation that most of the New Zealand beaches had high plastic pellets concentrations, further studies indicated that different prion species ingest the plastic debris. Hungry prions mistake these plastic pellets for food, and the particles were seen intact in the birds' proventriculi and gizzards. Pecking marks related to those made by the northern fulmars in cuttlebones are found in plastic debris, like Styrofoam, on the Dutch coast beaches, indicating that this bird species also make the mistake of ingesting plastic debris for food.

An estimation of 1.5 million Laysan albatrosses, inhabiting Midway Atoll, have plastic debris in their digestive tract. Midway Atoll is midway between North America and Asia, and the north of Hawaiian archipelago. In this midway remote location, the blockage of plastic has proven lethal to these birds, especially the ones that exclusively live and feed in the ocean. These seabirds choose brown, red, blue, and pink plastic pieces due to resemblances to their natural sources of food. As a result of ingesting plastic debris, the digestive tract (system) can be blocked leading to starvation, and, at the run, death. The windpipe may also be obstructed, resulting in asphyxiation. The plastic debris may also accrue in the animal's gut, giving them untrue sense of fullness, and subsequently result in starvation. On the seashore, thousands of dead birds can be seen with plastic debris remaining where their stomach was once positioned. The plastics durability is evident among the remains of the birds. In some cases, the piles of plastic are still present even though the bird's carcass has decomposed.

Like to humans, animals' exposure to plasticizers and plastic additives can experience defects in development. Particularly, sheep are known to have lower birth weights once prenatally exposed to BPA (bisphenol A). Exposure to BPA may reduce the distance between a tadpole eyes. It may also impair development in frogs and may lead to a reduction in body length. In different fish species, exposure may stall the hatching of eggs and lead to a decrease in tail length, body length and body weight.

2.7.12. Effects of plastic pollution on human

Owing to the use of chemical additives in plastic production, plastics have potential detrimental effects that can prove to be carcinogenic or endocrine disruptors in humans. A number of these additives are used as brominated flame retardants and phthalate plasticizers. By means of biomonitoring, chemical additives in plastics, such as phthalates and BPA, have been found in the human population. Individuals are exposed to these additives via the skin, nose, or mouth. Even though the exposure level varies depending on geography and age, most people experience simultaneous exposure to lots of these chemical additives. On the average, daily exposure levels are lower than the levels estimated to be unsafe, but further research is required to ascertain the effects of exposure to low dose on humans (Thompson, 2009). Lots are unknown about how severely humans may be physically affected by exposure to these chemicals. Most of the chemicals used during plastic production have the potency to cause dermatitis when in contact with the human skin (Brydson, 1999). In several plastics, these toxic chemicals are used in trace amounts only, but substantial testing is often necessary to make sure that these toxic elements are enclosed in the plastic by inert polymer or material (Brydson, 1999).

Plastic pollution can also affect humans by creating an eyesore that interferes with the enjoyment and fun of the natural environment.

2.7.12.1. Clinical consequence

Due to the prevalence of plastic products, majority of humans are continuously exposed to the toxic chemical components of plastics. Over 95 percent of adults in the US have had detectable BPA levels in their urine. The percentage is highly likely to be higher in Asian and Sub-Saharan African countries where the knowledge of clinical effects of the exposure to plastic debris and management of plastic wastes are very low. Exposure to chemicals like phthalates and BPA have been implicated in fertility disruptions, sexual maturation, reproduction, and other various health effects. Specific phthalates have also resulted in severe biological effects than others.

2.7.12.1.1. Thyroid hormone axis

Bisphenol A can affect expression of gene connected to the thyroid hormone axis, affecting biological functions like body development and metabolism. BPA can lessen the biological activities of thyroid hormone receptor (TR) by increasing the TR transcriptional co-repressor activities. This then reduces the level of the thyroid hormone binding proteins which bind to triiodothyronine. By impairing the thyroid hormone axis, exposure to bisphenol A can cause hypothyroidism.

2.7.12.1.2. Sex hormones

Some chemical additives used in the production of plastic, such as bisphenol A, can disrupt normal sex hormones physiological levels. This is done by binding to globulins which normally bind to sex hormones like estrogens and androgens, resulting to the interruption of the usual balance between the globulins and sex hormones. Also, bisphenol A can affect sex hormones catabolism or metabolism. It regularly acts as an anti-androgen or an estrogen, which could lead to the disruptions in sperm production and gonadal development.

2.7.13. Plastics usage reduction efforts

Persistent efforts to plastics usage reduction and promotion of recycling of plastic have been initiated. Most supermarkets place charge on their customers for plastic bags. In most places more efficient biodegradable or reusable materials are used in preference to plastics. Some countries, businesses, and local communities have placed a ban on some frequently used plastic items, such as plastic bags and bottled water (Malkin, 2009).

Global Alliance to End Plastic Waste (GAEPW) was formed in January 2019. The alliance aims at increasing recycling and cleaning existing waste from the environment as priorities, but it does not reference reduction of plastic production as one of its targets (Staff, Waste360, 2019).

2.8. The Endocrine System

The human endocrine system is a system of chemical messenger consisting of hormones feedback loops released directly into the circulatory system by the internal glands of an organism, regulating and targeting distant organs. The main endocrine glands in humans are the adrenal glands and the thyroid gland. The hypothalamus in vertebrates is the neural control, regulator, and center for all endocrine systems. Endocrinology is one of the branches of internal medicine that deals with the study and science of the endocrine system and its associated disorders (Marieb, 2014). Many glands that send signal to each other in sequence are commonly referred to as an axis, for instance, the hypothalamic-pituitary-adrenal axis. Adding to these specialized endocrine organs pointed out above, several other organs which are part of other body systems, like kidney, liver,gonads, heart, and bone, have secondary endocrine functions. For instance, the kidney secretes endocrine hormones likerenin and erythropoietin. Hormones can be made up of either steroids, eicosanoids, leukotrienes, amino acid complexes, or prostaglandins (Marieb, 2014).

The endocrine system can be distinguished from both exocrine glands that secrete hormones to the outside body using ducts and paracrine signaling which takes place between cells over a relatively small distance. Endocrine glands do not have ducts, are vascular, and usually have intracellular vacuoles or granules which store their hormones. In distinction, exocrine glands, such as sweat glands, salivary glands, and glands in the gastrointestinal tract, have a propensity to be much less vascular and have a hollow lumen or ducts.

2.8.1. The structure of the endocrine systems

2.8.1.1. The major endocrine systems

The endocrine system of human is made up of several systems which operate through feedback loops. Several significant feedback systems are mediated through the pituitary and hypothalamus (Sherwood, 1997).

- GnRH – LH/FSH – sex hormones
- TRH – TSH – T3/T4
- CRH – ACTH – cortisol
- leptin vs. insulin
- Renin – angiotensin – aldosterone

2.8.1.2. Glands

Endocrine glands are the glands of the endocrine system which secrete their products, hormones, directly straight into interstitial spaces and then later absorbed into the blood instead of via a duct. The main glands of the endocrine system are the pituitary gland, pancreas, ovaries, pineal gland, testes, thyroid gland, adrenal glands, parathyroid gland, and hypothalamus. The pituitary gland and hypothalamus are neuroendocrine organs.

2.8.1.3. Cells

There are numerous types of cells that consist of the endocrine system and these many cells normally make up larger organs and tissues that function outside and within the endocrine system.

- Posterior pituitary gland
- Hypothalamus
- Pineal gland
- Anterior pituitary gland
- Thyroid gland
  - The thyroid gland follicular cells produce and secrete T_3& T_4 in response to increased TRH levels, produced by the hypothalamus, and subsequent increased TSH levels, produced by anterior pituitary gland, which additionally regulates the metabolic rate and activity of all cells, including tissue differentiation and cell growth.
- Parathyroid gland
  - The epithelial cells of parathyroid glands are abundantly supplied with blood from thesuperior and inferior thyroid arteries and secrete PTH (parathyroid hormone). PTH acts on the kidneys, the GI tract, and bone to increase reabsorption of calcium and excretion of phosphate. In addition, parathyroid hormone stimulates Vitamin D conversion to 1,25-dihydroxyvitamin D_3, its most active variant, which further stimulates the absorption of calcium in the GI tract (Marieb, 2014).
- Adrenal glands
  - Adrenal medulla
  - Adrenal cortex
- Pancreas
  - Alpha cells
  - F Cells
  - Beta cells
  - Delta cells
- Testis
  - Leydig cells
- Ovaries
  - Granulosa cells

2.8.2. Development

The endocrine system is a ductless glands control system that secrete hormones within particular organs. Hormones function as messengers, carried by and through the bloodstream to different body cells, which interpret and quickly act on these messages as they receive them. Hormones are responsible for the ability of body to respond to stimuli and maintain homeostasis. Without hormones, one cannot grow, produce offspring, maintain a constant temperature, or carry out the basic functions and metabolic roles essential for life. Endocrine system offers an electrochemical linking from the brain hypothalamus to the organs that control the metabolism, growth and development of the body, as well as reproduction. The hormones are regulated by the system via negative feedback, except in very precise cases such as childbirth. Increase in the activity of hormone decreases the production of that particular hormone. The immune system and many other factors contribute to the maintenance of constant levels of hormone. The major endocrine glands include the pituitary (anterior and posterior lobes), hypothalamus (neuroendocrine gland), thyroid, parathyroid, pancreas, gonads, and adrenal (cortex and medulla).

2.8.2.1. Role of the Thyroid Gland

The thyroid gland is primary endocrine gland responsible for development and among the body's largest endocrine glands. It is located on the neck below the larynx. It has two lobes, with one on each side of the trachea. It takes part in the production of the hormones triiodothyronine (T3) and thyroxine (T4). These two hormones increase the metabolic activities of the body cells. Prolong iodine deficiency in the diet results to the thyroid gland enlargement, commonly called a simple goiter. Also, the thyroid produces and releases the hormone (thyrocalcitonin) calcitonin, which takes part in the regulation of calcium levels of the blood. Thyrocalcitonin reduces the calcium concentration in the blood. Most of which (the calcium removed from the blood) are stored in the bones.

The thyroid gland has two lobes that manifest remarkable and powerful active transport mechanism for iodide ions uptake from the blood. As the blood flows through the thyroid gland, iodide is converted to active form of iodine, which in turn combines with tyrosine (an amino acid). Two molecules of the iodinated tyrosine then associate to form thyroxine. A normal thyroid gland can store supply of thyroxine in this bound form for several weeks.

Thyroid-Stimulating Hormone & Thyroxine

Enzymatic splitting of thyroxine from the thyroglobulin happens when TSH (thyroid-stimulating hormone) made by the pituitary gland, are released into the blood. Thyroid-stimulating hormone stimulates some major rate-limiting steps in the secretion of thyroxine. Various body defects, either hereditary, dietary, or disease-induced, might decrease the thyroxine amount released into the blood. The most widely known of these defects is the one that arises from dietary deficiency of iodine. There is enlargement of the thyroid gland in the continuous presence of thyroid-stimulating hormone from the pituitary, forming a goiter; this is unsuccessful effort to synthesize thyroid hormones for levels of iodine that are too low. Typically, thyroid hormones act on pituitary to reduce stimulation of the thyroid through a negative feedback loop. In the goiter, the feedback loop is interrupted, resulting to continuous thyroid stimulation and the unavoidable protuberance on the neck. The occurrence of goiter has been reduced drastically by iodizing table salt.

The stimulation of oxidative metabolism in cells is done by thyroxine. Thyroxine also increases the consumption of oxygen and heat production of many tissues of the body, with the marked exception of the brain. Also, thyroxine is required for normal growth, by promoting the growth hormone effects on synthesis of protein. Thyroxine absence significantly lessens the growth hormone ability to stimulate uptake of amino acid and synthesis of RNA. Thyroxine plays an important part in the closely connected area of organ development, specifically that of the CNS (central nervous system).

2.8.2.2. The Endocrine System and Aging

Aging affects three hormone axes: cortisol/dehydroepiandrosterone (DHEA), testoterone/estradiol, and insulin-like growth factor I (IGF-I)/growth hormone (GH).

Points to note

- The endocrine system is made of organs and glands that make and secrete hormones. Three most significant hormone axis in endocrine system affected by aging are mainly cortisol/dehydroepiandrosterone (DHEA), testoterone/estradiol, and insulin-like growth factor I (IGF-I)/growth hormone (GH).
- The change in GH/IGF-I axis is termed Somatopause, which involves a reduction in sensitivity and production to IGF-I and GH. Normally, the secretion of GH drops 14% with every decade of one's life.
- The reduction in pituitary GH secretion is linked with loss in mass of skeletal muscle, adiposity increase, and other negative effects of aging. A reduction in the quantity of circulating GH and IGF-I leads to weaker bones of reduced density.
- In the mid-20s, dehydroepiandrosterone (DHEA) peaks and then slowly declines with age (called adrenopause). Cortisol is relatively unchanged with aging, leading to hormone levels imbalance and which thus alter immune function.
- Menopause/andropause refers to the decline in estradiol production and circulation in females and testosterone production and circulation in males. Adding to their roles in growth and reproduction, both hormones show neuroprotective effects and are theorized to reduce Alzheimer's disease effects.
- Insulin-like growth factor I(IGF-I), also known as somatomedin C, is a protein in humans that is encoded by IGF1 gene.
- Estradiol: ((17)-estra-1,3,5-triene-3,17-diol) A potent estrogenic hormone made in the ovaries of female vertebrates; and medicinally, the synthetic compound is used to treat breast cancer and estrogen deficiency.
- Cortisol: (also called hydrocortisone) Asteroid hormone produced by the adrenal cortex and regulates carbohydrates metabolism and maintains blood pressure.
- Dehydroepiandrosterone (DHEA): A hormone of androgen secreted by the adrenal cortex. The synthetic version is used as dietary supplement.

- Testosterone: A steroid hormone primarily produced in the testes of male. It is responsible for the development of men's secondary sex characteristics.

The endocrine system is made of glands and organs which produce and release hormones affecting the body in many ways and helping in the control of functions like metabolism, growth and development, reproduction, tissue homeostasis, and response to stress.

In the endocrine system, the three most essential hormone axes that are affected by aging include cortisol/dehydroepiandrosterone (DHEA), testoterone/estradiol, and insulin-like growth factor I (IGF-I)/growth hormone (GH).

2.8.2.2.1. Insulin-like Growth Factor I (IGF-I)/ Growth Hormone (GH) Axis

Somatopause is a word used to refer to the change in the GH/IGF-I axis, which involves a decline in the production and sensitivity to GH/IGF-I. Usually, secretion of GH declines 14% with every ten years of life. In the developing body of human, GH in the anterior pituitary gland stimulates the production and the release of IGF-I by the human liver, which is transported in the human blood to stimulate the growth of muscle and bone.

Declines in IGF-I signaling, deficiency of GH, and GH resistance lead to extended lifespan and delayed aging in animal models; sharp contrast to GH/IGF-I effects in humans. Decreases in pituitary GH secretion are linked with the loss of mass of skeletal muscle, adiposity increase, and other damaging effects of aging in the elderly. Currently, the main reason for the contrasting actions of GH/IGF-I in different animal species is not understood.

With aging, a reduction in the quantity of circulating GH and IGF-I leads to weaker bones of low bone mineral density (BMD). Adding to the lower IGF-I circulating amounts, the responsiveness of bone to the protein has been demonstrated to decrease in animal models. This may be attributed to a decline in the pathways of IGF-I signaling with advanced cell age. The binding of IGF-I to its receptors usually initiates signaling cascades having to do with phosphorylation of AKT (cyclin-dependent kinase) and ERK 1/2 (extracellular signal related kinase). These two pathways combine to promote osteoblast proliferation and survival.

2.8.2.2.2. Dehydroepiandrosterone (DHEA)/ Cortisol

Cortisol/DHEA axis is another hormone axis which changes with aging. The hypothalmus-pituitary-adrenal pathway plays essential role in controlling the function of the immune system. Two adrenal hormones, cortisol and DHEA, have opposite effects on the function of the immune system, with DHEA generally improving immunity while cortisol suppresses it. The adrenal cortex releases DHEA in response to adrenocorticotrophic hormone (ACTH). Dehydroepiandrosteronepeaks in mid-20's and afterwards gradually declines with aging (called adrenopause), potentially reaching just 5 percent of its original level. Cortisol always remains relatively unchanged with aging, leading to an imbalance in levels of hormone and thus altering the function of the immune system. Glucocorticoids (GCs), like cortisol, also respond to adrenocorticotrophic hormone (ACTH) and are released from adrenal glands. One particular mechanism through which glucocorticoids suppress the immune system is by inhibition of an inhibitor. A transcription factor, nuclear factor kappa B, inhibits programmed cell death (the activation-induced apoptotic response) that becomes more predominant with aging. GCs inhibit nuclear factor kappa B, the transcription factor, which invariably reduces inhibition of apoptosis.

2.8.2.2.3. Estradiol and Testosterone

Andropause/Menopause refers to the decline in the production and circulation of testosterone in males and estradiol (estrogen) in females. The Leydig cells secrete a steroid hormone called testosterone that can act on several target organs, resulting to the development of secondary sexual characteristics as well as growth spurt during puberty. The female equivalent of testosterone is estradiol, which is secreted from granulosa cells. Estradiol is also a steroid that directly acts on several target organs for the development of secondary sexual characteristics and prepare uterus for potential pregnancy every month.

In addition to estrogen and testosterone roles in reproduction and growth, both show neuroprotective effects and are theorized to lessen the effects of Alzheimer’s disease (AD). Alzheimer’s disease is characterized by age-linked deposits of protein in the brain. Particularly, the protein beta-amyloid (Ab) gathers in vulnerable regions of the brain and plays a pivotal role in the AD progression. Cells treated with testosterone, in vitro, showed a decline in the release of beta-amyloid. Nevertheless, the testosterone effects are not as potent as estrogen effects. Estrogen acts on the cell nucleus by binding to the nuclear endoplasmic reticulum (ER). As soon as it binds to the ER, initiation of a series of activation steps are begun, leading to the binding of estrogen- nuclear endoplasmic reticulum complex to the estrogen responsive element (ERE). The unit mediates neurotrophic factors expression in the brain, which adds to neuroprotection. In addition, estrogen provides antioxidant effect at cellular level by stopping oxidation induced by exposure to beta-amyloid. Consequently, the effects of Alzheimer’s disease are reduced in both estrogen and testosterone presence. Thus, a decrease in both hormones with usual aging makes the brain more vulnerable to AD together with other pathologies. Levels of estrogen in particular considerably plunge with menopause.

2.8.3. Functions of the human endocrine system, organs and actions

2.8.3.1. Hormones

Hormone is any class of signaling molecules made by the glands in multicellular organisms and transported to target distant organs by the circulatory system to regulate behaviour and physiology. Hormones have various chemical structures, mostly of 3 classes: steroids, eicosanoids, and amino acid/protein derivatives (proteins, amines, and peptides). The glands that secrete hormones made up the endocrine system. Sometimes, the word “hormone” is stretched to include chemical substances produced by cells that affect same cell (intracrine or autocrine signaling) or neighboring cells (paracrine signaling).

Hormones serve as means to communicating between tissues and organs for behavioral activities and physiological regulation, such as metabolism, respiration, tissue function, digestion, sensory perception, growth and development, mood, sleep, excretion, lactation, stress, movement, and reproduction (Neave, 2008).

Distant cells are affected by hormones as the hormones bind to specific receptor proteins in the target cells causing a change in function of cell. This may result to cell type-specific responses which include slower changes in target genes expression or rapid changes to the existing proteins activity. Amino acid–based hormones (peptide or protein hormones and amines) are soluble in water and act on target cells surface through the pathways of signal transduction; steroid hormones, being soluble in lipid, move via target cells plasma membranes to act in their nuclei.

2.8.3.2. Cell signaling

In the endocrine system, the typical mode of cell signaling is endocrine signaling, i.e., reaching distant target organs by using the circulatory system. However, other modes exist, i.e., neuroendocrine, paracrine, and autocrine signaling. On the other hand, purely neurocrine signaling between neurons belongs to the nervous system entirely.

2.8.3.2.1. Autocrine signaling

Autocrine signaling is a type of cell signaling in which a cell secretes a chemical messenger or hormone (known as the autocrine agent) which binds to autocrine receptors on that same cell, resulting to changes in the cells.

2.8.3.2.2. Juxtacrine signaling

Juxtacrine signaling is a typical type of intercellular communication which is transmitted through protein, oligosaccharide, or lipid components of the cell membrane, and can affect either the immediate adjacent cells or the emitting cell. It occurs between the adjacent cells possessing broad patches of very closely opposed plasma membrane connected by transmembrane channels called connexons. The gap between the cells may commonly be between only 2 and 4 nm (Vander, 2008).

2.8.3.2.3. Paracrine signaling

Some clinicians and endocrinologists include the paracrine system as a part of the endocrine system, although there is no consensus. Paracrines are very slower in acting, targeting cells in the same organ or tissue. Somatostatin is a typical example of this; which is released by a number of pancreatic cells and also targets other pancreatic cells (Marieb, 2014).

2.8.4. Clinical significance

2.8.4.1. Endocrine disease

Diseases of endocrine system are common (Kasper and Harrison, 2005), including disease conditions like diabetes mellitus, obesity, and thyroid disease. Endocrine diseases are characterized by structural enlargement in a critical site like the thyroid (toxic multinodular goitre), misregulated release of hormone (a productive pituitary adenoma), inappropriate signaling response (hypothyroidism), or lack of a gland (diminished erythropoiesis in chronic renal failure, diabetes mellitus type 1). Endocrine glands hypo-function may occur as a result of hypo-secretion, active destruction, agenesis, loss of reserve, or atrophy. Hyper-function of the endocrine glands can occur as a result of loss of suppression, hyper-stimulation, or hyper-secretion, hyperplastic (or neoplastic change).

Endocrinopathy is classified as primary, secondary, or tertiary depending on the conditions involved. An endocrine disease is classified as primary if it inhibits the action of downstream glands. A problem with the pituitary gland indicates secondary endocrine disease. Tertiary endocrine disease is linked with the dysfunction of hypothalamus as well as its releasing hormones (Macksey, 2012).

As the thyroid, and hormones are implicated in proliferation of signaling distant tissues, for instance, the estrogen receptor has been demonstrated to be involved in some breast cancers. Endocrine, autocrine, and paracrine signaling are all implicated in proliferation, part of the required oncogenesis steps (Bhowmick *et al.*, 2004).

Other notorious diseases resulting from the dysfunction of the endocrine system include Addison's disease, Graves' disease, and Cushing's disease. Addison's disease and Cushing's disease are pathologies known for involving the adrenal gland dysfunction. Adrenal gland dysfunction may be caused by primary or secondary factors and may lead to hypocortisolism or hypercortisolism. Cushing's disease is characterized by and known for the hypersecretion of the ACTH (Adrenocorticotropic Hormone) due to pituitary adenoma which ultimately results to endogenous hypercortisolism by stimulating adrenal glands (Buliman *et al.*, 2016). Few clinical signs of Cushing's disease are hirsutism, obesity, and moon face (Vander, 2008). Addison's disease is a disease of the endocrine system which results from hypocortisolism triggered by the insufficiency of the adrenal gland. Adrenal gland insufficiency is a concern as it is correlated with reduced ability to maintain the blood pressure and blood sugar level, a defect that may be fatal (Inder *et al.*, 2015).

Graves' disease involves hyperactivity of the thyroid gland that produces T3 and T4 hormones (Vander, 2008). Effects of Graves' disease range from high blood pressure, excess sweating, fatigue, and heat intolerance to eyes swelling that causes puffiness, redness and in rare cases double or reduced vision.

2.8.4.2. All other animals

Neuroendocrine system has been seen in all the animals that have a nervous system and all the vertebrates have a hypothalamus-pituitary axis (Hartenstein, 2006). All the vertebrates have a thyroid. In amphibians, thyroid is crucial for the larvae transformation into adult form. All the vertebrates have tissue of adrenal gland, with mammals distinctive in having it organized in layers. All vertebrates have certain form of renin–angiotensin axis; all tetrapods have a primary mineralocorticoid known as aldosterone (Colombo *et al.*, 2006).

2.8.5. Conditions of the thyroid system

Insufficient amount of thyroxine results to hypothyroidism, with symptoms caused by a decrease in the oxidative energy-releasing reactions rate within the cells of the body. A condition known as cretinism (hypothyroidism in children) can lead to permanent sexual immaturity, mental retardation, and dwarfism. Sometimes too much thyroxine is produced by the thyroid gland, a condition called hyperthyroidism. This condition (hyperthyroidism) produces symptoms like profuse sweating, an abnormally high body temperature, high blood pressure, muscular pain and weakness, weight loss, and irritability. Hyperthyroidism can be treated by partial radiation destruction or partial removal of the gland. Currently, many drugs that inhibit the activity of the thyroid have been discovered; their use is gradually replacing surgical treatment. Conditions of the thyroid require lifetime treatment. Both suppressing and supplementing function of thyroid can take months or years to regulate.

2.9. Endocrine Disrupting Chemicals (EDCs) and potential EDCs

Endocrine disrupting chemicals (EDCs), including potential EDCs, are commonly man-made chemicals found in many materials such as metals, additives or contaminants in food, pesticides, and personal care products. Endocrine disrupting chemicals have been alleged to be connected with altered function of the male and female reproductive system; increased occurrence of cancer of the breast, neurodevelopmental delays and abnormal growth patterns in children, and changes in functions of the immune system.

Exposure of human to EDCs occurs through intake of food, dust and water, through inhalation of particles and gases in the air, and via the skin. Also, EDCs may be transmitted from a pregnant woman to the developing child or fetus via breast milk and the placenta. Children and pregnant mothers are the more vulnerable groups to be affected by developmental related exposures, and the effect of EDCs exposures may not manifest until later in life. Research also indicates that EDCs exposures may increase susceptibility to non-communicable diseases.

2.10. Endocrine disruptors

An endocrine disruptor is a chemical that interfere with hormone (or endocrine) systems at certain dosages. These endocrine disruptions can cause birth defects, cancerous tumors, and other developmental disorders. Any of the systems regulated by hormones in the body may be disrupted by hormone (or endocrine) disruptors. Particularly, endocrine disruptors may be connected with severe attention deficit disorder, the development of learning disabilities, brain and cognitive development problems; body deformations (including limbs); prostate cancer, breast cancer, thyroid and other cancers; sexual development problems such as masculinizing effects on females or feminizing of males, etc. (Sanders, 2010).

The Endocrine Society published a statement in 2015 on EDCs precisely listing female reproduction, obesity, thyroid, diabetes, male reproduction, prostate cancer in males, hormone-sensitive cancers in females, and neuroendocrine systems and neurodevelopment as affected biological aspects of exposure to EDCs (Gore *et al.*, 2015). The developmental critical period for some organisms is usually between the transitions from a fertilized egg to a fully formed infant. There are critical hormones and protein changes balances that must take place as the cells start to grow and differentiate. Thus, a dose of endocrine disrupting chemicals may significantly harm a developing fetus. The same dosage may not substantially affect adult mothers.

There are controversies over endocrine disruptors, with various groups calling for rapid actions by regulators and policymakers to take them away from the market. Some regulators and a few scientists are calling for further research. Some endocrine disrupting chemicals were removed from the market after been identified as endocrine disruptors (for instance, a drug called diethylstilbestrol), though it is still unclear whether some endocrine disruptors in the market really harm wildlife and humans at the doses to which they are exposed to wildlife and humans. In addition, a key scientific research paper, published in the journal *Science*in 1996, which helped the launch for the movement of individuals opposed to endocrine disruptors, was withdrawn and its author found to be responsible and accountable for scientific misconduct.

Seen in lots of industrial and household products, an endocrine disruptor is any chemical substance that interferes with synthesis, secretion, binding, action, transport, or elimination of natural body hormones which are responsible for development, behavior, homeostasis maintenance (normal cell metabolism), and fertility (Crisp *et al.*, 1998). Sometimes they are also called endocrine disrupting chemicals (Diamanti-Kandarakis *et al.*, 2009), hormonally active agents (Krimsky, 2001), or endocrine disrupting compounds (substances). The range of terms used to refer to these substances reflects not only variety of meanings but a wide range of connotations, with *endocrine disruptor* putting emphasis on harmful effects, whilst *xenohormone* or *hormonally active agent* are more neutral, in compliance with the principle of pharmacology *the dose makes the poison*.

Many researches in cells and laboratory animals show that endocrine disrupting chemicals can cause adverse biological and biochemical effects in animals, and exposures to low-level may as well cause similar adverse effects in human beings (World Health Organization, *2002*). Endocrine disrupting chemicals in the environment can also be correlated to infertility and reproductive problems in wildlife. Bans and restrictions on their usage have been connected with the recovery of certain wildlife populations and a decrease in health problems.

2.10.1. The history of endocrine disruptors

The term "*endocrine disruptor"* was officially coined in 1991 at the Wingspread Conference Centre in Wisconsin. One of the early published papers on the phenomena was by Theo Colborn *et al.* (1993). In the paper, she clearly stated that chemicals in the environmental disrupt endocrine system development, and effects of the exposure during development are usually permanent. Although the realities of endocrine disruption has been argued and disputed by some scholars (Grady, 2010), sessions of work from 1992 to 1999 have undoubtedly generated consensus statements from researchers and scientists concerning the hazard of endocrine disruptors, specifically in wildlife and in humans (Bern *et al.*, 1992; Bantle *et al.*, 1995; Benson *et al.*, 1997; Alleva *et al.*, 1998; Brock *et al.*, 1999).

The Endocrine Society published a scientific report explaining endocrine disruptors' mechanisms and effects on thyroid, metabolism and obesity, breast development and cancer, cardiovascular endocrinology, male and female reproduction, prostate cancer, and neuroendocrinology, as well as showing how epidemiological and experimental studies converge with clinical observations "to implicate endocrine disrupting chemicals as a serious concern to public health and nutrition. The statement made known that it is hard to demonstrate that endocrine disruptors contribute to human diseases, and also it recommended that precautionary principle should be adhered to (Diamanti-Kandarakis *et al.*, 2009). A concurrent statement emphasizes policy concerns.

Endocrine disrupting chemicals encompass a range of classes of chemicals, including pesticides, drugs, compounds used in the manufacturing of plastics and in production of consumer products, industrial pollutants and by-products, and some naturally made botanical chemicals. Many are pervasive and broadly dispersed in the environment and can bioaccumulate. Some of the chemical substances are persistent organic pollutants (POPs), and may be transported long distances and across national boundaries and are found in nearly all around the world, and may accumulate near the North Pole, because of cold conditions and weather patterns. Others are quickly degraded in the human body or in the environment or may be present for just a short period of time (Damstra *et al.*, 2002). Health effects associated with endocrine disrupting compounds are a range of reproductive problems which include abnormalities of male and female reproductive tract, reduced fertility, and skewed female/male sex ratios, menstrual problems, loss of fetus (Harrison *et al.*, 1995); changes in hormone levels; brain and behavior problems; various cancers; early puberty; and impaired immune functions.

One typical example of the exposure consequences of developing animals, humans inclusive, to hormonally active agents is the instance of diethylstilbestrol (DES), a drug and a nonsteroidalestrogen and not environmental pollutant. Before its ban in early 1970s, physicians prescribed diethylstilbestrolto over five million pregnant women to prevent spontaneous abortion, an off-label use of DES prior to 1947. Its discovery came after the children passed through puberty and DES impaired the development of their reproductive system as well as caused vaginal cancer. The significance of DES saga to the exposure to endocrine disruptors' risks is disputed, as the doses are much higher in these people than in those caused by environmental exposures (Golden *et al.*, 1998). Marine life exposed to EDCs in urban effluents had decreased serotonin levels and increased feminization (Willis, 2007).

In 2013 the United Nations Environment Programme and the WHO jointly released a study report on EDCs emphasizing the need for more research to completely understand the links between EDCs and the risks to human health and animal life. The team raised concern on the wide gaps in knowledge and evidence, and called for more research to establish a better picture of the environmental impacts and the health effects of endocrine disruptors. To expand global knowledge the team recommended:

- *Research: more scientific based evidence is needed to ascertain the effects of mixtures of endocrine disrupting chemicals on wildlife and humans (mostly from by-products of industries) to which wildlife and humans are increasingly exposed.*
- *Testing: known endocrine disrupting chemicals are only small indication of a larger possibility of more discovery and more comprehensive methods for testing are required to identify other likely endocrine disruptors, routes of exposure, and their sources (WHO, 2013).*
- *Reporting: many EDCs sources are unknown as a result of insufficient reporting & information on the chemicals in products, goods, and materials (WHO, 2013).*
- *Collaboration: more sharing of data among scientists and among nations can fill the gaps in data, primarily in emerging economies and developing countries (WHO, 2013).*

2.10.2. More on the Endocrine System

Endocrine systems are seen in most animal species. The endocrine systems are made up of of glands that secrete hormones, and the receptors that identify and respond to the hormones. These hormones act as chemical messengers as they travel all through the body. Hormones interface with body cells that have matching receptors on or in their surfaces. The hormone identifies and binds with the receptor, just like a key would fit into a padlock. The endocrine system is responsible for the regulation of adjustments via slower internal processes, with hormones as messengers. Endocrine system secretes hormones in responding to orchestrate reproductive and developmental changes and to environmental stimuli. The adjustments brought by the endocrine system are naturally biochemical, varying the cell's internal and external biochemistry to cause a long term body change. These systems work hand in hand to maintain the appropriate body functioning throughout its entire life cycle. Estrogens and androgens (sex steroids), as well as thyroid hormones, undergo feedback regulation, which inclines to limit these glands' sensitivity.

Hormones work at part per billion ranges (very small doses). Endocrine disruption can thus also arise from very low dose exposure to hormonally active chemicals or exogenous hormones such as bisphenol A, phthalates. These chemical could bind to receptors for some other hormonally mediated processes. Additionally, as endogenous hormones are readily present in the body in biologically and biochemically active concentrations, further exposure to relatively small doses of exogenous hormonally active chemicals can disrupt the correct functioning of the endocrine system of the body. Thus, an endocrine disruptor can cause adverse health effects at much lower doses than a common toxicity, acting through different mechanism.

The exposure timing is also critical. Many critical development stages take place in utero, the site where the fertilized egg divides, quickly developing structures of a fully formed baby, much of the brain wiring inclusive. Any interference with the communication of the hormones in utero can result to profound effects both toward brain development and structurally. Depending on the reproductive development stage, interference with hormonal signaling may result to irreversible effects not found in adults exposed to same doses for the same duration (Guo *et al.*, 1995; Bigsby *et al.*, 1999; Castro *et al.*, 2008). Experiments with animal models have indicated critical time points' development in utero and some days after birth as when exposure to chemicals that mimic or interfere with hormones have adverse effects which continue into adulthood (Bigsby *et al.*, 1999; Eriksson *et al.*, 1991; Recabarren *et al.*, 2008; Szabo *et al.*, 2008). Thyroid function disruption in early development may be attributed to abnormal sexual development in both females (Talsness *et al.*, 2005) and males (Lilienthal *et al.*, 2005) learning impairments, and early motor development impairment (Eriksson *et al.*, 2002).

There are studies of wildlife, accidentally exposed humans, cell cultures, and laboratory animals that indicate environmental chemicals cause a range of reproductive, behavior, developmental, and growth effects. Therefore, while endocrine disruption in humans by hormonally active and pollutant chemicals remains generally undemonstrated, the underlying science is clear and sound and the potential for the effects is real (Rogan and Ragan, 2003). While compounds that produce antithyroid, estrogenic, androgenic, and antiandrogenic actions have been studied, many are unknown about interactions with other body hormones.

The interrelationship between chemical exposures and their health effects are very complex. It is difficult to conclusively link a specific chemical with a precise health effect, and adults exposed to these chemicals may not show ill effects. However, embryos and fetuses, whose development and growth are greatly controlled by endocrine system, are most vulnerable to exposure and may suffer subtle or overt lifetime health effects and/or reproductive abnormalities (Bern, 1992). Exposure in prebirth, in most cases, may lead to permanent and lifetime alterations and even adult diseases (Colborn and Carroll, 2007). Some scientists are concerned that endocrine disruptors' exposure early in life or in the womb may be linked with some neurodevelopmental disorders including autism, reduced IQ, and Attention Deficit Hyperactivity Disorder (ADHD) (Institute for Children's Environmental Health, 2008). Uterine abnormalities and some cancers in women are connected with Diethylstilbestrol (DES) exposure in the womb as a result of DES used as medical treatment.

In a different case, phthalates in the urine of pregnant women was associated with subtle, but specific, changes of genitals in their male infants – a shorter, female-like anogenital distance and accompanying incomplete testes descent and a smaller penis and scrotum (Swan *et al.*, 2005). The science and rationale behind this study have been questioned by renowned phthalate industry consultants (McEwen and Renner, 2006). By June 2008, there were only five studies on anogenital distance in humans (Postellon, 2008), and one researcher stated Whether measures of anogenital distance in humans connect to clinically significant outcomes, on the other hand, is yet to be ascertained, as does its effectiveness as an androgen action measure in epidemiological studies (Romano-Riquer *et al.*, 2007).

2.10.3. Effects of endocrine disruptors on the levels of body's own hormones

While the chemical differences between endogenous hormones and endocrine disruptors have occasionally been cited as argument for endocrine disruptors only affecting some of the traits (not all) that hormones can affect, toxicology research indicates that most of the endocrine disruptors effects target the features of hormone effects which make a hormone regulate the making and/or degradation of the hormones of the body. These regulatory effects are interweaved so that a hormone levelly affected by a different hormone in return affects multiple levels of other hormones made by the body itself, causing no endogenous traits or hormones affected by their actions unaffected by endocrine disruptors (Ming-Ho *et al.*, 2016).

2.10.4. The U-shaped dose-response curve

Many toxicants, endocrine disruptors inclusive, have been shown to obey a U-shaped dose response curve (Calabrese and Baldwin, 2003). What this means is that very high and very low levels have more impacts than exposure to mid-level of a toxicant. Effects of endocrine disruptors have been shown in animal models exposed to environmentally related levels of some chemicals. For instance, a well-known common flame retardant, BDE-47, has effects on the thyroid gland and reproductive system of female rat models in doses related to the order of those humans are exposed to (Talsness *et al.*, 2008). Endocrine disruptors, at low concentrations, can have synergistic effects in the amphibians, but it is unclear that this effect is mediated via the endocrine system.

Critics and faultfinders have debated that data put forward that the quantities of these chemicals in our environment are very low to have an effect. A unanimous statement made by the Learning and Developmental Disabilities Initiative (LDDI) argued that the effects of endocrine disruptors at very low-dose cannot be predicted with data from high-dose studies, which invariably contradicts the usual standard 'dose makes the poison' in toxicology rule. Nontraditional dose-response curves are known as nonmonotonic dose response curves.

Objection of dosage could be overcome if and only if low concentrations of various endocrine disruptors are synergistic (Arnold *et al.*, 1996). The paper was published in June 1996 in *Science*, and was one of the reasons for the Food Quality Protection Act passage in 1996. The results was not confirmed with alternative and the same methodologies (Ramamoorthy, 1997), and the original paper was withdrawn (McLachlan, 1997). Arnold was found to be guilty of scientific misconduct by the US Office of Research Integrity.

At low doses, Tamoxifen and some phthalates are claimed to have fundamentally different and unsafe effects on the body than at high doses.

2.10.5. Exposure routes

Food is the major pathway by which individuals are exposed to pollutants and toxins. Diet account for up to 90 percent of an individual's DDT and PCB body burden (Fürst, 2006). In a study involving 32 different popular food products from three different grocery stores in Dallas, seafood and other products of animals were found to be polluted with PBDE (Schecter *et al.*, 2004). Since these compounds and chemicals are soluble in fat, it is very likely they are concentrating from the surroundings in the fatty tissue of animals we consume. Some hold the belief that consumption of fish is a main source of most environmental contaminants exposure. Undeniably, both farmed and wild salmon from all parts of the world are known to contain a range of manufactured organic compounds (Hites *et al.*, 2004).

With the rise in household products containing pollutants and the decline in building ventilation quality, indoor air has turn into a significant source of exposure to pollutant (Weschler, 2009). Residents living in houses made of wood floors treated in 1960s with PCB-based wood finish are in a higher body burden than other population (Rudel *et al.*, 2008). A study of indoor household dust and dryer lint of 16 houses found high levels of all the 22 different congeners of PBDE tested for in all samples (Stapleton *et al.*, 2005). Recent studies and publications put forward that contaminated home dust, not food, might be the main source of PBDE in human bodies (Anderson *et al.*, 2008; Morland *et al.*, 2005). One study estimated that intake of house dust is responsible for approximately 82% of PBDE burden in human body (Lorber, 2008).

It has been demonstrated that contaminated home dust is a major source of lead in bodies of young children. It may be that toddlers and babies ingest more contaminated home dust than adults they live with, and consequently have much higher pollutants' levels in their body systems.

Another potential sources of endocrine disruptors' exposure are consumer goods. Analysis of the composition of 43 "chemical free" products versus 42 personal care and household cleaning products was performed. The products were found to contain 55 different chemical compounds: 41 were found in 43 "chemical free" product samples representing 39 types of product, while 50 were detected in the 42 conventional product samples representing 170 types of product. Parabens, a group of chemicals that has been connected to issues of reproductive-tract, were found in seven of the products that were "chemical free", including 3 sunscreens which did not enlist parabens on their label. Vinyl products like shower curtains were seen to have over 10% by weight of the Bis(2-ethylhexyl) phthalate (DEHP), which when present in the dust has been linked with asthma & wheezing in children. The exposure risks to EDCs increase as products, both "chemical free" and conventional, are used together. If a user used the alternative laundry detergent, toothpaste, surface cleaner (tub and tile cleaner), conditioner and shampoo, facial lotion and cleanser, and bar soap, [he/she] would be potentially exposed to at least 19 chemical compounds: 2 parabens, 5 alkylphenols, 3 phthalates, MEA, DEA, and 7 fragrances (Dodson *et al.*, 2012).

The analysis of EDCs in Old Order Mennonite females in their mid-pregnancy found that they have far lower levels in their body systems than other general population. Mennonites commonly consume fresh, unprocessed foods, farmed without pesticides usage, and use little or no cosmetics and personal care products. A woman who reported using perfume and hairspray had high monoethyl phthalate levels, while other women had levels below detection. About three women who testified being in a truck or car within 48 hours of providing urine sample had higher diethylhexyl phthalate levels which is contained in polyvinyl chloride, and is used in interiors of cars and trucks (Martina *et al.*, 2012).

Additives added to plastics during production may leach into environment after the discarding of the plastic item; additives in plastics in landfills can leak and leach into the surrounding soil and then gradually into groundwater, while additives in micro-plastics in ocean leach into ocean water(Teuten *et al.*, 2009).

2.10.6. Types of endocrine distruptors

As endocrine disrupting chemicals are seen in low doses in thousands products, all individuals are exposed to chemicals that have estrogenic effects in their daily life. Chemicals regularly detected in people include bisphenol A (BPA), DDT, polychlorinated biphenyls (PCB's), a variety of phthalates, and polybrominated diphenyl ethers (PBDE's). In fact, nearly all plastic products, inclusive of those promoted as "BPA free", are found to leach EDCs (Yang *et al.*, 2011). A study in 2011 found that some products advertised as "BPA-free" released more endocrine active chemicals than products containing BPA. Other kinds of endocrine disruptors are plant hormones (phytoestrogens).

2.10.6.1. Xenoestrogens

Xenoestrogens are type of xenohormone that mimics estrogen. Widely used industrial compounds, like PCBs, phthalates, and BPA are synthetic xenoestrogens that have estrogenic effects on living organisms.

2.10.6.2.Alkylphenols

Alkylphenols are xenoestrogens (Kochukov *et al.*, 2009). The EU has implemented use and sales restrictions on some applications requiring the use of nonylphenols due to their alleged toxicity, the liability to bioaccumulate, and persistence but the US Environmental Protections Agency (EPA) took a slower approach to ensure that actions are based on "sound science" (Renner, 1997).

Long chain alkylphenols are commonly used extensively as the precursors to detergents, as the additives for lubricants and fuels, polymers, and as phenolic resinscomponents. Also, these compounds are used as the building block chemicals which are also used in producing fragrances, thermoplastic elastomers, fire retardant materials, antioxidants, and oil field chemicals. Via the downstream use in producing alkylphenolic resins, alkylphenols can also be found in carbonless copy paper, high performance rubber products, tires, adhesives, and coatings. Their use in industry is over 40 years. Some alkylphenols are products of degradation from nonionic detergents. The nonylphenol is considered a low-level endocrine disruptor due to its estrogen imitating tendency (Soares *et al.* 2008).

2.10.6.3. Bisphenol A (BPA)

BPA is commonly found in dental materials, plastic bottles, plastic food containers, and the linings of infant formula cans and metal food. Another exposure to BPA comes from the receipt paper commonly used at restaurants and grocery stores, as nowadays the paper is usually coated with a bisphenol A containing clay for the purposes of printing.

BPA is a well-known endocrine disruptor, and many studies have indicated that laboratory animals exposed to low levels of BPA have elevated rates ofmammary and prostate cancers, diabetes, decreased sperm count, obesity, neurological problems, reproductive problems, and early puberty (Gore, 2007; O'Connor and Chapin, 2003; Okada *et al.*, 2008; vom Saal and Myers, 2008). Early developmental stages seem to be the greatest sensitivity period to its effects; some studies have associated prenatal exposure with later neurological and physical difficulties. Many regulatory bodies have determined the safety levels for humans, although those safety levels are presently under review or are being questioned as a result of recent scientific studies (Ginsberg and Rice, 2009; Beronius *et al.*, 2010). A study in 2011 which researched on the number of chemical compounds pregnant women are commonly exposed to in the United States found bisphenol A in 96 percent of women. The World Health Org. expert panel in 2010 recommended no new regulations banning or limiting the use of BPA, maintaining that commencement of public health measures would be too early (Brown, 2010).

The United States FDA issued a draft reassessment in August 2008, reconfirming their early opinion stating that it is safe based on scientific evidence. Nevertheless, FDA's advisory Science Board in October 2008 resolved that the Agency's own assessment was flawed and had not proven the safety of the chemical for infants formula-fed (Szabo, 2008). The FDA issued a report in January 2010 showing that, because of findings of the recent studies which used innovative approaches in the testing for subtle effects, both the FDA and the National Toxicology Program at National Institutes of Health have certain level of concerns regarding the likely effects of bisphenol A on the behavior and brain of fetuses, younger children, and infants (US Food & Drug Administration, 2012). The FDA, in 2012, did ban the use of bisphenol A in baby bottles, nevertheless the Environmental Working Group (EWG) called the ban purely and merely cosmetic. They said in a statement that if the agency really wants to prevent individuals from exposure to this toxic chemical linked with a variety of chronic and severe conditions it has to ban its use in cans of food and beverages, infant formula. The Natural Resources Defense Council (NRDC) termed the move insufficient stating that the FDA needs to ban bisphenol A from all food packaging (Common Dreams, 2012). A statement issued by a FDA spokesman said the action of the agency was not based on concerns related to safety and the agency continues to offer support to the safety of bisphenol A for use in products holding food.

2.10.6.4. Bisphenol S (BPS)

BPS is an analog of BPA. It is commonly found in household dust, thermal receipts, and plastics. Also, traces of bisphenol S may be found in personal care products (Rochester and Bolden, 2015). Currently, it is being used more because of the ban placed on BPA. In "BPA free" items, bisphenol S is used in place of BPA. However, bisphenol S has been indicated to be equivalent as much an endocrine disruptor as bisphenol A (Eladak *et al.*, 2015)

2.10.6.5. Dichlorodiphenyltrichloroethane (DDT)

DDT (Dichlorodiphenyltrichloroethane) had its first use as pesticides against Colorado potato beetles on agricultural crops starting in 1936. Rises in the incidence of typhoid fever, malaria, epidemic typhus, and dysentery led to its use as pesticide against the mosquitoes, houseflies, and lice which carried these diseases. Before the World War II, an extract of a flower called pyrethrum from Japan, was used for the control of these insects and the diseases they spread. During the World War II, Japan stopped the exporting of pyrethrum, pushing the search for alternatives. Being wary of an epidemic typhus outbreak, every American and British soldier was issued dichlorodiphenyltrichloroethane, who used it as a routine to dust tents, beds, and barracks all around the world.

Dichlorodiphenyltrichloroethane was permitted for general, non-military usage after the war ended (Davis, 1971). It became used globally to increase the yields of monoculture crops that were threatened by the infestation of pests, and to lessen malaria spread which constitutes a high rate of mortality in various parts of the world. Its usage for the purposes of agriculture has since been banned by national legislation of many countries, whilst its use as control against malaria vectors is approved, as specified by the Stockholm Convention on POPs (Persistent Organic Pollutants).

In 1946, the harmful effects of dichlorodiphenyltrichloroethane on bird, marine invertebrates, beneficial insects, and fish were found in the environment. The most egregious example of these harmful effects were seen in the large predatory birds' eggshells, which did not develop and mature to be thick as required to provide support for the adult birds sitting on them (Lundholm, 1997). Further research found dichlorodiphenyltrichloroethane in very high concentrations in the carnivores all around the world, the lead to biomagnification via the food chain (Szlinder-Richert *et al.*, 2008). Twenty years after its extensive use, DDT was seen trapped in samples of ice taken from the Antarctic snow, suggesting water and wind are another environmental transport means (Peterle, 1969). Recent studies indicate the historical record of the deposition of DDT on remote glaciers in the Himalayas (Daly and Wania, 2005).

More than 60 years ago when biologists commenced to study the DDT effects on laboratory animal models, it was found that DDT affected reproductive development (Tauber and Hughes, 1950; Stoner,1953). Recent studies suggest that DDT may obstruct the proper development of the female reproductive organs which adversely affects the reproduction into maturity (Tiemann, 2008). Further studies put forward that a marked decline in fertility of adult males may be due to the exposure to DDT (Hallegue *et al.*, 2003). It was advised that DDT exposure in utero may increase risk of childhood obesity of a child (Verhulst *et al.*, 2009). DDT is still in use as anti-malarial insecticide in parts of Southeast Asia and Africa in limited quantities.

2.10.6.6. Polychlorinated biphenyls (PCBs)

Polychlorinated biphenyls are a class of chlorinated chemical compounds used as industrial lubricants and coolants. PCBs are produced by heating benzene, a gasoline refining byproduct, with chlorine (Francis, 1994). They were first commercially produced by the Swann Chemical Company in the year 1927. In 1933, the direct PCB exposure health effects were reported in individuals who worked with the chemicals at the manufacturing plant in Alabama. Monsanto acquired the company in 1935, licensing PCB production technology internationally and taking over US production.

One of the largest United States companies to incorporate polychlorinated biphenyls into manufactured equipment was General Electric. Amid 1952 and 1977, the General Electric plant in New York had dumped over 500,000 pounds waste of PCB into the Hudson River. Polychlorinated biphenyls were first discovered in environment far-off from its industrial uses by scientists in Sweden carrying out a study on DDT.

The acute exposure effects to PCBs were popular within the companies that used Monsanto's polychlorinated biphenyls formulation who saw the effects of the PCBs on their workers who came in regular contact with it. Direct contact with the skin results in severe acne-like condition known as chloracne (Tang *et al.,* 2008). Exposure to PCBs increases the risk of brain cancer, skin cancer, and liver cancer (Loomis *et al.,* 1997; Sinks *et al.,* 1992). Monsanto tried for several years to play down the health problems associated with exposure to PCBs in order to continue sales (Grunwald, 2002).

The harmful health effects of PCBs exposure to humans gradually became undisputable when two distinct incidences of contaminated cooking oil poisoned too many (in thousands) of residents in Taiwan, Yu-cheng disease, 1979, and Japan, Yushō disease, 1968 (World Health Organization, 1976), leading to a global ban on PCBs use in the year 1977. Studies indicated the endocrine interference of some PCB congeners is toxic and poisonous to the thyroid and liver (Kodavanti, 2006), increases childhood obesity rate in children exposed prenatally, and can increase risk of developing diabetes (Uemura *et al.*, 2008; Mullerova *et al.*, 2008).

Also, polychlorinated biphenyls in the environment may be correlated to infertility and reproductive problems in wildlife. In the Alaska, it is believed that they can contribute to antler malformation, reproductive defects, and infertility in some populations of deer. Drops in the populations of sea lions and otters may also be partly due to their PCBs exposure, the insecticide DDT, and other persistent organic pollutants. Restrictions and bans on the EDCs use have been linked with a reduction in health complications and recovery of some populations of wildlife (Science Daily, 2013).

2.10.6.7. Polybrominated diphenyl ethers (PBDEs)

Polybrominated diphenyl ethers are a class of compounds commonly found in flame retardants used in the manufacturing of the plastic cases of computers and televisions, lighting, bedding, clothing, electronics, carpets, foam cushions, car components, and other textiles. PBDE's are structurally related to PCBs (Polychlorinated biphenyls), and have similar neurotoxic effects (Eriksson *et al.*, 2006). Research has associated halogenated hydrocarbons, like PCBs, with neurotoxicity (WHO, 1976). Polybrominated diphenyl ethers are related in chemical structure to PCBs (Polychlorinated biphenyls), and it has been submitted that PBDEs act by same mechanism as PCBs (WHO, 1976).

In 1930s and 1940s, the plastic industry developed innovative technologies to make a variety of plastic materials with broad applications (American Chemistry Council,2008). Once the World War II started, the United States military used these innovative plastic materials to improve weapons, to replace heavy components in vehicles and aircraft, and protect equipment (American Chemistry Council,2008). After the WWII, manufacturers and industrialists saw the potentials plastics could have in several industries, which led to the incorporation of plastics into new designs of consumer products. Plastics gradually began to replace metal and wood in existing products too, and today plastic materials are the most commonly used manufacturing materials (American Chemistry Council, 2008).

By 1960s, almost all homes had electricity and numerous electrical appliances. Cotton were the dominant textile used to manufacture home furnishings, but now synthetic materials are mostly used to manufacture home furnishings. Over 500 billion cigarettes were consumed every year in the 1960s, compared to less than 3 billion each year in the commencement of the 20th century. When this was combined with the high density living, the likelihood and potential for household fires was higher during that same period than it ever had been in the United States. By the late 1970s, roughly 6000 individuals in the United States lost their life every year in home fires (Karter, 2008).

In 1972, as a response to this situation, the NCFPC (National Commission on Fire Prevention & Control) was formed to study fire problems in the United States. They published their findings in 1973 in America Burning, a report of 192 pages that made recommendations and suggestions to increase the prevention of fire. Most of the recommendations and suggestions dealt with improved building engineering and education on the prevention of fire, such as the installation of smoke detectors and fire sprinklers. The Commission projected that with these recommendations, a 5% decrease in fire losses would be expected per year, cutting the annual losses by half within 14 years.

In history, treatments with borax and alum were used to lessen the flammability of wood and fabric, as far back as the Roman eras. Since plastic materials are non-absorbent once created, flame retardant chemicals are included to plastics during the polymerization reaction as it is formed. Halogen (like bromine and chlorine) based organic compounds are used as additive (the flame retardant) in plastic materials and items, and also in fabric based textiles. The extensive use of brominated flame retardants could be because of the push from GLCC (Great Lakes Chemical Corporation) to profit from its massive bromine investment. In 1992, the global market consumed roughly 150,000 tons of brominated flame retardants, and Great Lakes Chemical Corporation produced 30% of the global supply.

PBDEs have the potency to disrupt the balance of thyroid hormone and add to a variety of developmental and neurological deficits, including learning disabilities and low intelligence (U.S. Environmental Protection Agency, 2008). Many of the most common polybrominated diphenyl ethers were banned in the EU in 2006 (Betts, 2008). Studies involving rodents have recommended that even brief PBDEs exposure can cause behavioral and developmental problems in juvenile rodents (Costa and Giordano, 2007), and exposure to PBDEs interferes with adequate thyroid hormone regulation.

2.10.6.8. Phthalates

Phthalates can be found in some flooring, air fresheners, medical equipment, soft toys, and cosmetics. They are potential health concerns as they are well-known to disrupt animals' endocrine system. Some research has implicated phthalates in the increase in the birth defects of male reproductive system (Fisher, 2004; Barret, 2005).

Europe, Washington, and California have banned phthalates from toys, though an expert panel resolved that there is no sufficient evidence that they harm infant reproductive system (Kaiser, 2005). A phthalate, bis(2-ethylhexyl) phthalate, known as DEHP, used in medical tubing, blood bags, and catheters, may harm male infants sexual development. In 2002, the th US FDA released a public report that cautioned against male babies' exposure to DEHP. Though there are no direct studies with human the FDA report stated that DEHP exposure has resulted to a variety of adverse effects in laboratory animal models, but of greatest concern are the effects on the development of the reproductive system of males and normal sperm production in young animals. In the light of the available animal data, precautionary measures should be taken to reduce the exposure of developing male to DEHP (Feigal, 2002). Similarly, phthalates can play causal role in disruption of masculine neurological development once exposed prenatally (Swan *et al.*, 2009).

Another phthalate, DBP (dibutyl phthalate), has also disrupted glucagon and insulin signaling in animal models (Williams *et al.*, 2016).

2.10.6.9. Perfluorooctanoic acid (PFOA)

Perfluorooctanoic acid (PFOA) exerts effects on hormones including the alteration of levels of the thyroid hormone. In a 2009 study, PFOA blood serum levels were associated with increased time to pregnancy or infertility. PFOA exposure is associated with reduced quality of semen. Perfluorooctanoic acid appeared to behave as an endocrine disruptor in young girls through a potential mechanism on the maturation of breast. A C8 Science Panel report on status noted a link between exposure in girls and later onset of puberty.

2.10.6.10. Other possible endocrine disruptors (EDCs)

Some other examples of alleged endocrine disruptors are polychlorinated dibenzo-furans (PCDFs) and -dioxins (PCDDs), phenol derivatives, polycyclic aromatic hydrocarbons (PAHs), and a number of pesticides (most prominent are organochlorine insecticides such as endosulfan, DDT, and chlordecone (kepone) and its derivatives, the fungicide vinclozolin and the herbicide atrazine), 17-alpha ethinylestradiol (a contraceptive), as well as the naturally occurring mycoestrogens such as zearalenone (a mycotoxin) and phytoestrogens such as genistein.

The molting in crustaceans is a process controlled by the endocrine system. In the marine penaeid shrimp *Litopenaeus vannamei*, endosulfan exposure led to increased mortalities and increased susceptibility to acute toxicity in the shrimp postmolt stage (Tumburu *et al.*, 2011). Many sunscreens have oxybenzone, a chemical blocker which provides broad-spectrum Ultra-Violet coverage, nevertheless it is subject to lots of controversy because of its potency to possibly cause estrogenic effect in humans (Burnett and Wang, 2011).

Tributyltin (TBT) are compounds of organotin that for over 40 years TBT was applied as biocide in anti-fouling paint, generally known as bottom paint. Tributyltin has been made known to impact the development of vertebrate and invertebrate, disrupting the endocrine system, causing lower survival rates, masculinization, and many health problems in mammals.

2.10.7. The temporal trends of the body burden

Since the ban of DDT and PCB, average human body burdens of PCB and DDT have been declining (Knobeloch *et al.*, 2009; Norén and Meironyté, 2000). Since their ban in the year 1972, the body burden of PCB in 2009 was 1% of what it was compared to early 1980s. Conversely, monitoring programs of samples of European breast milk have indicated that the levels of PBDE are increasing (Norén and Meironyté, 2000). A PBDE content analysis in samples of breast milk from the US, Canada, and Europe shows that levels are 40 times very higher for women from North America than women from Sweden, and that levels of PBDE in North America double every two to six years (Hites, 2004)

2.10.8. Legal approach to endocrine disruptors

2.10.8.1. The United States

The multitude of potential endocrine disruptors are regulated in the US technically, by many laws, including: the Food Quality Protection Act, the Toxic Substances Control Act (Susan and Penelope, 2016), the Clean Air Act, the Clean Water Act, the Safe Drinking Water Act, and the Food, Drug & Cosmetic Act. The United States Congress has improved the process of regulation and evaluation of drugs and other chemicals. The 1996 Food Quality Protection Act and the 1996 Safe Drinking Water Act simultaneously offered the first legislative direction necessitating the EPA to address the endocrine disruption by establishment of a program for testing and screening of chemical substances.

The EPA in 1998 stated the Endocrine Disruptor Screening Program (EDSP) by establishing a framework for priority setting, testing, and screening over 85,000 chemicals in commerce. While the 1996 Food Quality Protection Act required the EPA to only screen pesticides for potential to have effects that are similar to estrogen in humans, also it gave the EPA authority to screen the effects of other types of chemicals on the endocrine system (Susan and Penelope, 2016). Based on the recommendations from a panel of advisory, the agency extended the screening programme to include the thyroid system, the male hormones, and the effects on fish as well as other wildlife (Susan and Penelope, 2016). The rudimentary concept behind the programme is that prioritizing will be basing on existing information about structure-activity, toxicity, chemical uses, and production volume. Screening is done through use of *in vitro* systems of test (by the examining, for example, if any agent interacts with the androgen receptor or the estrogen receptor) and through the use of animal models, like the uterine growth in prepubertal rodents and the development of tadpoles. Full scale testing by the EDSP framework will involve examining effects not only in mammals (for instance, rats) but also in many other species (invertebrates, frogs, fish, and birds). As the theory involves effects of these chemical substances on a functioning system, testing involving animal models is required for scientific validity and logical frame, but has been contrasted by animal rights groups. In the same way, proof that these effects take place in humans will require testing with humans, and such testing has been opposed also, due largely to ethical and health reasons.

After the failure to meet many deadlines to commence testing, the EPA lastly announced their readiness to begin the testing process for dozens of chemical substances that are suspected to be endocrine disruptors in early 2007, roughly eleven years after the announcement of the program. There was objection and opposition to the design of the final structure of the tests when it was announced. Critics maintained that the entire process was compromised by the interference of chemical companies. In 2005, the EPA selected a panel of experts saddled with the responsibility to openly conduct a peer-review of the program as well as its orientation. Their outcomes found and concluded that the long-term goals and the range of science questions in the program of EDC are appropriate, nevertheless this study was conducted more than a year before the EPA made the announcement on the screening program final structure. It is still difficult for the EPA to execute an efficient and credible endocrine testing program (Susan and Penelope, 2016). As at 2016, the EPA had results of estrogen screening for 1,800 chemicals (Susan and Penelope, 2016).

2.10.8.2. In Europe

In 2013, many pesticides having endocrine disrupting chemicals (EDCs) were in draft of the EU criteria to be banned and prohibited. On the 2nd of May, negotiators of US TTIP insisted the European Union drop the criteria, stated that an approach based on risk should be taken on regulation. Late same day Catherine Day wrote a letter to Karl Falkenberg requesting for the removal of the criteria (Brussels, 2015).

The European Commission had been out to set the criteria by December 2013 classifying endocrine disrupting chemicals in thousands of products — including toiletries, disinfectants, and pesticides — that have been associated with cancers, development disorders in children, and birth defects. However, the process was delayed by the body, prompting Swedish authority to announce that it would file a law suit against the commission in May 2014 — putting blame on chemical industries lobbying for the disruption.

The delay is because of the European chemical lobby that, once again, put pressure on different commissioners. Disruptors of hormone are gradually becoming a colossal problem. In most places in Sweden, double-sexed fish can be seen. There are scientific reports on how this may affect fertility of young girls and boys, and other severe effects, Lena Ek, a Swedish Environment Minister, told the AFP, stating that action had also been demanded by Denmark.

In November 2014, the Nordic Council of Ministers based in Copenhagen released own independent report that made estimates on the impact of environmental endocrine disrupting chemicals on the reproductive health of males, and its resulting cost to the public health systems. It conclusion was that EDCs probably cost health systems across the European Union anywhere from roughly 59 million to 1.18 billion Euros per year, stating that this only represented a fraction of the endocrine associated diseases" (Ing-Marie, 2014).

2.10.9. The cleanup of environment and human body

There is indication that as soon as a pollutant is not in use any longer, or once its usage is restricted heavily, there is always a decline in human body burden of the pollutant. Through the efforts of many large-scale monitoring programs (Centers for Disease Control and Prevention, 2009), the most predominant pollutants in human population are fairly known very well. The first stage in decreasing the human body burden of these prevalent pollutants is phasing out or eliminating their production. The second step to lowering human body burden is creating awareness of and potentially labeling foods which are likely to contain high quantities of the pollutants. In the past this strategy has worked – nursing and pregnant women are cautioned against consuming seafood that is well-known to accumulate mercury at high levels. Ideally, a process of certification should be put in place to routinely and customarily test animal products for the concentrations of persistent organic pollutants, POP. This would enable the consumer to identify which foods contain the highest pollutants levels.

The utmost challenging part of this problem is the discovery of how to eliminate and contain these compounds from our environment and where remediation efforts are to be focused. The basic understanding of how these chemical pollutants, once in the environment, move via the ecosystems, is important to designing ways to remove and isolate them. Working towards the back through the food chain can help to detect areas of prioritization for remediation efforts focusing. It may be very challenging for marine mammals and contaminated fish with a large habitat and consume fish from several different areas throughout their lives.

Lots of persistent organic compounds, PBDE, PCB, and DDT included, accumulate in sediments of marine and river. Currently, many processes are being used by the EPA for cleaning up areas that are heavily polluted, as outlined in its Green Remediation program. Among the most interesting ways is the application and utilization of the naturally occurring microorganisms that degrade congeners of PCB to remediate contaminated areas (Field and Sierra-Alvarez, 2008).

There are several success stories of efforts to clean up large heavily polluted Superfund sites. A 40,000 m^2 (10 acre) landfill in Austin, Texas that was contaminated with illegally dumped Volatile Organic Compounds (VOCs) was restored within a year to an educational and wetland park.

A United States uranium enrichment site which was contaminated with PCBs and uranium was cleaned up with high technological equipment used to discover the pollutants in the soil. The water and soil at a contaminated wetlands site were cleaned up of lead, VOCs, and PCBs, native plants were installed and fitted as biological filters, after which a community program was implemented to make sure ongoing monitoring of the concentrations of pollutants in the area is achieved. These case studies are unique and encouraging because of the short time required for the site remediation in addition to the high and commendable level of success achieved.

Research suggest that bisphenol A (Genuis *et al.*, 2012), phthalate compounds, and some PCBs are preferentially eliminated from the body (human) through sweat.

2.10.10. The economic effects of exposure to endocrine disruptors

Human exposure may cause certain health effects, such as adult obesity and lower IQ. These effects may lead to premature death, lost productivity, or disability in some individuals. One source estimated that, in the EU, these economic effects may have about two times the economic impacts as the effects caused by lead and mercury contamination (Leonardo *et al.*, 2015).

The socio-economic burden of EDCs-associated health effects for the EU was estimated based on current literature available and considering the uncertainties regarding causality with endocrine disrupting chemicals and corresponding health-associated costs to be within the range €46 billion to €288 billion each year (Ingrid *et al.*, 2016).

3.1. Global Seafood Production

Table 7 shows the average world seafood (fisheries and aquaculture) production and utilization in Million Tonnes

Table 7: Average World Seafood Production and Utilization (Million Tonnes)[a]

Year	2011	2012	2013	2014	2015	2016	2017	2018
Production								
Capture								
Inland	10.7	11.2	11.2	11.3	11.4	11.6	12.8	13.0
Marine	81.5	78.4	79.4	79.9	81.2	79.3	79.2	79.0
Total capture	92.2	89.6	90.6	91.2	92.7	90.9	92.0	92.0
Aquaculture								
Inland	38.6	42.0	44.8	46.9	48.6	51.4	50.9	52.3
Marine	23.2	24.4	25.4	26.8	27.5	28.7	28.8	29.1
Total aquaculture	61.8	66.4	70.2	73.7	76.1	80.0	79.7	81.4
Total world seafood (fisheries and aquaculture)	**154.0**	**156.0**	**160.7**	**164.9**	**168.7**	**170.9**	**171.7**	**173.4**
Utilization[b]								
Man consumption	130.0	136.4	140.1	144.8	148.4	151.2	153.2	155.2
Non-food usage	24.0	19.6	20.6	20.0	20.3	19.7	18.5	18.2
World population (*billions*)[c]	7.0	7.1	7.2	7.3	7.3	7.4	7.5	7.6
Apparent consumption per capita (*kg*)	18.5	19.2	19.5	19.9	20.2	20.3	20.4	20.4

[a]Excludes aquatic mammals, crocodiles, alligators and caimans, seaweeds and other aquatic plants.
[b]Utilization data for 2014–2016 are provisional estimates.

Source: *data.worldbank.org, FAO 2018, and own calculations based on FAO 2018 and World Bank data*

The information in Table 7 showed the average global seafood production from 2011 to 2018, as well as the consumption per capita with respect to the world population. World fish production, consumption and trade are estimated to increase, but with a growth rate that will reduce over time.

Capture: World total marine catch was 79.0 million tons in 2018, 79.2 million tons in 2017, and 79.3 million tons in 2016, representing a consistent decrease of almost 2 million tons from the 81.2 million tons in 2015. Capture fishery are all kinds of harvesting of the naturally occurring living resources in both marine and freshwater environments (FAO, 2018). Capture fisheries can be generally classified as recreational, small-scale (or artisanal), and industrial scale. Catches of anchoveta by Chile and Peru, which are regularly sizeable yet highly variable due to the El Niño influence, contributed to 1.1 million tons of this decline, with other major nations and species, mostly cephalopods, also showing decreased catches between 2015 and 2016 (FAO, 2018). Total marine catch by China, the world's top producer by far and significant margin, were stable in 2016, and marginally reduced in 2017 and 2018 because of the progressive catch reduction policy inclusion in the Chinese Thirteenth Five-Year Plan, from 2016 to 2020 (FAO, 2018) which is estimated to result in substantial decreases in the subsequent years. Capture fisheries is a linking system that connects fish and the marine environment – be it a lake, the sea, or a river – with humans, as the fish are captured, sold, processed, and consumed (FAO, 2018). The world supply of shrimp would shrink by 15% in the year of a sudden outbreak. Though, with the simulated recovery, the estimated impact of a sudden outbreak of disease on the world aquaculture is negative and negligible by 2030 (World Bank, 2013). In 2014, Alaska pollock once again beat anchoveta as top species in 2016, and the highest in this current decade. On the other hand, 2017 preliminary data indicated a significant recovery of catches of anchoveta. Skipjack tuna ranked the third for seventh consecutive year. Combined catches of tuna and species like tuna levelled off at about 7.5 million tons after an all-time highest in 2014 (FAO, 2018). After five years of incessant and continuous growth that began in 2010, cephalopods catches were stable in 2015 but fell in 2016 when catches of three major species of squid indicated combined loss of 1.2 million tons. Capture production of other groups mollusc began declining much earlier – clams in the late 1980s, oysters in the early 1980s, scallops since 2012, and mussels in the early 1990s (World Bank, 2013). In contrast, the most valuable groups of species with significant production – gastropods, crabs and lobsters – marked a new record of catch in 2016 (FAO, 2018).

The recent declines in the Southwest Atlantic catches and the Southwest Pacific catches were the consequence of greatly decreased catches by distant-water fishing countries. In contrast to the temperate regions, and the upwelling regions which are characterized by high yearly variability in catches, tropical regions have experienced a continuously and unceasingly trend in rising of production as large catches (mainly tuna) and catches of small species of pelagic continue to increase (FAO, 2018; World Bank, 2013; Aguilar-Manjarrez *et al.*, 2017). The Northwest Pacific maintains the most productive area of fishing, with catches in 2016 at 22.4 million tons, slightly higher than in the previous year, 2015, and 7.7% above the average for a decade; 2005 to 2014 (FAO, 2018; Aguilar-Manjarrez *et al.*, 2017). All other temperate regions have revealed decreasing trends for many years, with the solitary exception of Northeast Pacific, where, in 2016, catches were found higher than the average within 2005 to 2014, thanks to good catches of north Pacific hake, Alaska pollock, and Pacific cod (FAO, 2018).

Capture fisheries in the global inland waters made 11.6 million tons in 2016, which represented 12.8% of total inland and marine catches (FAO, 2018; Aguilar-Manjarrez *et al.*, 2017). The global catch from inland waters in 2016 showed an increase of 2.0% over the previous year and 10.5% in comparison to the 2005 to 2014 average (Aguilar-Manjarrez *et al.*, 2017), but this end result may be ambiguous as several of the increase could be attributed to improved and sophisticated data collection, processing, and assessment at the national level. Sixteen nations produced nearly 80% of the inland catches, mainly in Asia, where inland catches offer a key source of food for many local communities and individuals. Inland catches are also a vital source of food for many African countries, which accounts for 25% of global inland catches (FAO, 2018).

Aquaculture: From Table 1, it can be seen that world aquaculture production in 2016 stood at 80.0 million tons of food fish, gradually declined by 0.3 million tons to 79.7 million tons in 2017, and rose to 81.4 million tons in 2018. Global aquaculture production maintained relatively steady increase from 2011 to 2018. Farmed food fish production included 7.9 million tons of crustaceans, 17.1 million tons of molluscs, 54.1 million tons of finfish, and 938 500 tons of other marine animals. Aquaculture, commonly spelled aquiculture (Garner, 2016), also known as aquafarming, is the farming of algae, fish, molluscs, aquatic plants, crustaceans and other marine organisms. Aquaculture involves cultivating saltwater and freshwater populations under controlled and meticulous conditions and environments, and can be distinguished from commercial fishing, which involves the harvesting of fish from the wild. Mariculture refers to the aquaculture practiced and done in underwater habitats and in marine environments. According to the UN FAO, aquaculture means the farming (cultivation) of aquatic organisms including fish, aquatic plants, molluscs, and crustaceans. China, by far the main producer of farmed (cultivated) food fish in 2016, has continuously produced more than combination of the rest of the world every year ever since 1991. In 2016, the other main producers were India, Vietnam, Norway, Bangladesh, Indonesia, and Egypt. Farmed aquatic plants include mostly seaweeds and a very smaller volume of production of microalgae (FAO, 2018; Aguilar-Manjarrez *et al.*, 2017). By far, China and Indonesia were, as expected, the main producers of aquatic plants in the year 2016. According to the FAO, aquaculture (aquiculture) harvest keeps growing increasingly than other major sectors of food production, though it does not enjoy the high rates of annual growth of the 1980s and 1990s anymore; 11.3% and 10.0% respectively, excluding aquatic plants (FAO, 2018). Average annual growth decreased to 5.8% during the period 2000 to 2016, though double-digit growth still happened in a few individual nations, Africa in particular from 2006 to 2010.

Farming of fed species of marine animal has grown quicker than that of unfed species, though the volume of the latter keeps expanding. The total unfed species production in 2016 climbed to 24.4 million tons (30% of total farmed fish for food), consisting of 8.8 million tons of filter feeding finfish grown in inland aquaculture (mostly bighead carp and silver carp) and 15.6 million tons of marine invertebrates, majorly marine bivalve molluscs cultivated in seas, coastal ponds, and lagoons (FAO, 2018; Aguilar-Manjarrez *et al.*, 2017). Seaweeds and marine bivalves are occasionally described as extractive species; they can have benefits on the environment by the removal of waste materials, including waste materials from fed species, as well as lowering the load of nutrient in the water. The culturing of extractive species and fed species in the same sites of mariculture is encouraged in the aquaculture development (World Bank, 2013). Production of extractive species accounted for 49.5% of total global aquaculture production in 2016 (FAO, 2018; Aguilar-Manjarrez *et al.*, 2017).

Based on the UN FAO's monitoring of assessed aquatic fish stocks, the state of marine fisheries resources has continued to decline. The percentage of marine (oceanic) fish stocks fished and harvested within biological sustainable levels has shown a declining trend, from 90.0% in 1974 to 66.9% in 2015 (Aguilar-Manjarrez *et al.*, 2017), and still declining gradually. In contrast, the percentage of fish stocks fished at biological unsustainable levels increased from 10% in 1974 to 33.1% in 2015, with the largest increases recorded in the late 1970s and 1980s (FAO, 2018). In 2015, amongst the 16 major statistical zones, the Mediterranean Sea and Black Sea, Southwest Atlantic and Southeast Pacific had the maximum percentages of assessed stocks fished at levels that are unsustainable, while the Northwest Pacific, Eastern Central Pacific, Southwest Pacific, Northeast Pacific, and Western Central Pacific had the lowest. An estimated 43% of stocks of the major market species of tuna were fished at biological unsustainable levels in 2015, whereas 57% were fished in biologically sustainable levels (FAO, 2018; Aguilar-Manjarrez *et al.*, 2017; World Bank, 2013).

Over 89.5% of the total production of fish in 2018 was used for direct consumption by humans. Of the 171 million tons of total production of fish in 2016, about 88% (over 151 million tons) was utilized for direct consumption by humans. A share that has increased substantially in current decades. The utmost part of the 12% used for non-food purposes (around 20 million tons) was reduced to fish oil and fishmeal (FAO, 2018). Live, chilled or fresh is often the major highly priced and preferred form of fish and is a representative of the largest fish share for direct consumption by humans standing at 45% in 2016, seconded by frozen at 31 percent (FAO, 2018). Despite the improvements in the practices of processing and distribution of fish, wastage or loss between landing and consumption continue to account for an estimated 27% of landed fish (Aguilar-Manjarrez *et al.*, 2017). China remains the leading fish producer and since 2002 China has also been the major exporter of fish and products of fish, even though the fast growths of the 1990s and 2000s have subsequently slowed (FAO, 2018). After China, Norway, Viet Nam and Thailand were the major exporters in 2016. The EU represented the biggest single market for fish/fish products, followed by the USA and Japan; these three markets jointly accounted for approximately 64% of the total value of global fish imports and fish products (FAO, 2018). During 2016 and 2017, fish imports increased in all the three markets due to strengthened economic fundamentals.

3.2. Plastic wastes

3.2.1. World plastic production

In 1950s, the world produced only 2 million tons every year. Since then, production per annum has increased approximately 200-fold, increasing to more than 380 million tons in 2018. For context, this is approximately equivalent to mass of two-thirds of the population of the world (Hannah and Max, 2019). The short downturn in production per annum in 2009 and 2010 was mostly a consequence of the global financial crisis in 2008 – this dent is seen across many metrics of resource production and consumption, including energy.

Table 8: World plastic production in million tons

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018
Global plastic production	313	325	338	352	367	381	380	380	380

Cumulative Production (1950 - 2015) is over 7.82 Billion Tonnes
(Hannah and Max, 2019)

Table 8 shows the world production of plastic from 2010 to 2018. A continues increase can be observed within the 2010 to 2018. Figure 4.1 shows the cumulative world plastic production from 1950 – 2015 which stood at 7.82 billion tons. Though in 2018, the Economist maintained that from the 1950s up to 2018, estimated 6.3 billion tons of plastics have been produced worldwide. Whatsoever the exact estimated amounts may be, the fact still remains that the world witnessed and still witnessing a high increase in the production of plastics to date.

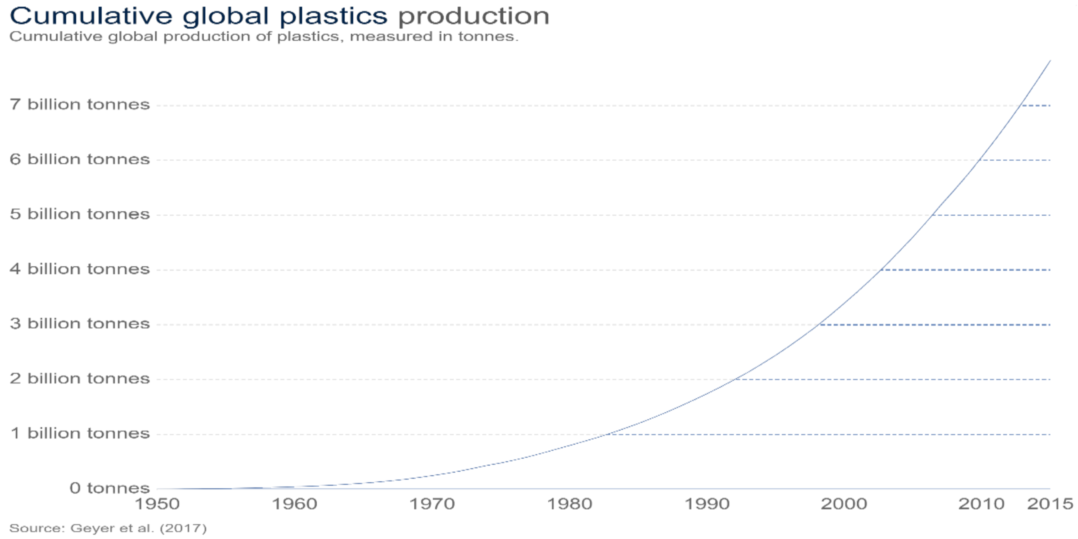


Figure 3: Cumulative world plastic production from 1950 - 2015

Plastic pollution is the accumulation and buildup of plastic objects (e.g.: plastic bottles, bags, and much more) in the Earth's environment which adversely affects humans, wildlife, and wildlife habitat (Laura, 2018). As of 2018, approximately 380 million tons of plastic is produced globally every year. From the 1950s up to 2018, about 7.5 billion tons of plastic has been produced globally, of which an estimated 9 percent has been recycled and another 12 percent incinerated (The Economist, 2018). In the United Kingdom alone, more than 5 million tons of plastic are expended per annum, of which only an estimation of one-quarter is recycled, and the remainder disposed in landfills. These large quantities of plastic waste invariably enter the environment. Studies suggested that the bodies of 90 percent of seabirds contain plastic debris (Nomadic, 2016; Mathieu-Denoncourt *et al.*, 2014). In some areas there are substantial efforts to reduce the prevalence plastic pollution, via reducing consumption of plastics and promoting plastic recycling (Walker and Xanthos, 2018). By 2050 there may be more plastics than fish in the world oceans on weight/weight basis (Sutter, 2016) and possibly by number. If this present trends continue till 2100, the world stands risk of fish crisis and substantial seafood decline.

3.2.2. Plastic waste generation

Table 9 and Figure 4 (a) and (b) show the mean annual primary plastics production (and usage) and waste generation by industries (in million tons). Packaging was the main use of primary plastics, with 42% of plastics entering usage phase. The second largest sector was building and construction which utilize 19% of the total. The production of primary plastic does not directly reflect the generation of plastic waste, as this is as well influenced by the type of polymer and the end product lifetime (Geyer *et al.*, 2017). The generation of plastic was strongly and hugely influenced by the use of primary plastic, and also the lifetime of the product. Packaging, for instance, has a very short lifetime of 'in-use' (normally not more than 6 months). This is contrast to building and construction, where the use of plastic has an average lifetime of 35years (Geyer *et al.*, 2017). Packaging is thus the dominant plastic waste generator, accountable for nearly half of the world total. The production of primary plastics was 407 million tons in 2015; around three-quarters (302 million tons) ended up as waste.

Table 9: Mean annual primary plastics production (usage) and waste generation by industries (in million tonnes)

Industrial sector	Annual primary plastics production	Annual plastics waste generation
Packaging	146	141
Building and construction	65	13
Textile	47	38
Consumer & Institutional Products	42	37
Transportation	27	17
Electrical/Electronic	18	13
Industrial Machinery	3	1
Other sectors	32	42

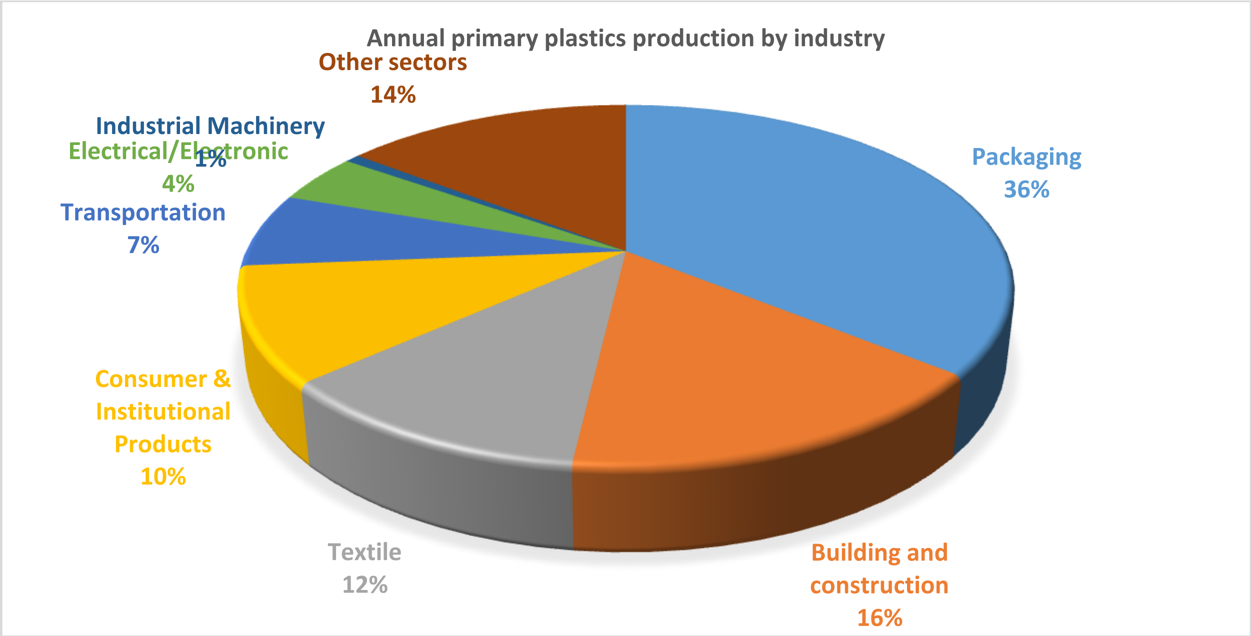


Figure 4 (a): Mean annual primary plastics production by industry

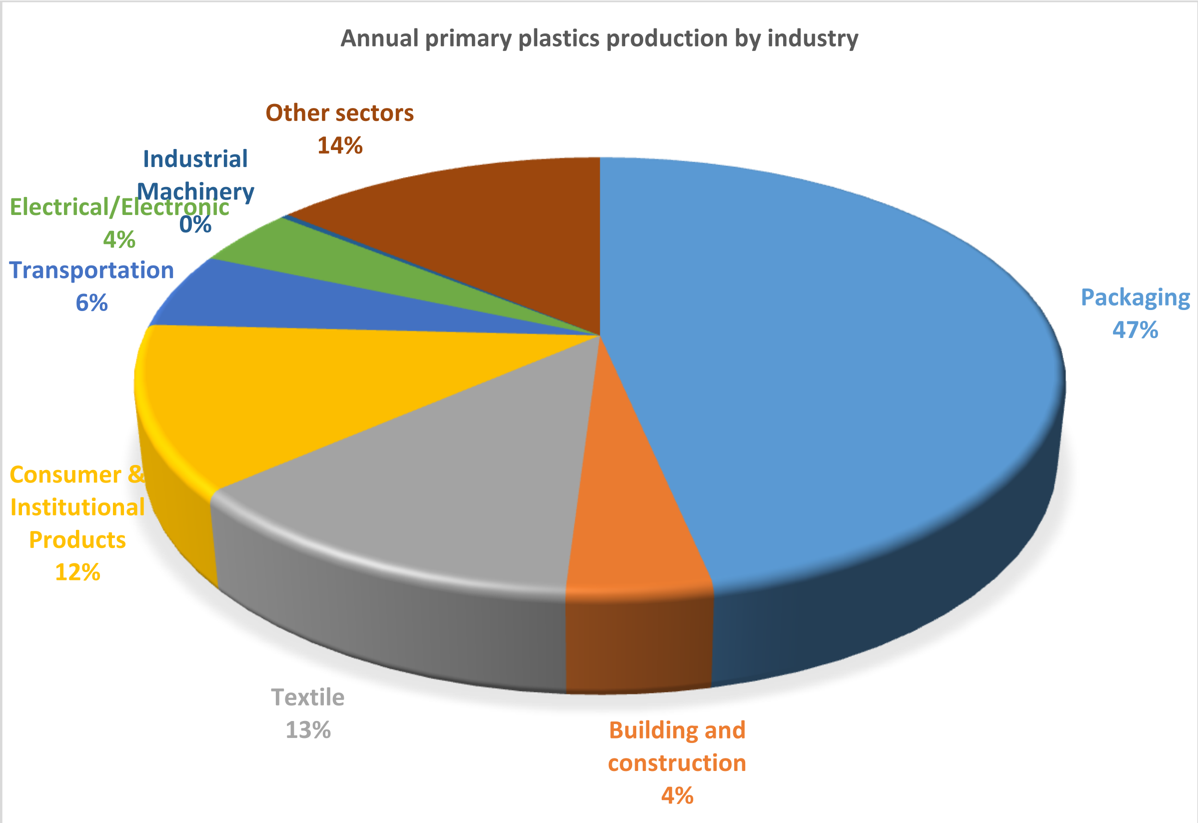


Figure 4 (b): Mean annual primary plastics production by industry by industry

3.3. Impacts of plastic wastes on seafood sustainability and human health

3.3.1. Sources of plastic wastes in oceans, seas, lakes

Plastics in the world oceans can arise from marine or land-based sources. Plastics pollutions and contaminations from marine sources refer to the pollution caused and generated by fishing fleets which leave behind fishing nets, abandoned vessels sometimes, lines, and ropes. There is often intense debate and discussion on the relative significance of land and marine sources for the pollution of ocean. At the global level, estimates suggest that roughly 80% of plastics in oceans come from land-based sources, while the remaining 20% from marine sources (Li *et al.*, 2016). Of the 20% from marine sources, it's projected that around10% arise from fishing fleets (such as abandoned vessels, nets, and lines). This is supported by the figures from the UNEP (United Nations Environment Programme) which suggests abandoned, discarded, or lost fishing gear contributes roughly10% to total ocean plastics (UNEP & FAO, 2009). Other estimates apportion a slightly higher marine sources contribution, at 28% of total ocean plastics (Lebreton *et al.*, 2018).

We use more plastic than ever used before; perhaps because it is durable, cheap to produce, and affordable, and we consume it at overwhelming rates. Presently, not less than 8 million pieces of plastics enter the oceans every day. Two-thirds of it comes directly from land-based sources: litter washed down rivers or left on the beach and drains from the litter being dropped in cities and towns. It comes from badly managed landfill sites, industrial spillage, and bins near the coast. Also, it can come by flushing down the loo. The rest is lost fishing gear or lost at sea such as container going overboard.

Although not certain, it is very likely marine sources contribute between 20 to 30% of plastics in the ocean, but the leading source remains land-based sources at 70 to 80%. While this represents the relative contribution as summative of global plastics in the ocean, the relative contributions of various sources vary depending on geographic location and context. For instance, it's estimated that plastic lines, fishing nets, and ropes comprise 52% of the plastic mass in the GPGP (Great Pacific Garbage Patch) and comprises 46% of the components of mega plastics of the Great Pacific Garbage Patch (Lebreton *et al.*, 2018). The relative marine sources contribution here is likely to be due to intensified fishing activities in the Pacific Ocean.

3.3.2. The impacts of plastic wastes on seafood sustainability

Plastic pollution can afflict oceans, land, and waterways. It is estimated that about 1.1 to 8.8 million metric tons of plastic waste enters the world ocean from coastal communities every year (Jambeck *et al.*, 2015). Living organisms, mostly marine animals, can be injured either by the mechanical effects, such as the entanglement in plastic objects and problems related to the ingestion of plastic wastes, or via exposure to chemicals in plastics that interfere with their body physiology. Also, humans are affected by plastic pollution, by disruption of various hormonal mechanisms, etc. The mainstream plastic wastes accumulations in the environment have adversely affected both terrestrial and aquatic wildlife and wildlife habitat (habitation); with humans utterly affected by the growing rate of plastic pollution. As less than 10 percent of plastic wastes are recycled, the population of the world is exposed to the dangers of plastic pollution. Recently, products of plastic waste are seen on every seashore, deep water, lakes, and rivers around the globe, from community lakes straight to busy tourist beaches, then to uninhabited, tropical islands nowhere appears to be safe. Polymeric wastes such as plastic bottles may last more than 500 years in the marine environments, gradually but steadily disintegrating and decomposing into lesser and smaller pieces that in the long run result in miniscule and microscopic fragments but never actually leave the aquatic environment. Aquatic and terrestrial organisms are affected by the plastic pollution by the exposure to chemical substances in plastics which interfere with their metabolism and physiology. Also, humans are affected through the interruption and disruption of various hormonal mechanisms. In various areas, significant efforts are in place to reduce the pervasiveness of plastic pollution, through the reduction of plastic consumption rate and promotion of plastic recycling (Walker and Xanthos, 2018). Since the 1950s, it was statistically estimated that more than 6.3 billion tons of plastics have been produced, and less than 10% recycled. This large quantity of plastic waste undoubtedly enters the environment; studies suggested that the bodies of 90 percent of sea birds contain plastic debris (Mathieu-Denoncourt *et al*., 2014). More than 380 million tons of plastics are produced every year. Less 10 percent of this plastics produced every year are recycled. Others end up as plastic waste, and enter into the environment.

More than 5 trillion pieces and fragments of plastic wastes are distributed in the world oceans worldwide. A pilot whale was found almost dead in June 2018, and later died, in a water canal at Southern Thailand close to the border with Malaysia after it swallowed more than 80 pieces of plastic bags which weighed up to 3Ib (1.36 kg). Experts suggested that the plastic bags may have prevented and stopped the whales from eating. If the plastic pollution problem is not solved, by 2050, there possibly will be more plastic wastes in the world oceans, rivers, lakes, etc. than fishes and other aquatic organisms; this puts the sustainability of seafood value chain in threat.

Plastic pollution has the potency to poison animals, including fish and other seafood, which may then adversely affect human supplies of food (Daniel, 2004). Plastic pollution has been shown to be highly detrimental to large aquatic mammals, as written in the lone book *Introduction to Marine Biology* as constituting the "single greatest threat" to marine mammals (Karleskint *et al.*, 2009). Some aquatic species, such as sea turtles, are found to contain large quantities of plastics in their stomach (Daniel, 2004). When this occurs, it leads to the starvation of the animal, as the plastic blocks its digestive tract (Daniel, 2004). Sometimes aquatic mammals are entangled in plastic products like nets, which can kill or harm them (Daniel, 2004). For aquatic wildlife such as seals, fishes, dolphins, and seabirds it can be very deadly as they mistake plastics for food or get entangled by it. Images coming from the Midway Atoll illustrated this problem to stunning effect when a photographer called Chris Jordan captured remains of albatross, stomachs filled with pieces of plastics because they accidentally consumed a meal from discarded waste. Currently, a Cuvier's beaked whale was seen malnourished and dying at the coast of Norway. Many experts had to put down the animal as it was in such a poor condition and autopsy showed a startling 30 plastic bags and a large quantity of plastic packaging with their labels in English and Danish in its intestines and stomach, causing pain and blockages of the gastrointestinal tract.

There are three main pathways by which plastic debris always affect wildlife; entanglement, ingestion, interaction.

3.3.2.1. Entanglement of aquatic animals

Entanglement in plastic debris is responsible for the deaths (both reported and unreported) of many aquatic organisms, such as fish, seals, and turtles, as well as birds. These marine animals get caught up in the plastic debris and end up suffocating/drowning. As they are not able to untangle themselves, they die from starvation or from their incapacity to escape their predators (Hammer *et al.*, 2012). Being entangled often results in severe ulcers and lacerations. In a 2006 report termed *Plastic Debris in the World's Oceans* (Greenpeace International, 2018), it was estimated that over 267 different species of animals have suffered entanglement and plastic debris ingestion. It was estimated and reported that at least 400,000 aquatic mammals perish annually as a result of plastic pollution in oceans (Daniel, 2004). Marine organisms get caught up in discarded fishing equipment, like ghost nets. Nets and ropes used for fishing are usually made of polymers and synthetic materials such as nylon, which increases the buoyancy and durability of fishing equipment. Also, these marine organisms can get trapped in circular plastic packaging materials. If the aquatic animal continues to grow in its size, the plastic packaging material can cut into their flesh, inflicting severe injury and even death. Equipment such as nets and ropes can drag along the seabed, and cause damage to coral reefs (Gregory, 2009).

3.3.2.2. Interaction

Interaction includes the contact with plastic debris (with exclusion of entanglement) including abrasions, use as substrate, collisions, and obstructions. There are multiple circumstances where this may have deleterious impacts on marine organisms. Fishing gear, for instance, has been shown to cause damage and abrasion to coral reef ecosystems through collision. The structures of ecosystem can be affected by plastics following the interference of plastics with substrate (impacting on organic matter availability, light penetration, and oxygen exchange).

3.3.2.3. Ingestion

Many marine animals, especially Sea turtles, are affected by the pollution caused by plastics. Some species are jelly fish consumers, but regularly mistake plastic bags for their natural prey, jelly fish. This plastic debris may kill the sea turtle by the obstruction of its oesophagus (Gregory, 2009). Baby sea turtles are most vulnerable as stated in a 2018 study done by Australian scientists (Gabbatiss, 2018).

So are whales too. Large quantities of plastic wastes have been found in stomachs of beached whales (Gregory, 2009). Since the 1970s, plastic debris began to appear in the sperm whale's stomach, and has been known to be one of the leading causes of death of many whales (Chua *et al.*, 2019). In June 2018, over 80 plastic bags were found in the stomach of a dying pilot whale that washed up on Thailand shores (The Guardian, 2018). In March 2019, the remains of a Cuvier beaked whale washed up in Philippines with 88 lbs of plastic pieces in its stomach (BBC, 2019). In April 2019, following a discovery of a dead sperm whale off the Sardinia with over 48 lbs of plastic in its stomach, an organization called the World Wildlife Foundation (WWF) warned that plastic pollution is one of the utmost dangerous threats to marine life, noting that over five whales have been reported killed by plastic over a period of two year (Barry, 2019).

Some of the tiniest particles and bits of plastic debris are being ingested by small fish, in part of the ocean's pelagic zone known as the *Mesopelagic zone*, that is 200 m to 1000 m below the surface of the ocean, and totally dark. Much is not known about these fish, except that there are several of them. They hide in the dark part of the ocean, dodging predators and then swimming back to the surface of the ocean at night to feed (Parker, 2014). Plastic wastes found in these fish stomachs were collected during the course of *Malaspina's circumnavigation*, a research plan that studies the global change impact on the oceans (Fernandez-Armesto, 2006).

A research conducted by Scripps Institution of Oceanography indicated that the average content of plastics in 141 mesopelagic fish stomachs (27 different species) was 9.2%. Their estimation for the rate of ingestion of plastic wastes by these fishes in the North Pacific stood between 12000 and 24000 tonnes per year (Carson *et al.*, 2011). The lantern fish is the most common mesopelagic fish. It lives in the central ocean gyres, a great system of rotational ocean currents. As lantern fish aid as a primary source of food for the fish that consumers buy, including swordfish and tuna, the plastics they swallow enter the food chain. Lantern fish is one of the major ocean based bait fish, and it ingests large quantities of plastic debris, which in turn makes them not nutritious enough for other fish to eat (Moore, 2014).Deep sea animal species have been found with quantities of plastics in their stomachs (Taylor, 2017).

4. Conclusion

Plastic pollution has continued to be one of the problems at the center of the challenges afflicting the world status quo. More than estimated eighty million tons of plastic related wastes are released into the sea annually. World total marine catch was 79.0 million tonnes in 2018, 79.2 million tonnes in 2017, and 79.3 million tonnes in 2016, representing a consistent decrease of almost 2 million tonnes from the 81.2 million tonnes in 2015. World aquaculture production in 2016 stood at 80.0 million tonnes of food fish, gradually declined by 0.3 million tonnes to 79.7 million tonnes in 2017, and rose to 81.4 million tonnes in 2018. While global aquaculture production maintained relatively steady increase from 2011 to 2018, marine catch have slightly declined over the years. Some of the factors that may have contributed to this decline in marine capture are the increasing rate of plastic wastes in the marine, overfishing, among others. Annual production of plastic has increased nearly 200-fold, reaching more than 380 million tonnes in 2018. Plastic waste generation has increased. Plastic in our oceans can arise from land-based or marine sources. At the global level, best estimates suggest that roughly 80 percent of ocean plastics come from land-based sources, and the remaining 20 percent from marine sources. Nearly 8.8 million metric tonnes of plastic waste enters the ocean from coastal communities each year. As at today, more than 5 trillion pieces of plastic wastes are distributed in world oceans globally. If the problem of plastic pollution is not solve, by 2050, there will be more plastic wastes in global rivers, lakes, oceans, etc. than fishes; this puts the sustainability of seafood value chain in jeopardy. If this present trends continue till 2100, the world stands risk of fish crisis and substantial seafood decline. Plastic pollution has the can poison animals, including seafood, which can then adversely affect the supplies of human food. Plastic pollution has been labelled as being highly detrimental to seafood. Three key pathways by which plastic debris can affect wildlife are by entanglement, ingestion, and interaction. Over 400,000 marine mammals die each year due to plastic pollution in oceans.

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