SEASCRAPER:
Reclaiming the Plastic Vortex Through Oceanic Stewardship and Inhabitation

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

Decades of humans carelessly tampering with the delicate ocean ecosystems are pushing wildlife to their breaking points, with an entire ecosystem collapse inching closer every day. My thesis will explore the known extent of plastic debris currently in the North Pacific Ocean; the successes and shortcomings of a variety of existing aquatic architectural precedents; finally, culminating in a theoretical prototype design for a semi-autonomous, ocean-based recycling facility.

How can an ocean-based architecture be used to develop a successful intervention to the millions of tons of plastic debris that are dumped into the oceans each year? This research will investigate the requirements of planning and building a self-sustaining, water-based recycling structure, but also offer a deeper understanding of how to overcome the challenges of building in such a harsh environment.

Using a range of interdisciplinary books, scientific journals and articles, websites and documents, an exploration will be conducted to achieve a full understanding of the requirements of the design. The design of the vessel itself is informed by factoring both the environmental issues of extended exposure in a harsh environment and the performance requirements of its primary objective. Since this vessel will be isolated from most human communities it must also be capable of functioning autonomously for extended periods of time. The results of the design explorations will be represented through a series of written texts, architectural drawings, and diagrams. The key impacts of my research will be not only to provide a possible solution to the growing waste plastic problem, but also to provide a prototype for the development of future ocean-based arcologies.

Acknowledgments

I would like to thank my supervisor, Val Rynnimeri, for all his guidance and support, Mohamad Araji, for his insight, and to my reader, John McMinn for his agreeing to examine my thesis.

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Photograph retrieved from: https://www.soest.hawaii.edu/UMC/cms/KiloMoana.php

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Fig. 1.1 Thesis Inspiration: Ocean Wildlife Swimming in Clear Water

Introduction

Introduction

Humans have a longstanding, complex, and often abusive relationship with the ocean. As terrestrial beings our sense of place is deeply ingrained with our surroundings; key landmarks and urban artifacts allow for a spatial understanding of one's place in the world. The ocean, however, is a featureless plane, that endlessly reaches past the horizon. The harsh and unforgiving nature of the ocean restricts the opportunities for human interaction and as a result it is often treated as a hostile alien environment. Oceanic expeditions, for example, are temporary endeavours across an endless expanse, which reach into the deep waters and extract as much as possible before retreating to the familiarity of the shore.

Decades of mistreatment has rendered a perspective of the ocean as "the other," a place for waste to accumulate without consequence. Over the course of the last 70 years humanity has made significant changes to the surface of the planet, but the impacts of one of the most widespread and near-permanent changes occur in the ocean and are obscured from view. The harsh, inhospitableness of the ocean restricts research expedition capabilities to a mere collection of snapshots in time. Therefore, rather than being able to weave a complex tapestry of knowledge, the resultant information is more akin to a net - a strong framework with many voids. Countries only claim responsibility for a portion of the ocean away from their borders, but who is responsible for the deep oceans? Who is responsible for the decades of human tampering with this fragile ecosystem that have primarily gone unnoticed or deliberately ignored?

The ocean is the single largest habitat on the planet and its inhabitants are too numerous to count, yet it remains a mostly unknown environment. The planetary scale of the ocean is far too vast for individuals to comprehend and prohibits the development of an empathetic connection. Consequently, the ocean remains a mysterious blue portal where valuable resources are removed, only to be replaced by refuse. The technological leaps of the industrial revolution have further removed the element of human interaction and have exponentially increased the quantity of resources withdrawn and the resultant waste deposited. This systematic science of extraction is an unnatural and unsustainable practice that will ultimately unbalance all ecosystems to the point of total annihilation.

The ocean is a living, breathing entity that is, at best, apathetic to the aspirations of humans. At its worst it is unpredictable as sudden changes on the ocean floor can develop into a dramatic causal reaction on the water's surface. In recent years there has been an increase in the number of storms, tidal surges, and the water levels further compounding the environment's hostility.

An environment's capability to sustain human civilisation comfortably dictates the civilisation's level of autonomy. If the territory is harsh, and unsustainable, the local community must make itself invaluable to surrounding communities so that it can be supported. Conversely, a perfected form of a civilisation is an arcology, a completely independent city that is reliant only on itself. However, this is an achievement that is currently only attainable in science fiction. Human societies have become a series of global communities and as a result, we have embedded dependencies and responsibilities to each other. Even the most seemingly isolated community, that of the International Space Station (ISS), is entirely dependent on supplies sent from Earth. Although this proposed ocean community is seemingly as isolated as the ISS it is also dependant on its connection to land-based communities. This dependency is appropriate since it is the land-based community that is the cause of this issue at hand.

Since there are no existing large-scale open-ocean recycling facilities in existence today, the design precedents for the structure proposed in this thesis come from a variety of structures, vehicles, and aquatic organisms. Key influential objects have been research vessels, oil rigs, and the streamlined forms of various ocean-dwelling creatures.

There must be an immediate correction to the path that humanity is on if we wish to continue to prosper. An intervention in the form of a structure capable of ocean plastic collection and removal can be a pivotal step taken towards the rejuvenation of the ocean's wildlife. Also, these self-propelled ocean structures can become much more than a vehicle to transport goods and people across the water. They have the capacity to become a uniquely crafted world; a micro-polis, that can sustain its occupants, but also provide comfort and social interaction in an otherwise hostile environment. Ocean-based architecture is a highly specialized form of design that has an entirely different set of problems to tackle compared to a typical terrestrial-based design. Even the chemical makeup of the water includes a high amount of sodium chloride which is highly corrosive to traditional terrestrial building assemblies; therefore, special precautions must be acknowledged in the selection of the materials. Consequently, the unique circumstances and environmental restrictions coupled with the highly demanding nature of an ocean-based recycling facility will result in a unique design solution.

Thesis Scope

The ocean is a global resource without a governing authority that communicates the consequences our actions have on the environment. For nearly a century, the collective negligence of our global society has caused the ever-increasing environmental plastic contamination to fester. How can we correct decades of environmental mismanagement?

To ensure that the ocean remains available to be used as a sustainable resource there is a fundamental need to alter our damaging interactions with it for the consideration of future generations. However, presently, swift reparations must be achieved through the creation of highly specialized equipment. This thesis will focus on the design of an experimental recycling structure that follows the circulation patterns of the Pacific Ocean and will become a medium for the present and continued action against the accumulation of plastic debris.

The terrestrial-based waste systems are clearly not capable of dealing with the prevention of plastic waste entering the ocean. There is a need for an on-site presence to remediate this growing plastic cancer. Since the biofouling of plastics in marine environments causes them to resist photodegradation, further increasing the plastic component's perpetuity, this issue will not dissipate on its own.[1] This biological agent must be separated from the plastic before it can be properly disposed of, and most recycling facilities are not equipped for this specialized task. Constructing an

1 Andrady, Anthony L. "Microplastics in the Marine Environment." Marine Pollution Bulletin 62, no. 8 (2011): 1596–1605. https://doi.org/10.1016/j.marpolbul.2011.05.030. 1599

ocean-based, dedicated recycling facility that specializes in cleaning, sorting, and properly disposing of collected marine debris is the best way to combat decades of neglect.

The vessel is designed as a hub for human activity on the water while it also functions as a recycling facility capable of operating under these unconventional conditions. It also provides a wealth of opportunities for the residents to fully engage with each other as one of the first ocean-dwelling communities. Moreover, the perpetual nature of this remediation project provides the opportunity to host interdisciplinary studies which monitor the increasingly worrisome condition of the ocean ecologies. Thusly, this architectural presence focuses on its primary objective of collecting and recycling plastic debris while emphasizing its areas for community living and ocean research.

This thesis is comprised of multiple sections. The first chapter explores the ocean: what it is comprised of, the factors that influence its behaviours, and how life thrives there. The second chapter outlines the emergence of plastic and the consequences of improper disposal. The third chapter investigates the intersection of architecture and water, evaluating its successes and shortcomings. The fourth chapter reflects on the feasibility of adapting various existing and theoretical technologies and designs that could be applied in the design of this thesis. Finally, the fifth section is an investigation of architectural values through explorations of community spaces and includes a series of drawings of the design of this prototype vessel. I stand by my theories since the design inspirations have been drawn from precedents that are tested and proven in real-world conditions.

The designed vessel functions as a base of operations for the remediation of plastics in the greater North Pacific Ocean. The harsh, churning sea imposes many requirements onto the design of the structure. First, it must be mobile; being able to relocate itself is critical to its daily functions as well as being able to avoid extreme weather conditions. Secondly, the vessel must be able to deploy, interact with, and return manned boats to collect surface plastics and perform scientific expeditions. Finally, the vessel must provide a comfortable environment for the on-board crew who will be stationed there for extended periods of time. The newly designed vessel is an entirely artificial environment designed for the stewardship and inhabitation of the ocean.

The ideas outlined in this thesis are not meant to be a pure technological solution to this problem. This thesis is borne out of a desire to incite a change in a social mindset of disregard towards the ocean. A seemingly Sisyphean task, this out-of-sight, out-of-mind mentality of waste disposal is an injustice that needs to be corrected while there is still a chance. The creation of an ocean-based recycling facility begins to erode the idea of the ocean as “the other.” A place for waste no longer, the ocean is a single living ecosystem, for which these designs address the consequences of our negligent actions. As this is a highly unnatural problem derived from human action, it requires human intervention to correct. I believe that my research for this thesis can act as the initial step towards a successful future relationship with the sea. Working from existing data sets and distilling the information into highly compact visualizations will assist in presenting this complex information in a concise format.

01

Chapter 1
The Ocean

Ocean

Water

Wind

Currents

Light

Biosphere

Ocean

From afar it is plain to see that our planet, Earth, is clearly misnamed. The Earth is primarily a marine planet which is a well-known fact that is often disregarded as land is given more inherent value. Meanwhile, the ocean has been the catalyst that began the transformation from a tempestuous molten earth into the lush, active world that it is now. The ocean is the main influencing factor of all life; it covers around 70% of the world's surface with the average depth at approximately 3,700m.[2,3] The clearly visible histories of rugged mountain peaks, lush forests and even the rolling plains are in stark contrast to the impenetrable, continuous membrane of water. Shrouding everything beneath, only a small portion of what lays below the surface has been properly explored and recorded.

Try as they might, no individual nation has any rightful claim to attempt to control the ocean and it is exactly this lack of ownership that reinforces the carelessness with which the global community treats it. There have been quarrels over swathes of land since time immemorial. Clear boundary lines have been drawn, and wars have been waged to dispute or expand upon these boundaries all in the name of more, that is, more land, more riches, more power. However, the world's nations have been mostly restricted to their homelands as maritime vessels of the bygone eras have been unable to survive extended periods against the ruthless churning of the waves. Unable to obtain a stable foothold over the ocean

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2 Byrne, R. Howard,; Mackenzie, Fred T.; and Duxbury, Alyn C. "Seawater." Encyclopaedia Britannica, November 5, 2020. https://www.britannica.com/science/seawater.

3 US Department of Commerce, National Oceanic and Atmospheric Administration. "How Deep Is the Ocean?" NOAA's National Ocean Service, June 1, 2013. https://oceanservice.noaa.gov/facts/oceandepth.html.

realm, many coastal nations have settled for being able to hold influence over a section of the ocean's resources a small distance away from their coastline. Under the protection of the nation's land-based forts and armaments, this small section's resources have belonged exclusively to that nation, while most of the ocean's resources have remained uncontested. This behaviour is reinforced by a doctrine known as the Freedom of the Seas, which was proposed in 1609, but did not become international law until the 19th century.[4] This has come about due to the local nations voicing their concerns of resource depletion caused by the exhaustive practices and pollution from long-distance fishing and transportation fleets. While the Freedom of the Seas Act has been initially effective, the 19th century's maritime boom has rendered it ineffective and outdated. The constant tension between the local and long-distance vessels has been compounded by the revolutions of maritime warfare capabilities. The ocean is an influencing element of our geopolitical climate, and as such every nation is responsible for its upkeep.

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4 "High Seas." Encyclopædia Britannica. Encyclopædia Britannica, inc. Accessed September 10, 2021. https://www.britannica.com/topic/high-seas#ref215901.

Water

Water is arguably both a finite and an infinite resource. The water cycles allow for a natural replenishment making it seem like there is an unending supply of this vital asset. Under ideal conditions and treatment, the finite amount of total water in the hydrosphere, shown in the following image (Fig. 2.4), would not be as much of a concern. As is common in global economics, the more plentiful the resource, the less it is valued and appreciated. The near-unlimited supply of water has put an emphasis on the extraction of resources, but not the maintenance of their ecosystems.

The water that makes up the oceans and seas, covers more than 70% of Earth's surface and constitutes more than 97% of the total hydrosphere.[5] Seawater is enriched with various important chemical elements, a complex mixture primarily comprised of approximately 96.5% water, 2.5% salts, and the remainder includes a concoction of dissolved inorganic and organic materials, particulates, and a few atmospheric gases.[6] Figure 2.5 provides a full breakdown of the 1.38 billion cubic kilometres of water in the hydrosphere. At the molecular level, water is made up of tightly packed atoms, two hydrogen and one oxygen. Water's complex chemical and physical properties cause unique conditions to occur. As shown in figures 2.1, 2.2, and 2.3, when in liquid form, water molecules can become significantly denser than in either solid or gaseous state. As a result, the solid form, ice, will float atop the water shielding the life below from the harsher, outside environmental conditions. However, when the threat

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5 Zumdahl, Steven. "Water." Encyclopædia Britannica. Encyclopædia Britannica, inc. Accessed September 10, 2021. https://www.britannica.com/science/water.

6 Encyclopaedia Britannica,"Seawater."

comes from within, like chemicals leaching from consumer goods or animals mistakenly consuming waste plastics, there is nothing in the water's composition that remedies this situation.

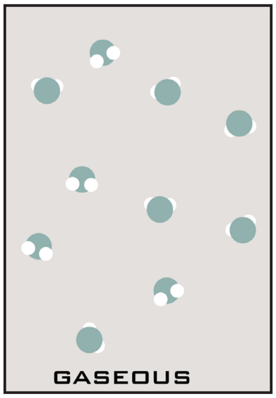

Fig. 2.1 Water Gaseous State

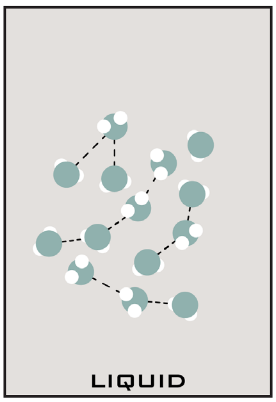

Fig. 2.2 Water Liquid State

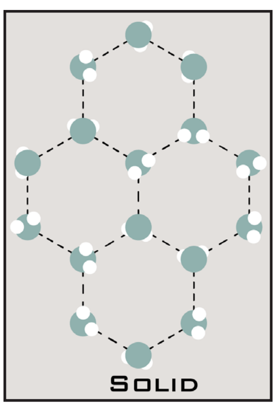

Fig. 2.3 Water Solid State

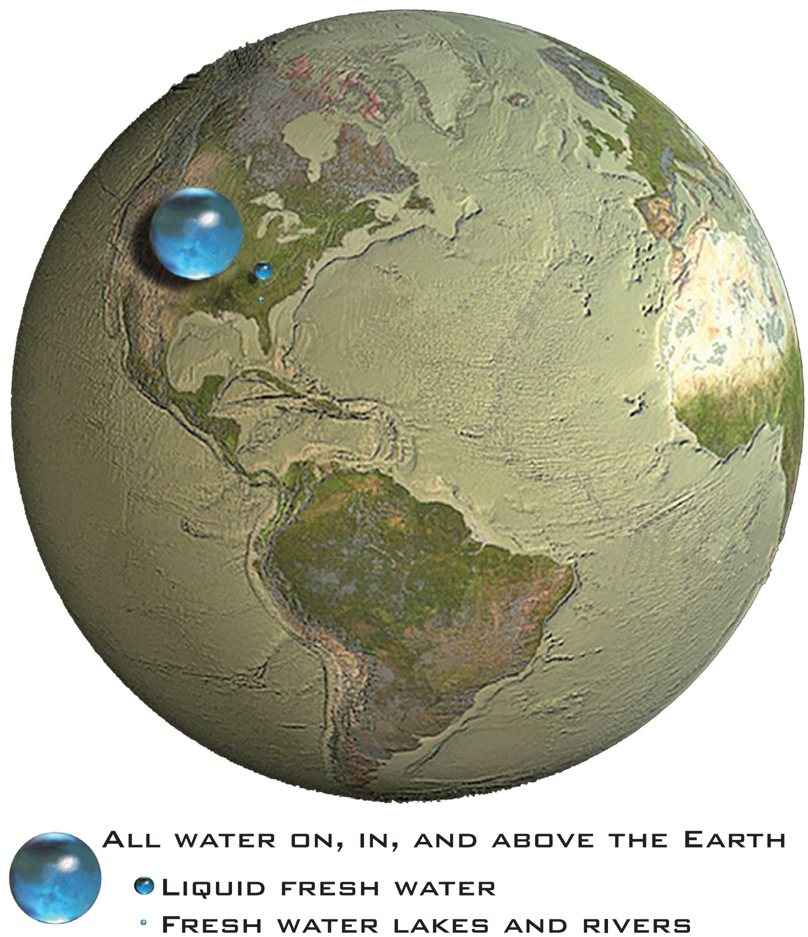

Fig. 2.4 All Water On, In, and Above the Earth

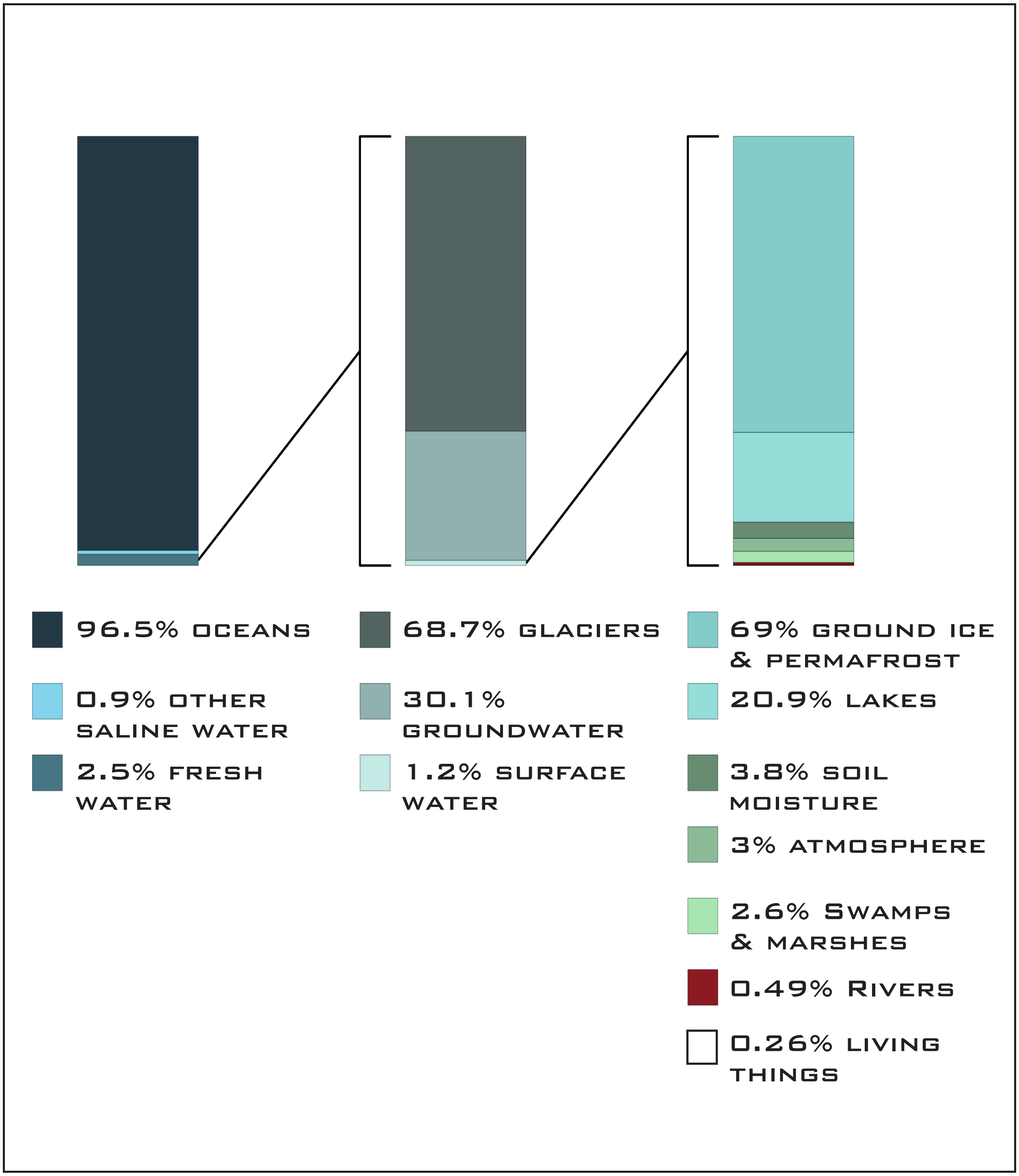

Fig. 2.5 Distribution of the World's 1.38 Billion Cubic Kilometres of Water

Wind

The impacts of the cyclical nature of the winds can be felt not only on the earth's surface, but also on the waters. The wind is a natural culprit that carries and deposits debris to all corners of the globe. It doesn't discriminate its payload or its final destination; all it knows is motion. Wind is the result of geological imbalances altering the surrounding atmosphere. These imbalances may occur locally, but their effects cause the global atmosphere to be in a state of perpetual flux. The wind is a force that cannot be seen or contained, nevertheless its presence is irrefutable. The sun's strength is the primary factor affecting airflow, and it is strongest at the equator compared to anywhere else on the planet. The equatorial air is heated, rises into the upper atmosphere, and drifts towards the poles. This transition is known as a low-pressure system. When the warm air begins to cool it densifies, falls from the upper atmosphere, and flows across the Earth's surface moving towards the equator to replace the previously heated air.[7] This is known as a high-pressure system. Winds typically flow from high-pressure systems to areas of lower pressure creating reliable patterns of movement. The interactions between these air pressure systems can be seen in the following image (Fig 2.6). Wind creates motion, motion carries debris, and that debris is often plastic.

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7 National Geographic Society. "Wind." National Geographic Society, November 13, 2012. https://www.nationalgeographic.org/encyclopedia/wind/.

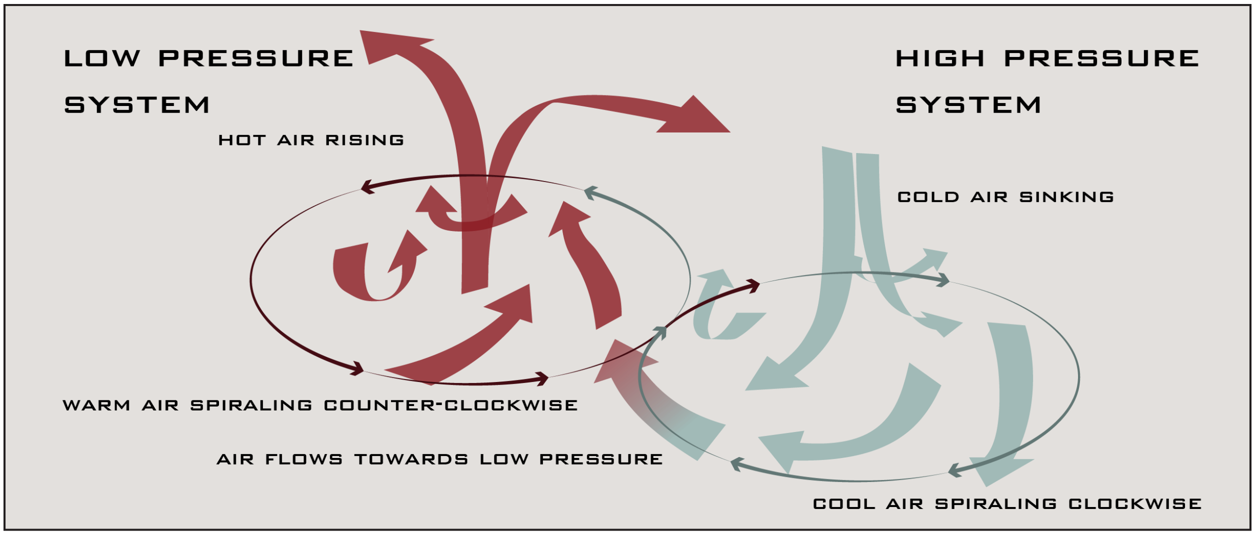

Fig. 2.6 Interactions of Air Pressure Systems

Currents

Ocean water is never stagnant; it is in a state of self-perpetuating motion with many different factors affecting its behaviour. The vastness of the ocean is magnitudes greater than its depth. Consequently, this results in exceptionally high levels of horizontal movement and relatively low levels of vertical movement. An example of the scale of the ocean can be seen in the following image (Fig. 2.7). The shape of the coastline, the seafloor, and the rotation of the Earth, all influence the path of surface currents.[8] However, it is the power of the winds raking across the surface of the ocean that manage to pull some of the surface water with them creating significant movement of the surface currents. With the ocean able to store more heat in the uppermost three meters than the entire global atmosphere, the global climate is heavily influenced by the ocean's heat exchange

8 National Geographic Society. "Ocean Currents." National Geographic Society, June 27, 2019. https://www.nationalgeographic.org/encyclopedia/ocean-currents/.

rates.[9] These surface currents are an important factor in the moderation of the climate. Much like the flow of the wind, the hot, equatorial water flows towards the poles and cools down. As the water approaches the poles it densifies and under ideal conditions surface ice may begin to form. The ice is formed through the natural freezing process of water molecules, however, the salt that is present in seawater is left behind further increasing the density of the water. As this water's density increases it begins to sink lower and as it does more ocean water flowing from the equator takes its place.[10] This process is known as thermohaline circulation.[11] At the planetary scale this process can be equated to a global circuit that cycles not only water, but also the heat, nutrients, and organisms contained within it. The following image, figure 2.8, shows the prevailing currents of the North Pacific Ocean.

There are five main current circuits that begin at the equator: the North and South Pacific Subtropical Gyres, the North and South Atlantic Subtropical Gyres, and the Indian Ocean Subtropical Gyre.[12] The gyres are composed of fast flowing, endlessly cyclical currents that maintain the healthy, thriving ecosystems through the constant distribution of resources. These system's high efficacy of resource reallocation also contributes to the heavy concentrations of plastic. Working in the same fashion as a vortex, the fast outer currents "catch" debris while the calmer inner currents draw it into the centre where escape is nearly impossible.

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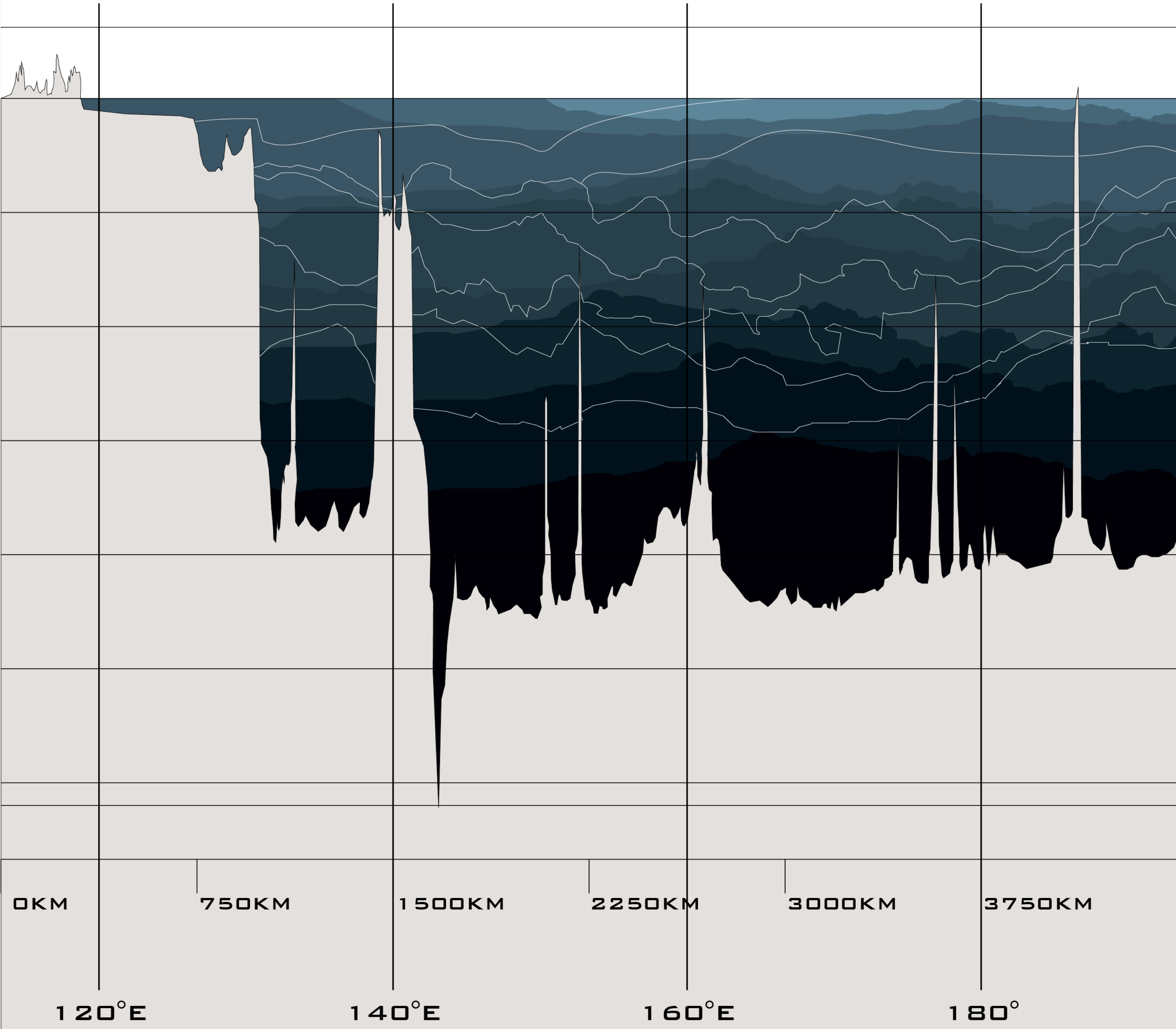
9 Bolles, Dana. "Climate Variability." NASA. NASA. Accessed September 13, 2021. https://science.nasa.gov/earth-science/oceanography/ocean-earth-system/climate-variability.

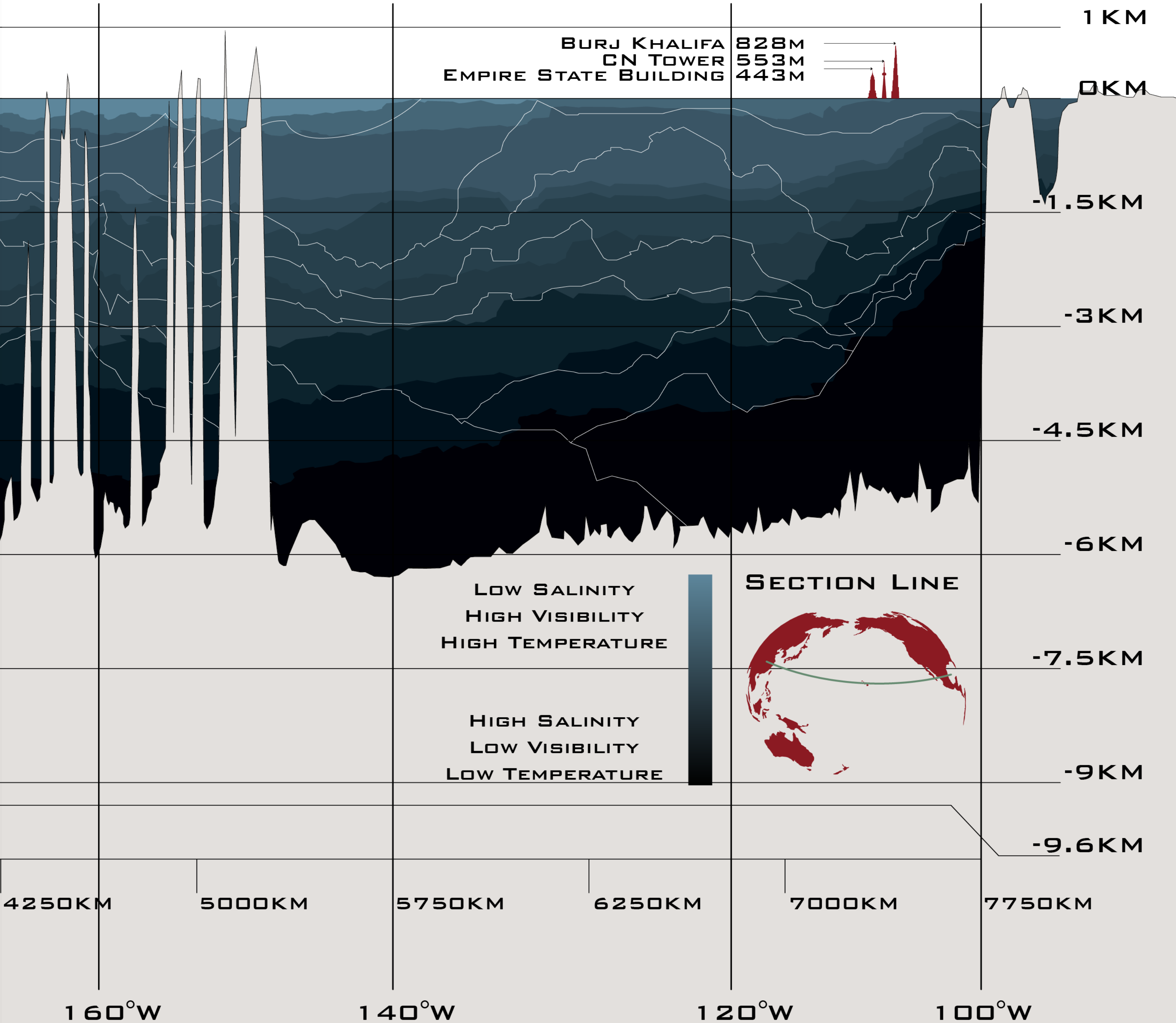
10 National Geographic Society, "Ocean Currents."

11 Thermohaline circulation: "thermo" referring to temperature and "haline" to saltiness. The oceanic circulation system controlled by horizontal differences in temperature and salinity.

12 National Geographic Society, "Ocean Currents."

Fig. 2.7 Pacific Ocean Site Section




1KM
Burj Khalifa 828m
CN Tower 553m
Empire State Building 443m
0KM
-1.5KM
-3KM
-4.5KM
-6KM
Low Salinity
High Visibility
High Temperature
High Salinity
Low Visibility
Low Temperature
Section Line
-7.5KM
-9KM
-9.6KM
4250KM
5000KM
5750KM
6250KM
7000KM
7750KM
160°W
140°W
120°W
100°W

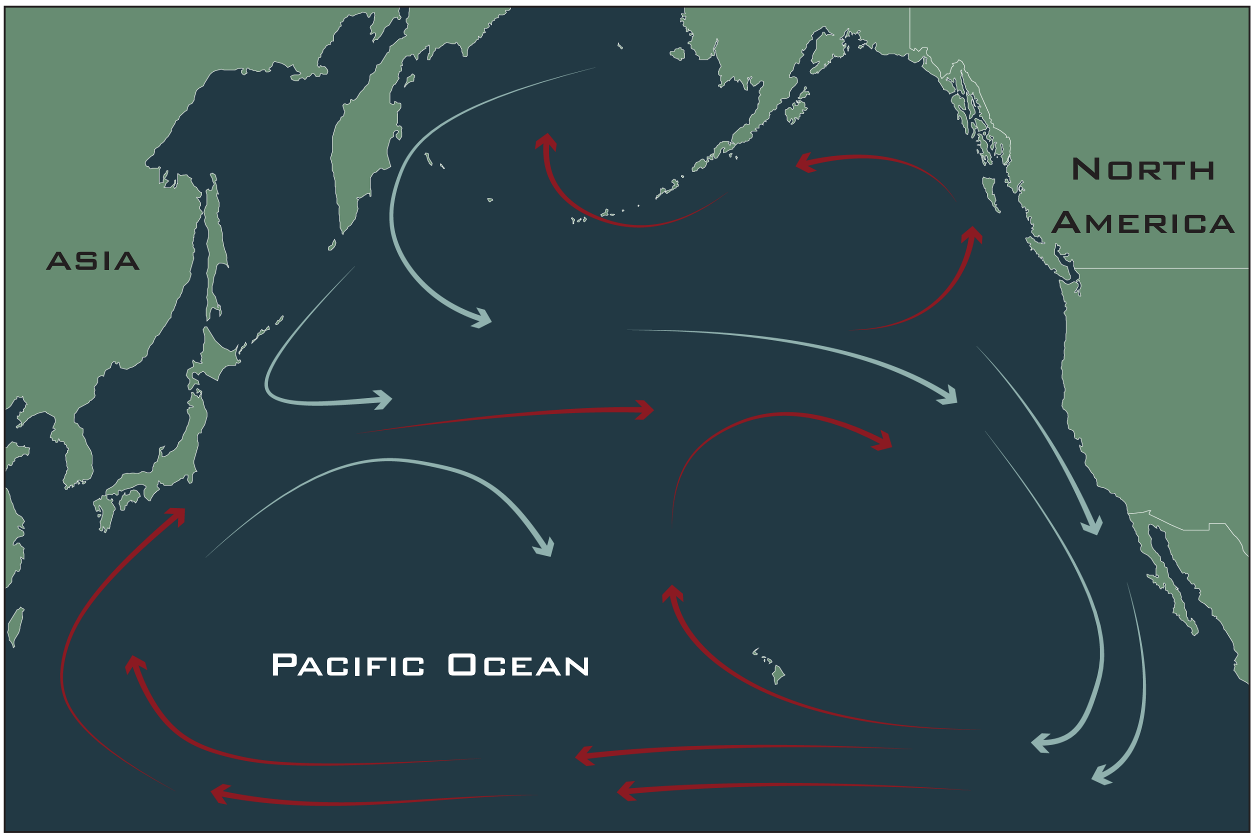
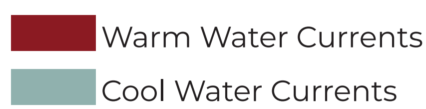


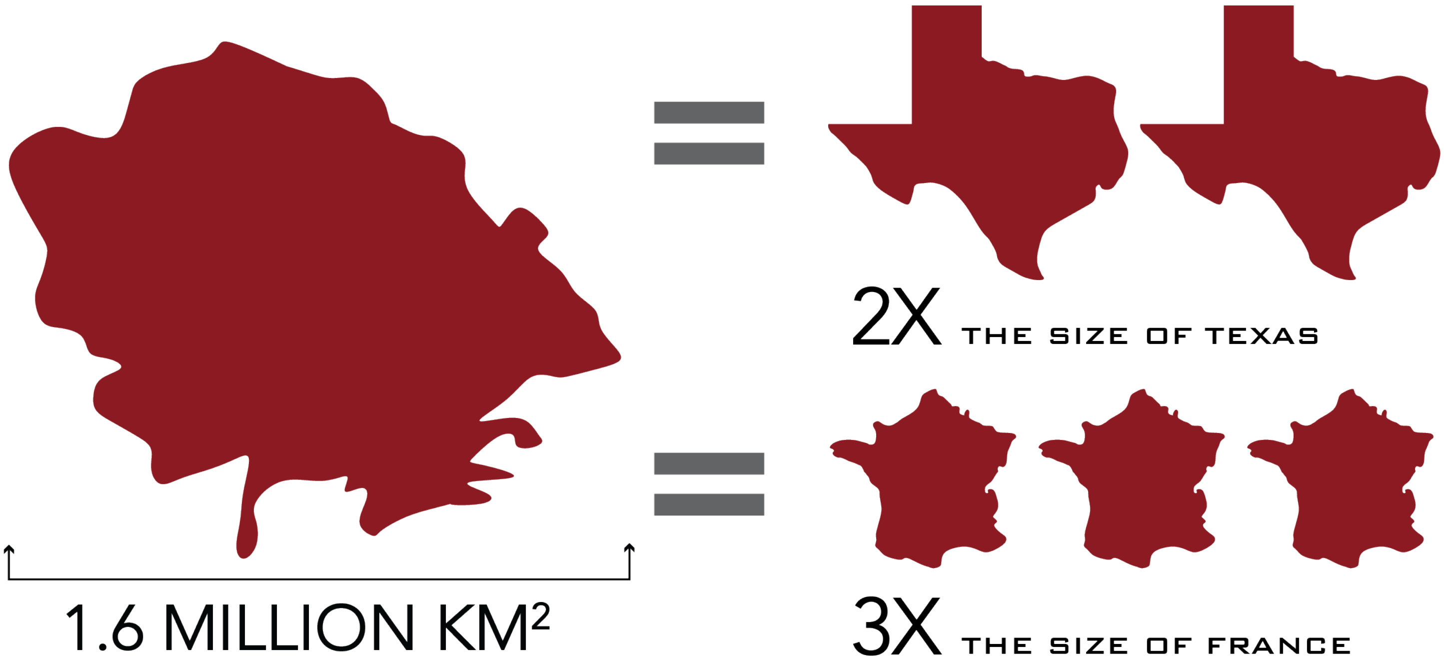
Fig. 2.8 Prevailing Currents in the North Pacific Ocean



As seen in figure 2.9, the Great Pacific Garbage Patch is the largest of these gyres and contains the highest estimated quantities of ocean plastics. The exact quantities of plastic in the Patch are difficult to define as it covers an area of approximately 1.6 million square kilometres.[13] A site three times the size of France, it is estimated to contain between 80,000 tons and 100,000 tons of plastic waste. The enormous size of the afflicted area is not the sole cause of the discrepancy in quantity. For example, in a typical terrestrial landfill the refuse is dumped and, aside from errant wind gusts or wildlife, confined to the specific area prepared to receive the waste. This is not the case with ocean plastics as the environmental and wildlife variables have a significant impact on the plastic's distribution. This culminates in plastic existing in varying densities, ranging from 10s to 100s of kilograms per square kilometre.

13 Lebreton, L., B. Slat, F. Ferrari, B. Sainte-Rose, J. Aitken, R. Marthouse, S. Hajbane, et al. Evidence that the Great Pacific Garbage Patch is rapidly accumulating plastic 8, no. 1 (2018). https://doi.org/10.1038/s41598-018-22939-w. 5

Scale



Mass distribution

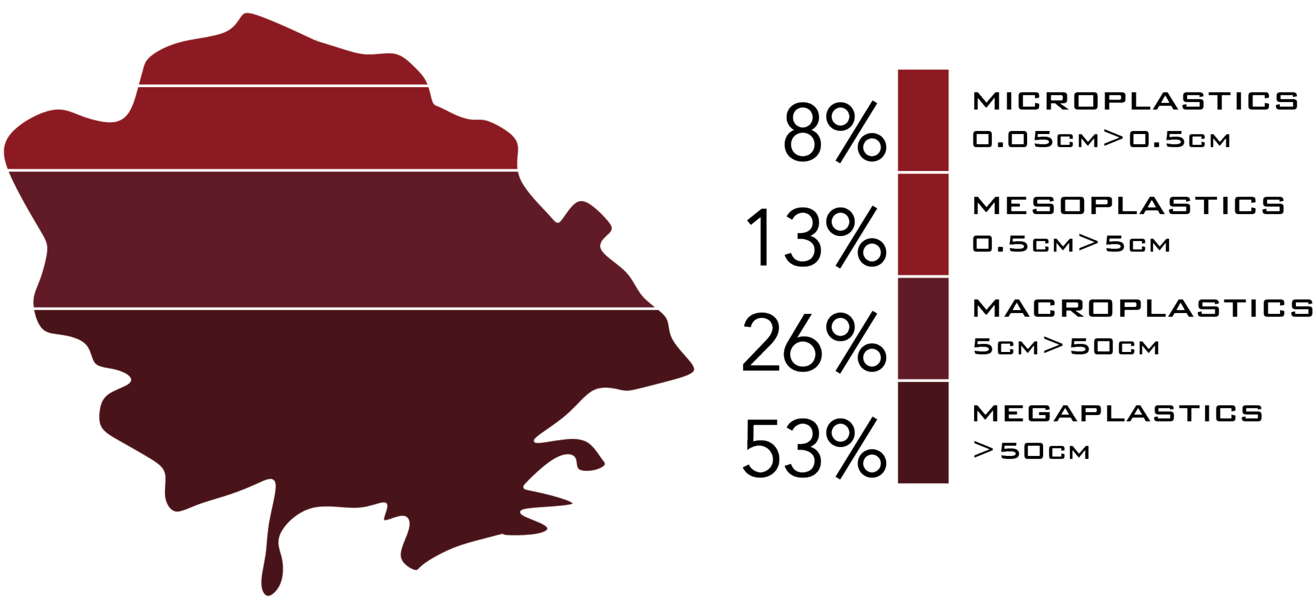


Fig. 2.9 Great Pacific Garbage Patch Metrics

Mass Concentration

80,000 tons of plastic are in the Great Pacific Garbage Patch

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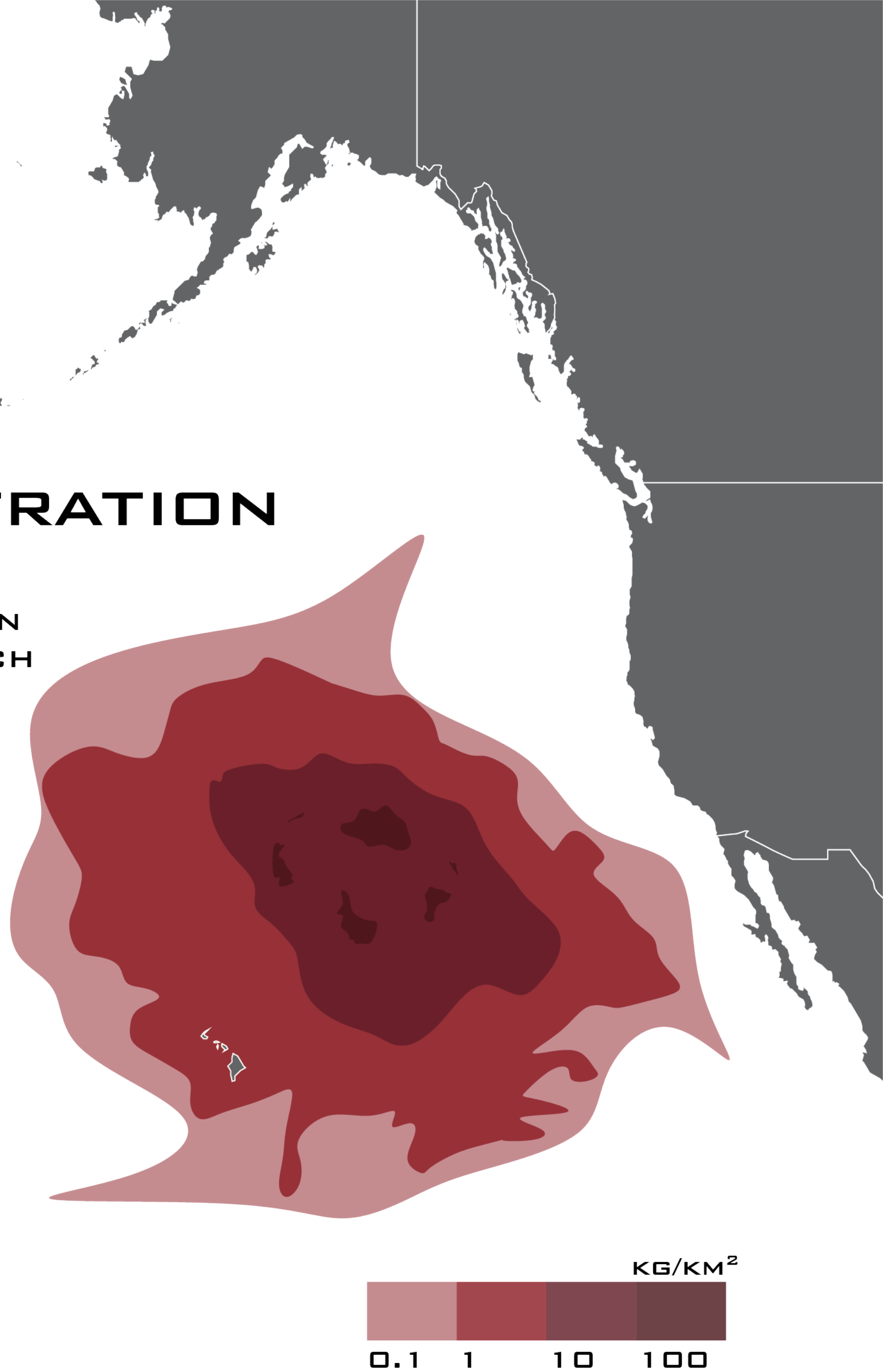
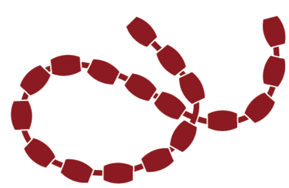
400 blue whales

=

1,066,800 humans



99% of the patch is plastic



46% of the total mass is discarded fishing equipment

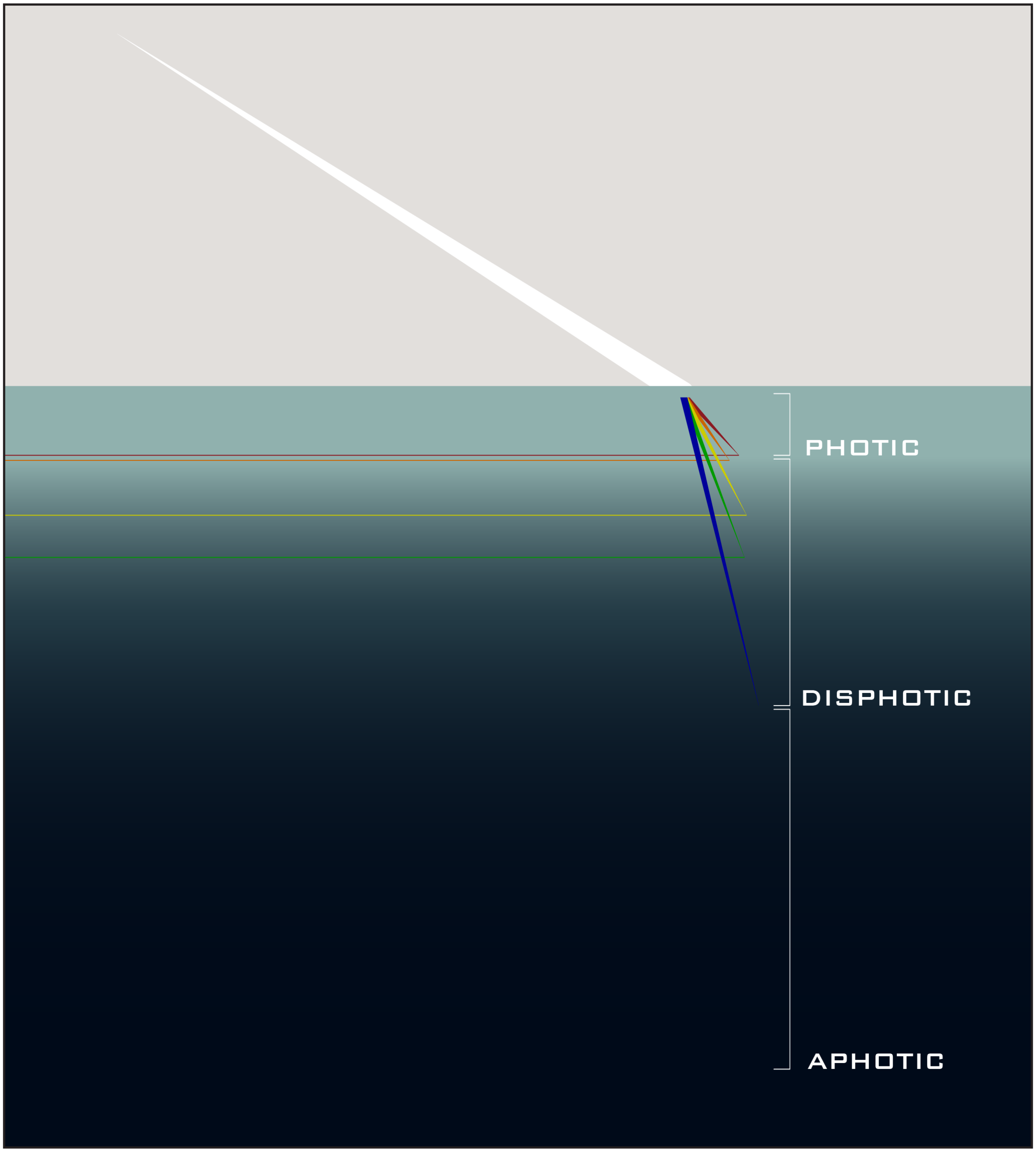


Fig. 2.10 The Degrees of Light Penetration in the Ocean

Photic zones of the ocean are bustling with life as this is the only zone where enough light penetrates the surface to sustain plant growth. Disphotic zones are darker areas where light is increasingly inaccessible, culminating in the pitch blackness that makes up the aphotic zones.

Light

Not all the sun's energy is directly absorbed into the ocean. A portion of it is immediately reflected at the surface and cannot be absorbed. Electromagnetic radiation that falls within the visible spectrum can penetrate through water, however it is significantly less capable of doing so than through the atmosphere. Since water is much denser than the atmosphere, the speed of light is affected, resulting in light rays that enter the water at any angle other than a right angle to be refracted (i.e., bent).[14] Energy that does manage to penetrate the surface can be converted into heat to warm the oceans, be used by vegetation in the process of photosynthesis, or provide visual light for the wildlife.

The water in the ocean is by no means a pure concentration of H_20. The vastness of the ocean results in the water becoming a catch-all environment. Rivers deposit mineral sediments; animals deposit organic matter; and humans deposit waste. All these sources deposit particulates that can become suspended in varying depths, further reflecting and scattering light. As shown in figure 2.10, the presence of light is strongest at the ocean's surface; in the shallow depths the effects of refraction and scattering are present, but minimal. Colours are often visible and true to form, however as the depths increase, the range of visible colours become severely muted, if not entirely scattered. The colours range from bright reds to dull browns; from vibrant yellows to a green-blue colour. Eventually, not even the longest wavelengths, blue and violet, are visible. Aside from the animal adaptation

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14 Flemming, Richard H. "Optical Properties." Encyclopædia Britannica. Encyclopædia Britannica, inc. Accessed September 17, 2021. https://www.britannica.com/science/seawater/Optical-properties.

of bioluminescence or the presence of volcanic activity, the ocean's deep inhabitants are in a state of complete darkness. While the wildlife is literally in the dark, humans find themselves in a similar state of ignorance when it comes to the extent of plastic pollution in the depths of the ocean.

Biosphere

Over the last century, maritime technologies have advanced so dramatically that the daunting task of ocean exploration has become relatively more straightforward than previous attempts. This increase in technological capabilities has created a new understanding of the fragile biotic interactions of the inhabitants of the ocean. Whether there is an extremely high density or low density of organisms, there is some form of life inhabiting all areas of the ocean and there are no known lifeless, azoic zones.

However, the following image (Fig. 2.11) symbolizes how human's increased industriousness is acting like a toxin, infecting the ocean ecosystem at every scale. For some unknown reason we are complacent in both the poisoning of the largest habitat on the planet and, by extension, the poisoning of ourselves. Human waste introduces unnatural toxins to all ocean wildlife indiscriminately, yet we still rely on the ocean wildlife as reliable source of food.

Terrestrial life is restricted to a primarily two-dimensional habitat, there are minor exceptions to this fact (i.e., birds), however the majority of wildlife occurs between a few meters of soil and the crowns of trees. Furthermore, very few, land-based animals live most of their lives in a near-perpetual state of three-dimensional movement, most of which eventually

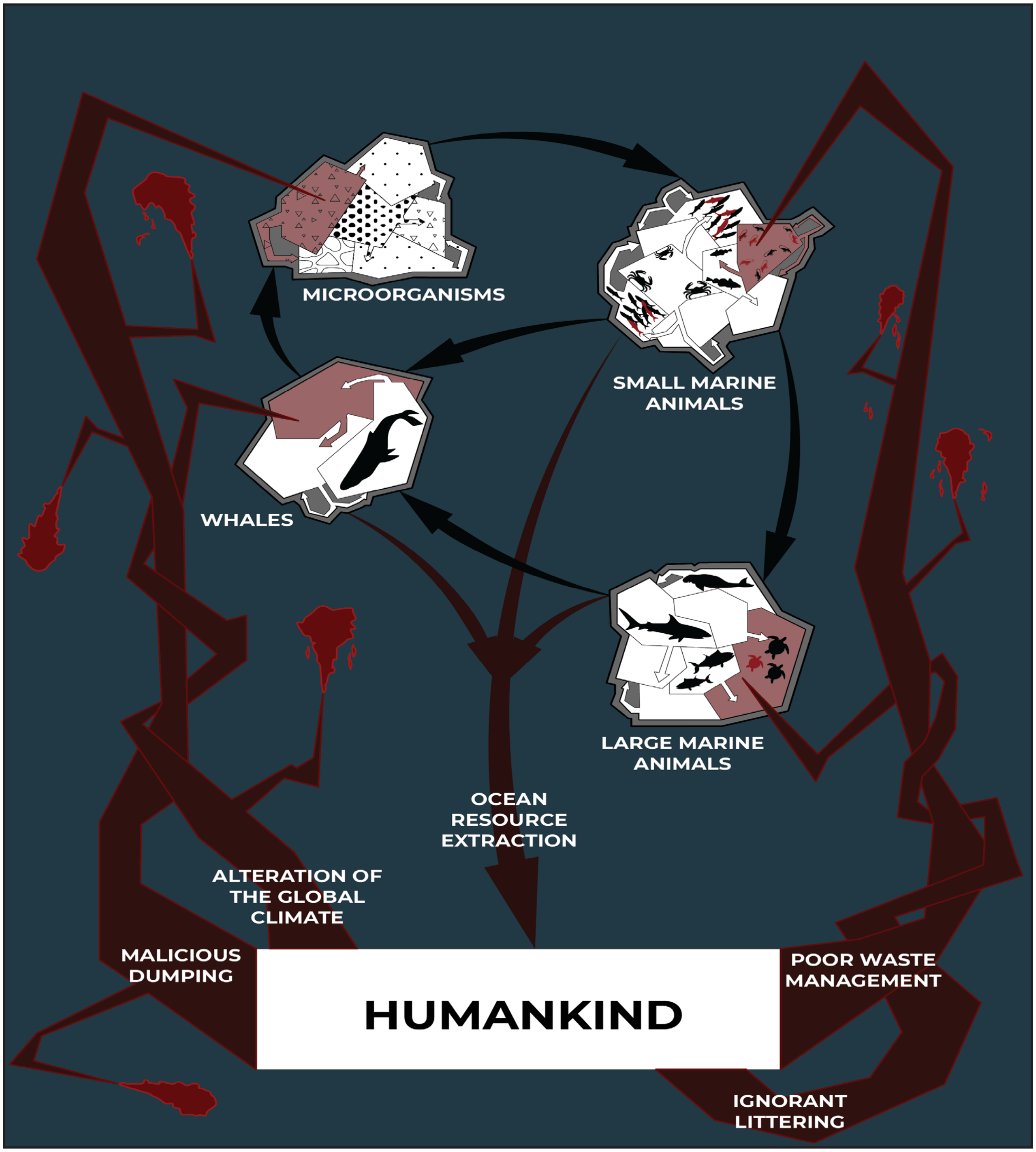

Fig. 2.11 Infected Interactions of Marine Ecosystems

return to a semi-permanent, terrestrial dwelling. However, for ocean-dwelling animals this perpetual movement state is a daily reality. On land it can be plainly seen that there is a patchwork of ecosystems bordering each other, often with clearly defined boundaries. There are easily recognizable geographical and climatological markers that influence the types of species that will inhabit specific locations such as types of rivers, forests, and mountains. From a human perspective the ocean is an ephemeral realm that is in a state of constant flux where the visibility of such markers is extremely limited. However, the ocean is the single largest spanning habitat; it is home to innumerable inhabitants of all shapes and sizes. From the surface of the ocean to the deepest known depths, life can be found, not just surviving, but thriving. To the scientific community, the ocean is a vast repository of potential discoveries, however to the general public the ocean remains a largely mysterious facet of daily life.

02

Chapter 2
The Plastic Revolution

The Plastic Revolution

Historically, a product has been designed and built to last or at least be repaired if it has been damaged, however the introduction of factories capable of mass production has revolutionized the way products are created. Prior to the industrial revolution, products have been created by skilled craftsmen, who have been able to manipulate natural, or slightly altered materials that could eventually biodegrade or be recycled indefinitely. The emergence of global industrialization has led to an ideology of optimizing efficiencies and lowering costs by any means necessary. This new capacity of production has allowed for the lowering of the quality of worker skill and has demanded a versatile new material, plastic, which can be formed into a myriad of new and exciting products.

Originating as an item used exclusively in the military, after World War II the household use of plastics has skyrocketed.[15] Through extensive developmental phases, scientists and engineers have discovered that the weight-to-strength ratio, versatility, and transparency of plastic has made it suitable for a wide variety of applications.[16] By replacing commonly used materials such as glass, metal, and paper, cheaply produced plastic has proved itself invaluable to the production of inexpensive household and commercial items. With the dramatic decrease in manufacturing cost and consequent reduction in consumer costs, many items have been succeeded by plastic variations and are now seen as

15 Roland Geyer, Jenna Jambeck, and Kara Law. "Production, use, and Fate of all Plastics Ever made." Science Advances 3, no. 7 (2017): Accessed January 15, 2021. 1-5. doi:10.1126/sciadv.1700782.

16 Andrady, Anthony L. "Microplastics in the Marine Environment." 1597

more readily disposable variants. The extreme durability and resilience of plastic has allowed it to become a cornerstone material, finding its way into every aspect of daily life.

The use of plastics has become so ingrained in our production ideals that by the end of 2015, the total plastic waste generated from primary plastics reached 5800 million metric tons (Mt).[17] Globally, humans produce a staggering 245 million metric tons of plastic products per year, about 35 kg per person. Figure 3.1 illustrates that since the 1950's over 8.3 billion Mt of plastic have been created with around 4.9 billion Mt being discarded. Of the discarded 4.9 billion Mt, most makes its way to landfills, however, the exact amount of plastic that infiltrates the natural environment is impossible to quantify at this point.[18] The amount of plastic produced each year is roughly equivalent to the cumulative weight of all existing human biomass with only about 21% of all plastic ever produced being disposed of correctly. A particularly high volume of plastic, nearly one third of the plastic resin in production, is produced as single-use plastic packaging that is improperly disposed of.[19]

The creation of a more readily disposable product has led to a paradigm shift in the consumption habits of the average person. Widespread usage, inherent unnatural resilience, and the adoption of the single-use product has caused an unyielding increase in the accumulation of plastics in natural environments.

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17 Geyer, "Production, Use, and Fate of All Plastics Ever Made." 2.

18 Geyer, "Production, Use, and Fate of All Plastics Ever Made." 1-3.

19 Geyer, "Production, Use, and Fate of All Plastics Ever Made." 1.

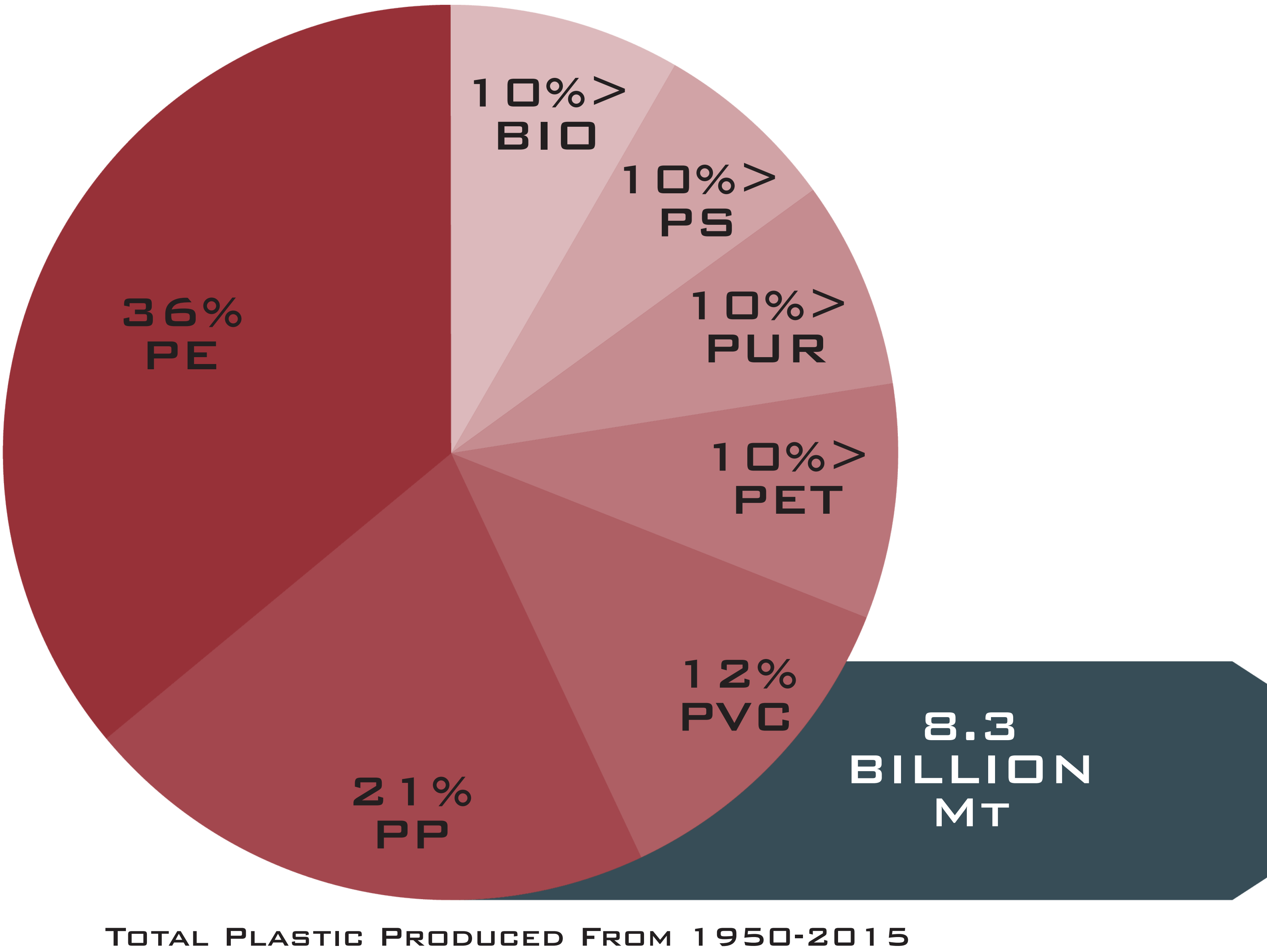
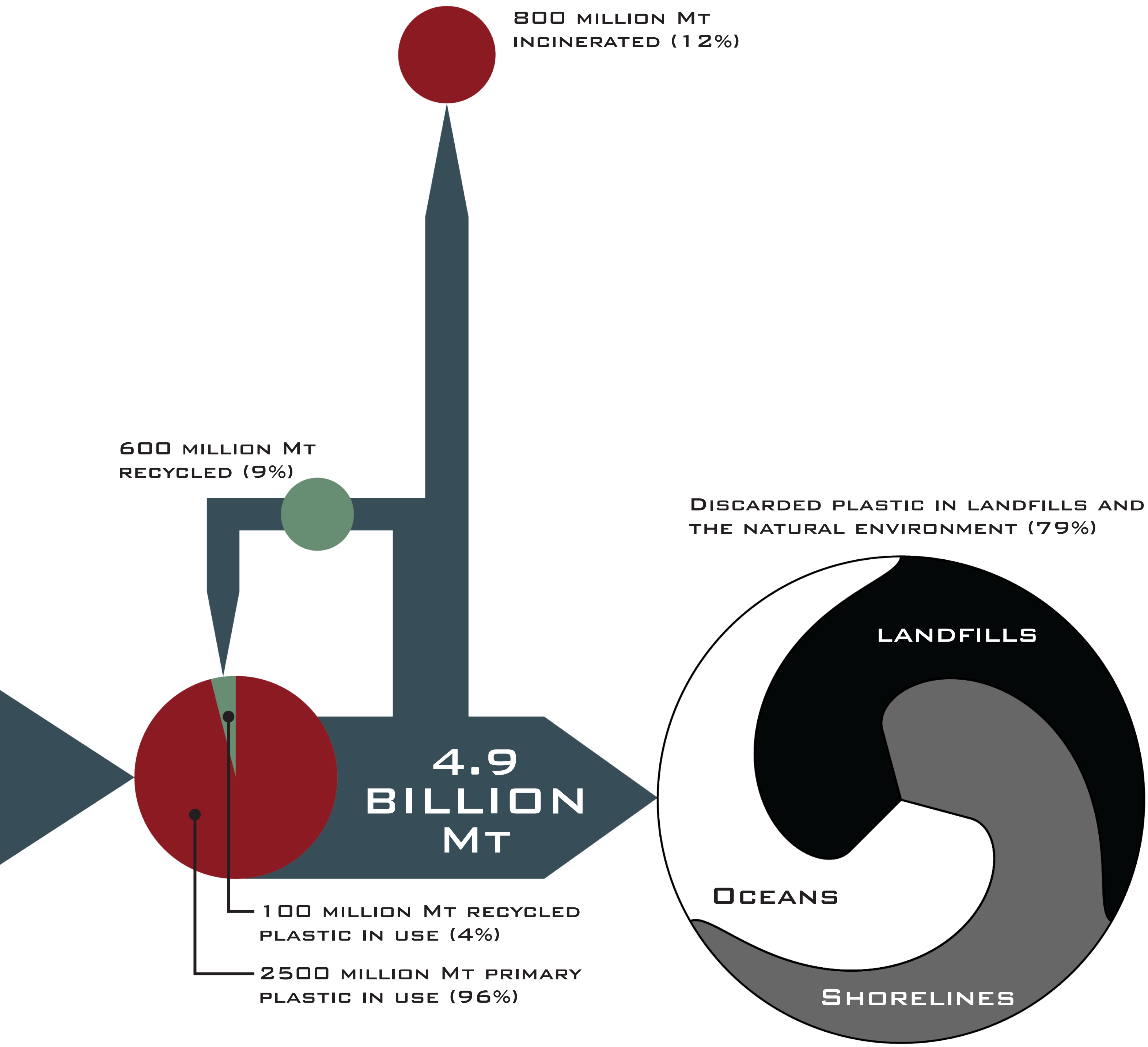


Fig. 3.1 Total Plastic Produced From 1950-2015


800 million Mt
incinerated (12%)
600 million Mt
recycled (9%)
Discarded plastic in landfills and
the natural environment (79%)
Landfills
4.9
billion
Mt
Oceans
100 million Mt recycled
plastic in use (4%)
2500 million Mt primary
plastic in use (96%)
Shorelines

Each year, millions of tonnes of plastic garbage enter the waterways, are swept away by the prevailing currents, and are deposited into the world's oceans.[20] Large accumulations of debris are connected by the North Pacific Subtropical Convergence Zone, essentially, a highway of ocean currents pushing debris from one vortex to another.[21] The Great Pacific Garbage Patch is a large, slowly flowing whirlpool of currents between Hawaii and California that draws debris into its calmer centre. The immense size of the affected area, the high mobility of the plastic elements, and the deeply entrenched position of existing plastic within the ecosystems make it difficult to actively clean.

The Myth of Recycling

The versatility of plastic allows it to take on nearly any form imaginable, however, to create this desired form, all plastics are a heavily manufactured product. This heavy machining and chemical alteration create a product that is radically different from its natural state. The transformation is so exhaustive that the final product is not readily biodegradable.[22] Comprised of artificially complex polymer chains, plastics require hundreds of years to degrade in even the best environmental conditions.[23] As a result, the discarded plastics accumulate indefinitely rather than return into a sustainable nutrient cycle.

20 National Geographic Society. "Great Pacific Garbage Patch." National Geographic Society, October 9, 2012.

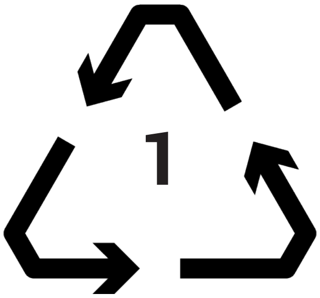
21 National Geographic Society. "Great Pacific Garbage Patch."

22 Barnes, David K. A., Francois Galgani, Richard C. Thompson, and Morton Barlaz. "Accumulation and Fragmentation of Plastic Debris in Global Environments." Philosophical Transactions of the Royal Society B: Biological Sciences 364, no. 1526 (2009): 1985–98.

23 Singh, Narinder, David Hui, Rupinder Singh, I.P.S. Ahuja, Luciano Feo, and Fernando Fraternali. "Recycling of Plastic Solid Waste: A State of Art Review and Future Applications." Composites Part B: Engineering 115 (2017): 409. Accessed March 2020 https://doi.org/10.1016/j.compositesb.2016.09.013.

To avoid overfilling landfills with plastic, attempts at a strong recycling initiative have been put into place. However, adequate levels of recycling are difficult to achieve on the same global scale of plastic production. Some of the difficulties in recycling plastic is the demand for high quality, clean, and high transparency plastics of the same type. Plastic is a broad term applied to many different variations of a similar product. As seen in figures 3.2-3.8, not all plastics are created equally, rather, they are meticulously designed as specialists that excel in particular roles and rarely can crossover to another role. This hyper-specialized designation demands that for the plastic feedstock to be successfully recycled into a new form it must first be sorted extensively by type and categorized by quality. Furthermore, plastics that have not been previously dyed are in higher demand than its dyed counterparts. Although recycling can reduce the amount of plastic entering into landfills, there are limitations to the number of times plastic can be recycled and oftentimes there are extensive contaminants that need to be removed prior to the recycling process. Even virgin or primary plastic material can only be reused effectively roughly 2 to 3 times in its service life, as every recycling process reduces the overall strength of the plastic.[24] Secondary recycling relies on a mechanical approach of shredding, melting, and extrusion or injection moulding to create new forms. This exhaustive service requires plastic to be cleaned, dried, shredded, and sorted by quality, colour, and variety. By combining many different types of plastics, the recycled plastic quality is reduced, restricting the type of recycled products that can be created. Tertiary and quaternary recycling are used in extenuating circumstances where the quality of the plastic has reduced so much that the standard method of

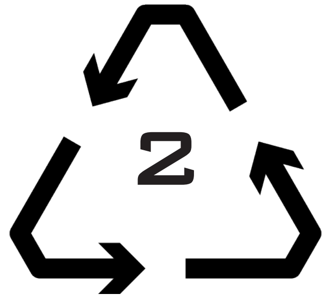
24 Singh, Hui, Singh, Ahuja, Feo, Fraternali, "Recycling of Plastic Solid Waste: A State of Art Review and Future Applications." 409.



PET
POLYETHYLENE
TEREPHTHALATE

Cosmetic containers
Plastic Bottles
Mouthwash Bottles
Food Trays

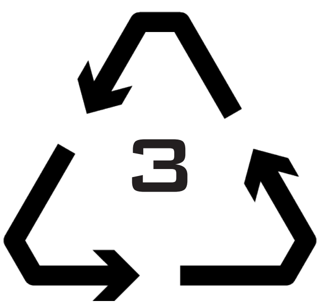
Fig. 3.2 PET: Polyethylene Terephthalate. Recycling symbol and related products.



HDPE
HIGH DENSITY
POLYETHYLENE

Detergent Bottles
Grocery Bags
Milk Bottles
Shampoo Bottles

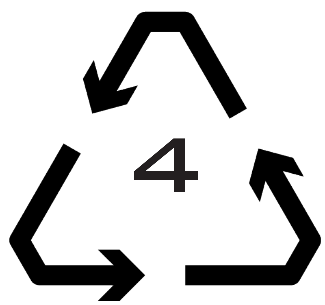
Fig. 3.3 HDPE: High Density Polyethylene. Recycling symbol and related products.



PVC
POLYVINYL
CHLORIDE

Garden Hose
Window Frames
Blood Bags
Blister Packs

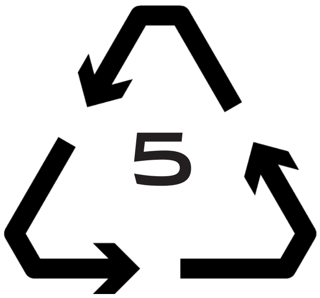
Fig. 3.4 PVC: Polyvinyl Chloride. Recycling symbol and related products.



LDPE
LOW DENSITY
POLYETHYLENE

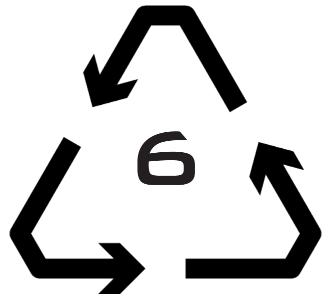
6 Pack Rings
Cling Film
Bread Bags
Squeezable Bottles

Fig. 3.5 LDPE: Low Density Polyethylene. Recycling symbol and related products.



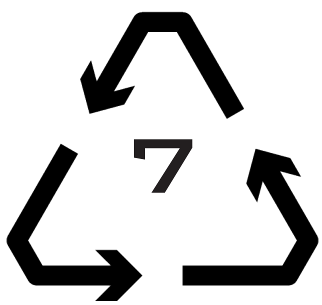
PP
POLYPROPYLENE
Bottle Caps
Packing Tape
Cereal Liners
Straws

Fig. 3.6 PP: Polypropylene. Recycling symbol and related products.



PS
POLYSTYRENE
Disposable Coffee Cups
Styrofoam
Plastic Cutlery
Foam Packaging

Fig. 3.7 PS: Polystyrene. Recycling symbol and related products.



OTHER
POLYCARBONATE
Baby Bottles
Water Cooler Bottles
Fiberglass
Tupperware

Fig. 3.8 Other Polycarbonate. Recycling symbol and related products.

recycling is inapplicable. Instead, this method of recycling focuses on energy recovery through the creation of a petrol-derivative product. These processes are known as pyrolysis and gasification.[25] Where landfills only hide the problem and recycling perpetuates it, pyrolysis fully eradicates the plastic. Resulting in a permanent method of removing existing plastic from all contaminated major ocean basins.

Parts Per Million

With plastic being the most prevalent material used in products there is ample opportunity, even under the most vigilant recycling and waste management systems, for plastic waste to infiltrate into the natural environment. The researchers from The Ocean Cleanup Organization concluded that “plastics were by far the most dominant type of marine litter found, representing more than 99.9% of the 1,136,145 pieces and 668kg collected…”[26] Plastics can make their way into marine environments through many methods such as active dumping, plastic degradation, and extreme weather. A majority of land-based plastics enter marine environments through inland waterways either through direct littering of trash from large coastal urban centres or when artificial fabrics shed their fibres that are then flushed away with the dirty water. Figure 3.9 illustrates the various locations for plastic waste to accumulate in aquatic environments. Human settlements are often nearby a river, estuary, or similarly sized body of water and as a result, these areas can be considered one of the origin points of the plastic pestilence. Like a parasite in bloom, figures 3.10

25 Pyrolysis converts waste plastics or biomass into a usable fuel source that is burned, and the resultant energy can be recovered.

26 Lebreton, L., B. Slat, F. Ferrari, B. Sainte-Rose, J. Aitken, R. Marthouse, S. Hajbane, et al. Evidence that the Great Pacific Garbage Patch is rapidly accumulating plastic 8, no. 1 (2018). https://doi.org/10.1038/s41598-018-22939-w. 9

and 3.11 show that the overwhelming volume suffocates and oppresses the surrounding ecosystems. As seen in the trail of plastic in figure 3.12, plastic flows out from rivers and into the ocean, it becomes dramatically more difficult to remove and as seen in figures 3.13 and 3.14, it requires a combination of large-scale and small-scale techniques to remove it. Plastics flow wherever the carrier waters take it, this means that any obstructions, such as river stones, riparian zones, and even beaches become covered in a thick coating of plastic debris. The careful monitoring of estuaries will allow us to intercept the plastic before it has a chance to escape into the vast ocean waters. The removal of plastics already existing in the ocean will reduce the opportunity for plastic to spread and embed itself into beaches and vulnerable reefs.

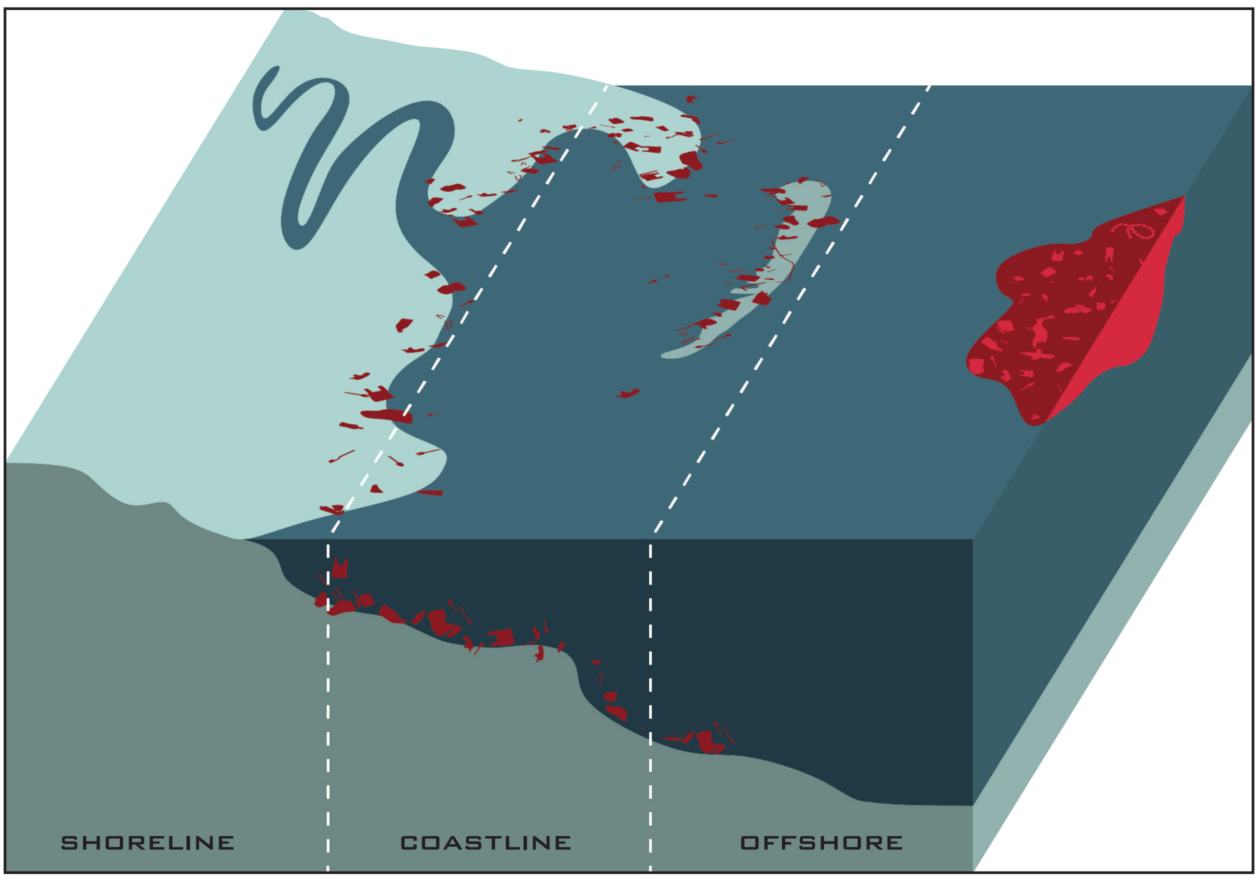


Fig. 3.9 Plastic Accumulation Across Three Distinct Environmental Conditions

Significant amounts of plastic can be traced back to origins of specifically engineered plastic that is resistant to degradation in marine environments.[27] This variety of durable plastic is prized for use in commercial fishing operations and in aquaculture as ropes, traps, or buoys. When this plastic is used extensively it begins to shed small fibres and then is eventually discarded. Out on the open water there is little to no authority to capture any lost cargo or equipment and is only recovered on a case-by-case basis.

Some plastics are less dense than the surrounding seawater and this excess buoyancy causes them to float along the surface in large groupings, seemingly creating an artificial archipelago. This grotesque parody of nature is commonly referred to as the garbage islands of the Pacific Ocean.

27 Andrady, “Microplastics in the Marine Environment.” 1597

Fig. 3.10 Mass Accumulation of Plastic Pollution in Las Vacas River, Guatemala

Fig. 3.11 Plastic Pollution on a Beach in Honduras

Fig. 3.12 Trail of Plastic Floating in the Great Pacific Garbage Patch

Meanwhile, specifically designed marine plastics, such as nylons used in fishing gear, are typically denser than the seawater and immediately sink to become an addition to the ocean floor's sediment.[28] The degree of plastic buoyancy can also vary depending on the interactions of the surrounding biosphere. Floating plastics are colonized by microorganisms that, over time, increase the total density and cause the plastic to sink. Once on the ocean floor the plastic will be able to sustain larger, more complex lifeforms that will become prey for fish and crustaceans. Consequently, the plastic, recently stripped of its previous inhabitants may return close to its original degree of buoyancy and once again float to the surface.[29]

28 Andrady, "Microplastics in the Marine Environment." 1597

29 Andrady, "Microplastics in the Marine Environment." 1599

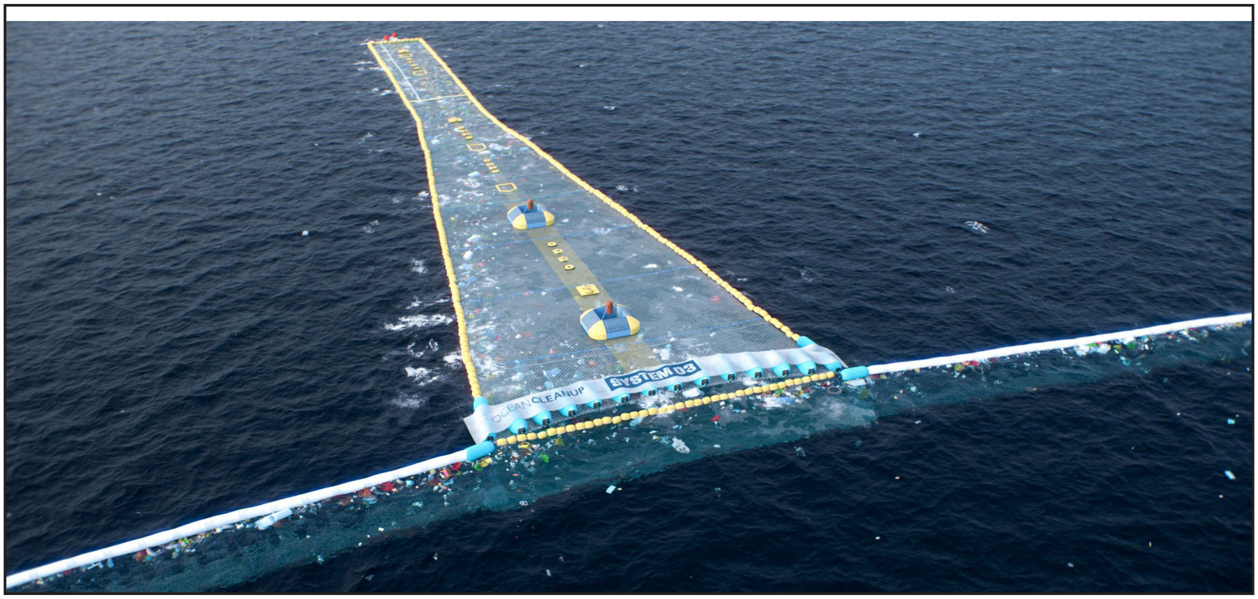


Fig. 3.13 Plastic Accumulation Across Three Distinct Environmental Conditions

Fig. 3.14 Plastic Accumulation Across Three Distinct Environmental Conditions

This cyclical loop of plastic purgatory, illustrated in the following image (Fig. 3.15), can cause the rate of degradation of a plastic item to reduce to nearly nil, further prolonging its existence in marine environments.[30] The effects of plastic purgatory are not isolated to one specific area of the ocean, and can be observed in the epipelagic zone, mesopelagic zone, and bathypelagic zone.

For many, the phrase “garbage island” evokes imagery of an island entirely composed of refuse. The idea of a “garbage island” is a projection of what one would see in a typical landfill transposed onto an aquatic background. This description of the Great Pacific Garbage Patch is an attempt to rationalize what has manifested out of sight at the farthest edge of our peripheries. A previously non-existent phenomenon, terrestrial terms have been mistakenly applied to a truly unique condition. As shown in the following series of images (Fig. 3.16-3.20), the Patch, influenced by the pull of the currents and the winds, is a constantly changing ocean-scape with areas of low, medium, and high densities of multiple classifications of plastic waste. Landfills are a static, man-made environment that are shamefully hidden from the public eye and then permanently sealed away in a concrete tomb. With landfills there are procedures and protocols to properly seal away anything harmful from leaching out into the environment, yet with the Great Pacific Garbage Patch, plastic trash is only masked under a veil of inaccessibility.

30 Andrady, “Microplastics in the Marine Environment.” 1599

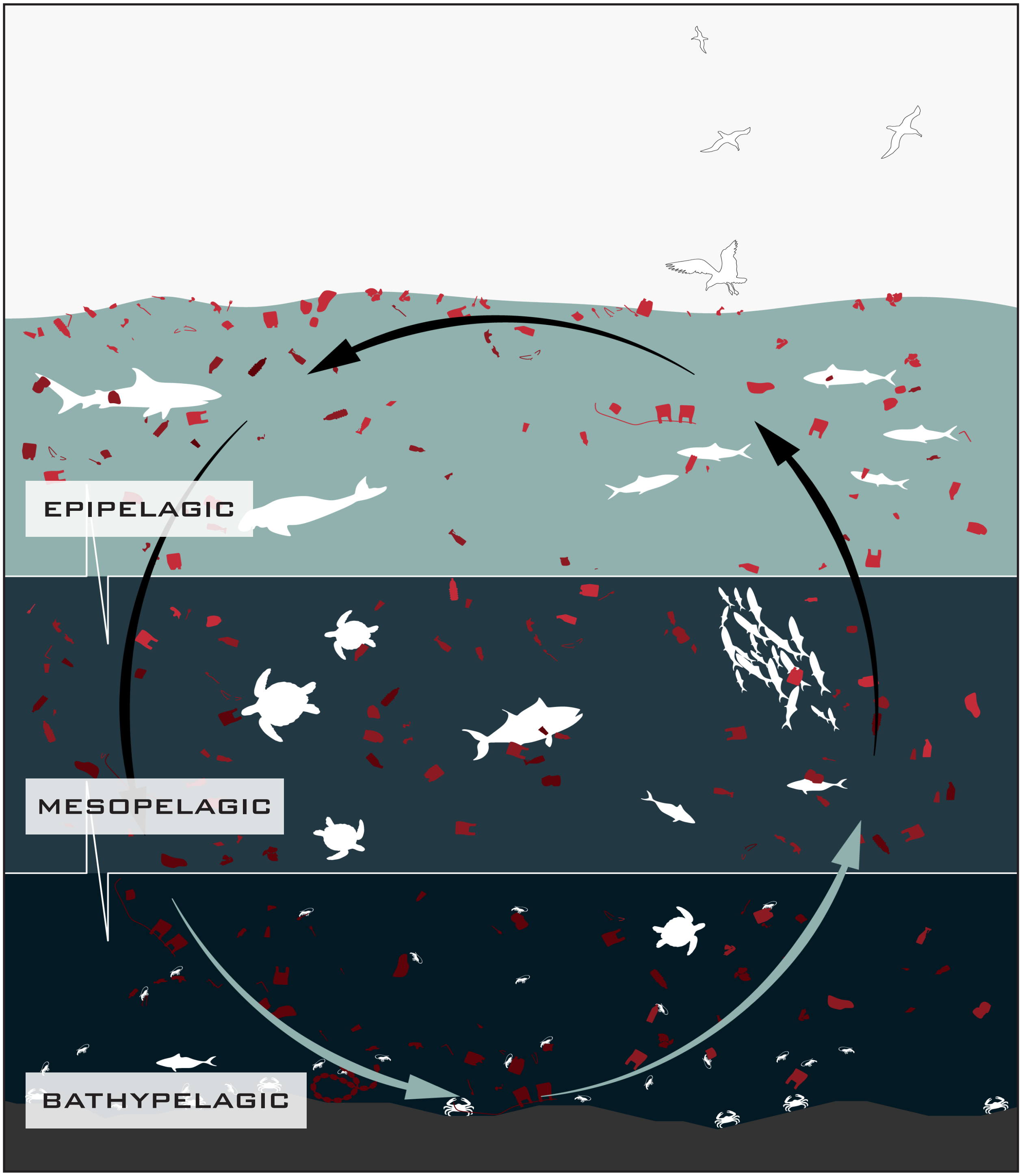


Fig. 3.15 The Effects of Plastic Purgatory

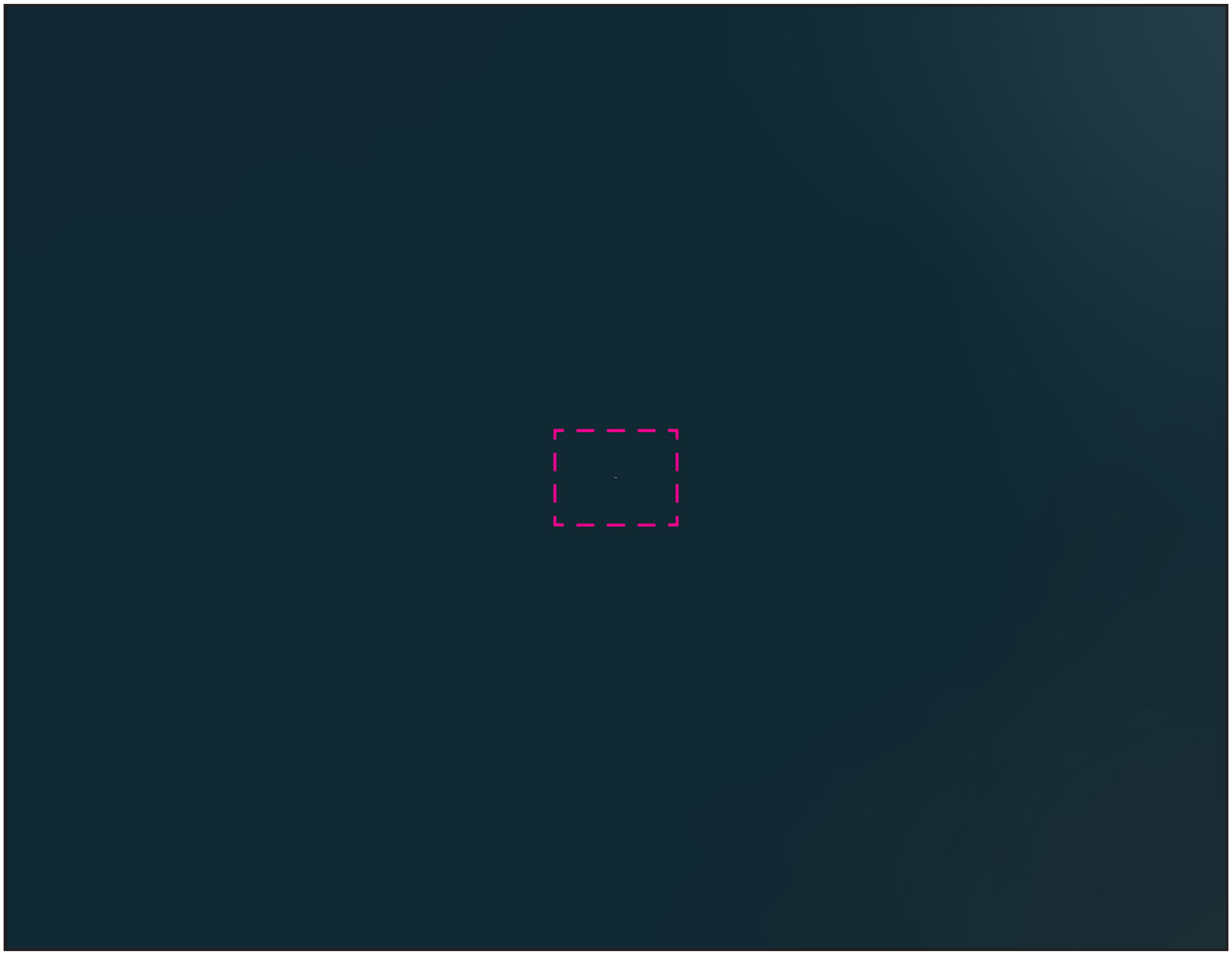


Fig. 3.16 Visibility of Ocean Plastic at 1:100,000

From the perspective of satellites, there are no discernible disturbances.

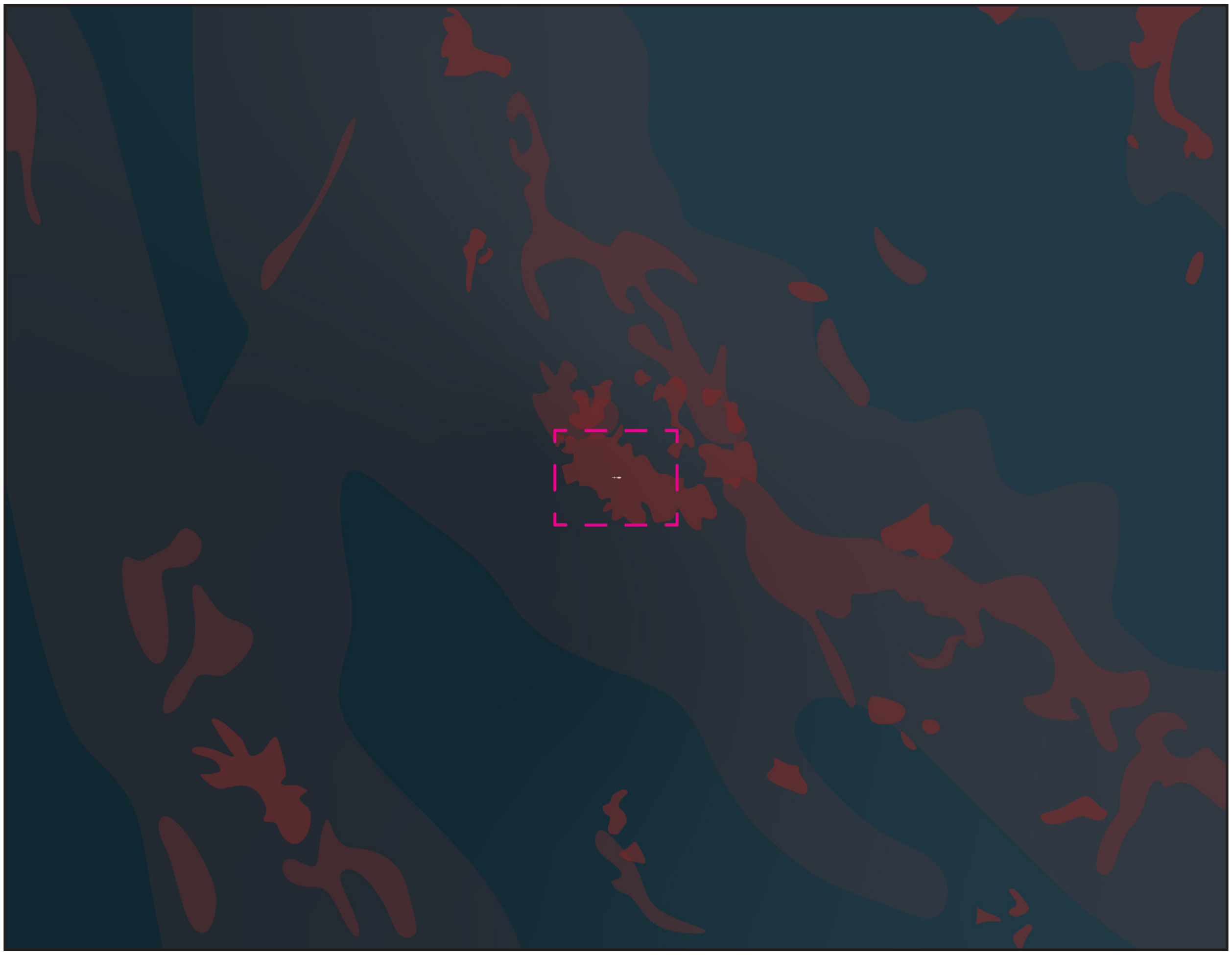


Fig. 3.17 Visibility of Ocean Plastic at 1:10,000

From the perspective of a low-flying aircraft there is significant space between concentrations of ocean plastic.

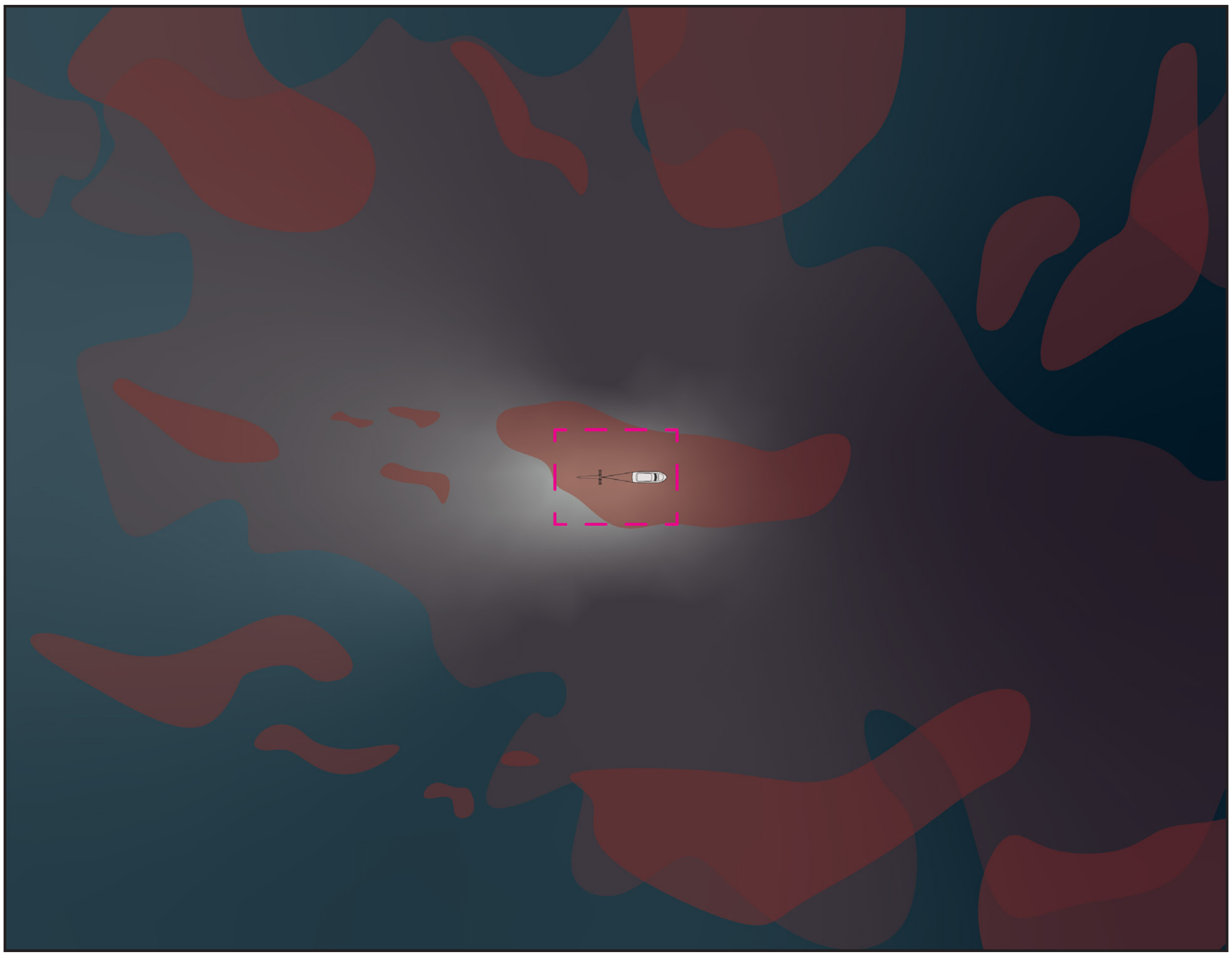


Fig. 3.18 Visibility of Ocean Plastic at 1:1000

Bird’s eye view reveals varying densities of plastic patches.

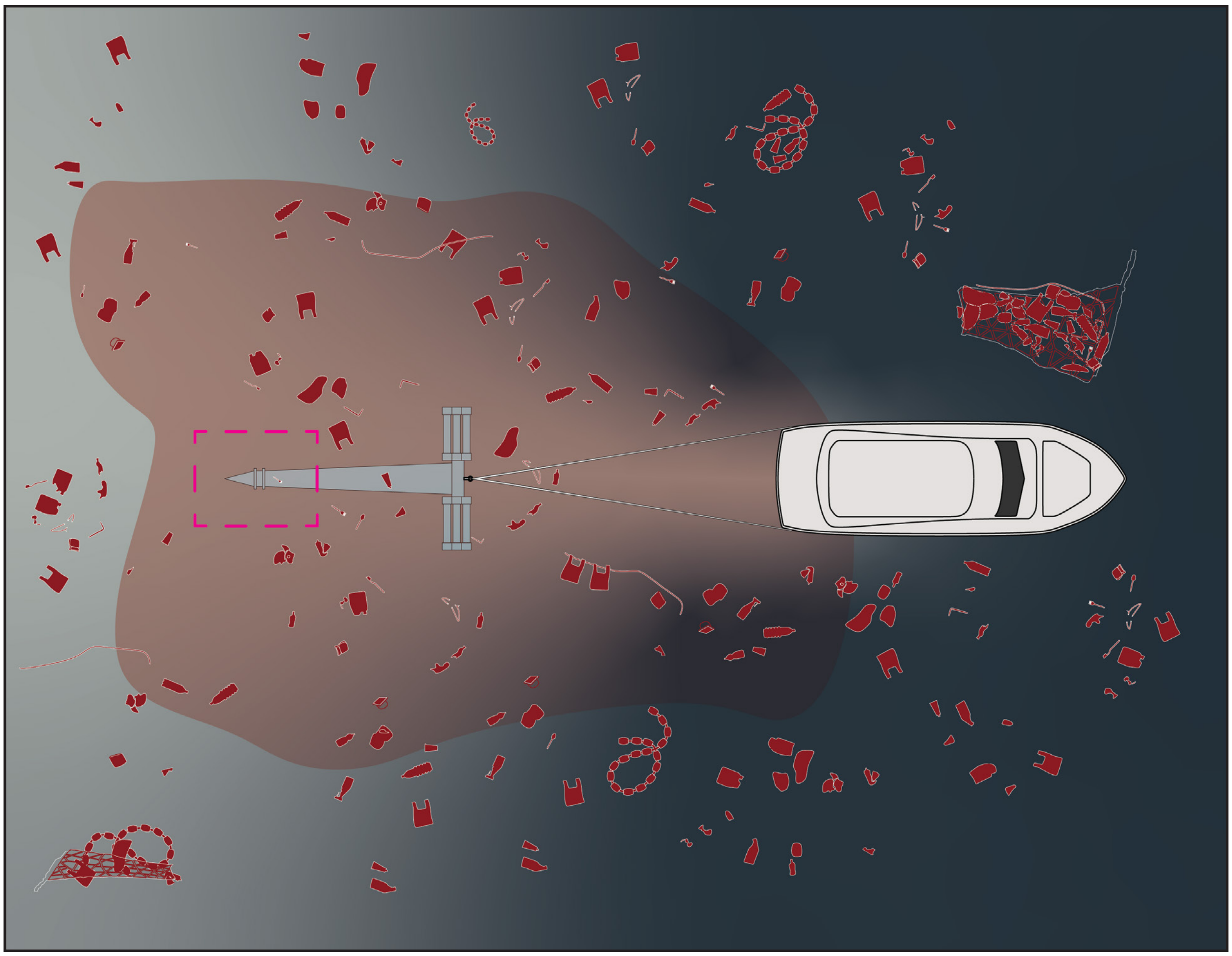


Fig. 3.19 Visibility of Ocean Plastic at 1:100

A manta trawl collecting plastic samples while towed behind a research vessel.

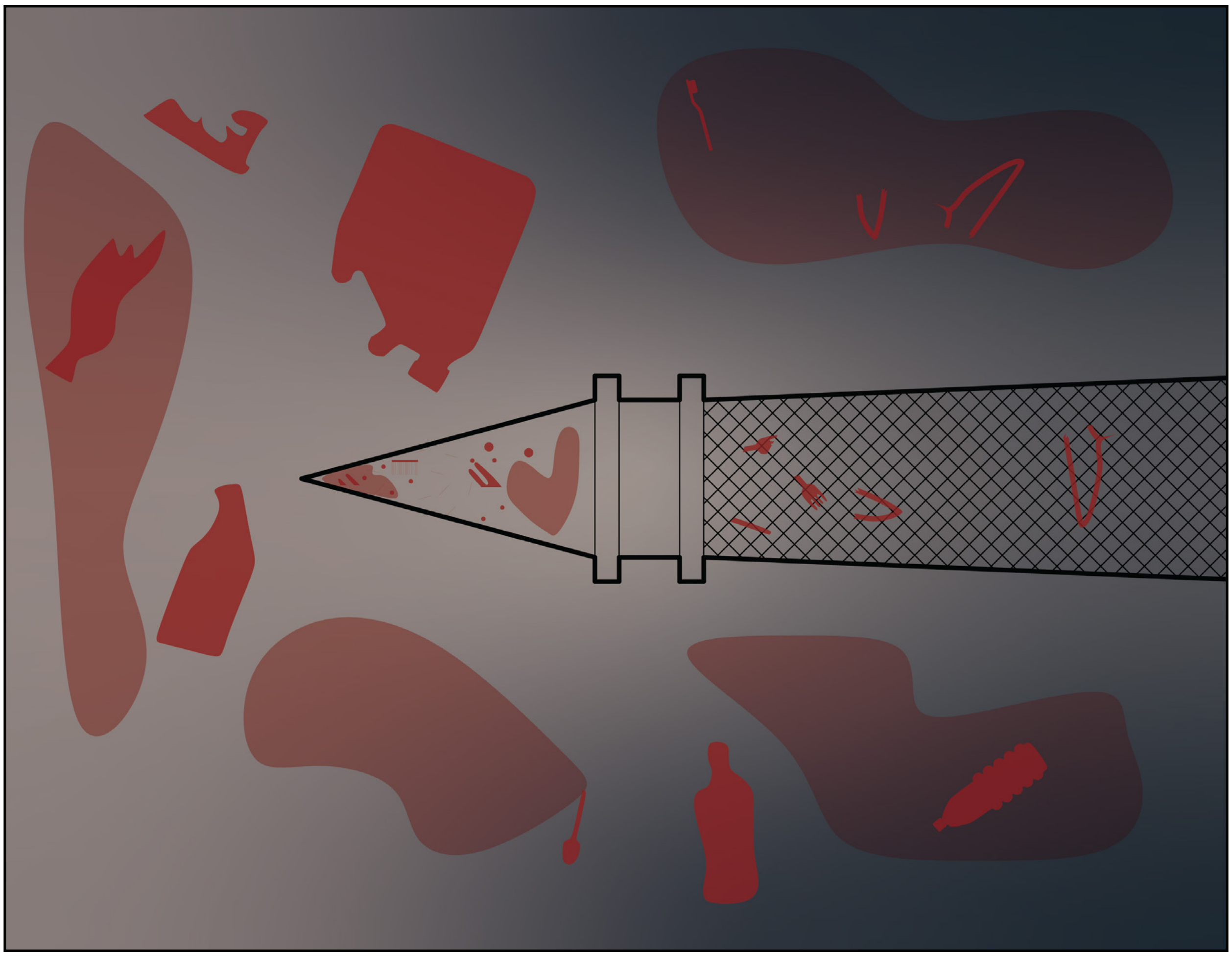


Fig. 3.20 Visibility of Ocean Plastic at 1:10

Microplastics are collected in a fine mesh net.

As plastic waste flows into the oceans it is exposed to a unique situation where the environmental conditions cause it to undergo many changes. Plastics enter the ocean as recognizable products, whether damaged, lost, or discarded the ocean accepts all. Over time the harsh environment grinds down the bonds of the plastic, fracturing it into smaller and smaller pieces whose origins begin to be unrecognizable. Both recognizable and unrecognizable pieces can be seen in the following image (Fig. 3.21). These pieces are given certain designations depending on their size. As seen in figure 3.22, there are four primary classifications of plastic marine litter: Megaplastics (>50 cm), Macroplastics (50-5 cm), Mesoplastics (5-0.5 cm), and Microplastic (0.5-0.05 cm). At each level, these plastics have the capacity to further break down into smaller and smaller component pieces continuing to negatively affect the marine environments.

The Great Pacific Garbage Patch is not a physical landmass that can be visited or walked upon. Rather, it is an aggregation of plastic debris of all sizes, shapes, and forms that, over time, will infect every aspect of daily human life. The carelessness of humans has allowed the Great Pacific Garbage Patch to evolve into a "super wicked" problem.[31, 32] I believe that through effective intervention, global education, and a departure from our dependence on plastic, future contributions to the growth of the Garbage Patch can be reduced, and ultimately, ended. Yet, there is the present issue of the innumerable quantities of plastics that are harming the marine ecosystems and need to be eradicated.

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31 A super wicked problem consists of four core components: a deadline that is rapidly approaching; contributors to the problem also aspire to provide a solution; a lack of central authority to address the problem; and the short-sightedness of the world governments do not consider a generational perspective.

32 Richard J. Lazarus, "Super Wicked Problems and Climate Change: Restraining the Present to Liberate the Future", 94 Cornell L. Rev. 1153 (2009). 1160

Fig. 3.21 The Ocean Cleanup's Plastic Collection Haul

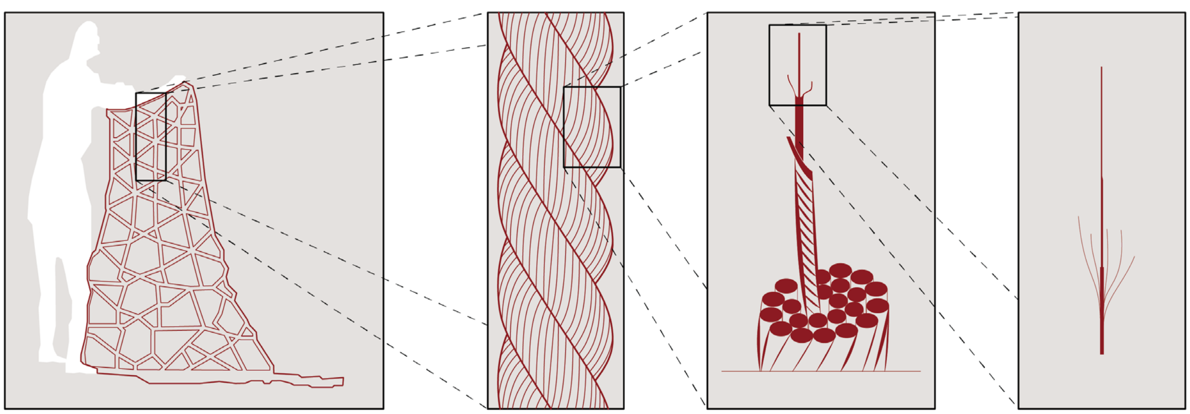

Fig. 3.22 Plastic Scale Transitioning From Megaplastic to Microplastic

The Harbinger - Environmental Systems on the Brink

Landscape systems exist as a causal loop of self-generating relationships; if there is a void caused by a particularly devastating disturbance, it will be rapidly filled by a diverse, pioneer ecosystem[33]. When in the midst of disturbances, the resilience of fragile ecosystems depends on the stability of landscapes which would, in turn, allow them to adapt and transform over time. In the case of the Great Pacific Garbage Patch, the change has happened gradually, yet consistently over the last century. Some of the smaller organisms may be able to adapt and change to this evolving environment, unfortunately the timeline of these changes is dramatic enough that it is nearly impossible for larger animals to adapt. This leads to the animals accidentally becoming entangled in or consuming large quantities of plastic and ultimately dying. Figure 3.23 illustrates the introduction and dispersion of plastic to the food chain. These sweeping deaths are the harbinger of something greater yet to come. Ecosystems are in a perpetual state of flux, falling in and out of balance constantly, making it impossible for nearly all forms of life to survive a large magnitude disturbance.

Territory on the ocean floor is fiercely defended by the local organisms as every square inch is highly valuable. However, ocean plastics provide free real estate for more adaptable species as both microorganisms and macroorganisms will latch on and multiply. Not only has this added surface area led to a boom in these species' populations, but it can also bolster

33 Kay, James J. "Ecosystems as Self-Organizing Holarchic Open Systems: Narratives and the Second Law of Thermodynamics." Essay. In Handbook of Ecosystem Theories and Management, 135–60. CRC Press, 2019.

the spread of potentially invasive species capitalizing on the movement of plastic throughout the ocean. Furthermore, extra precautions must be taken to ensure that this biological agent is separated from the plastic before it can be properly disposed of, and most recycling facilities are not equipped for this specialised task. Therefore, there is a newfound need for an ocean-based recycling facility, that specializes in cleaning, sorting, and properly disposing of collected marine debris, to help combat decades of neglect.

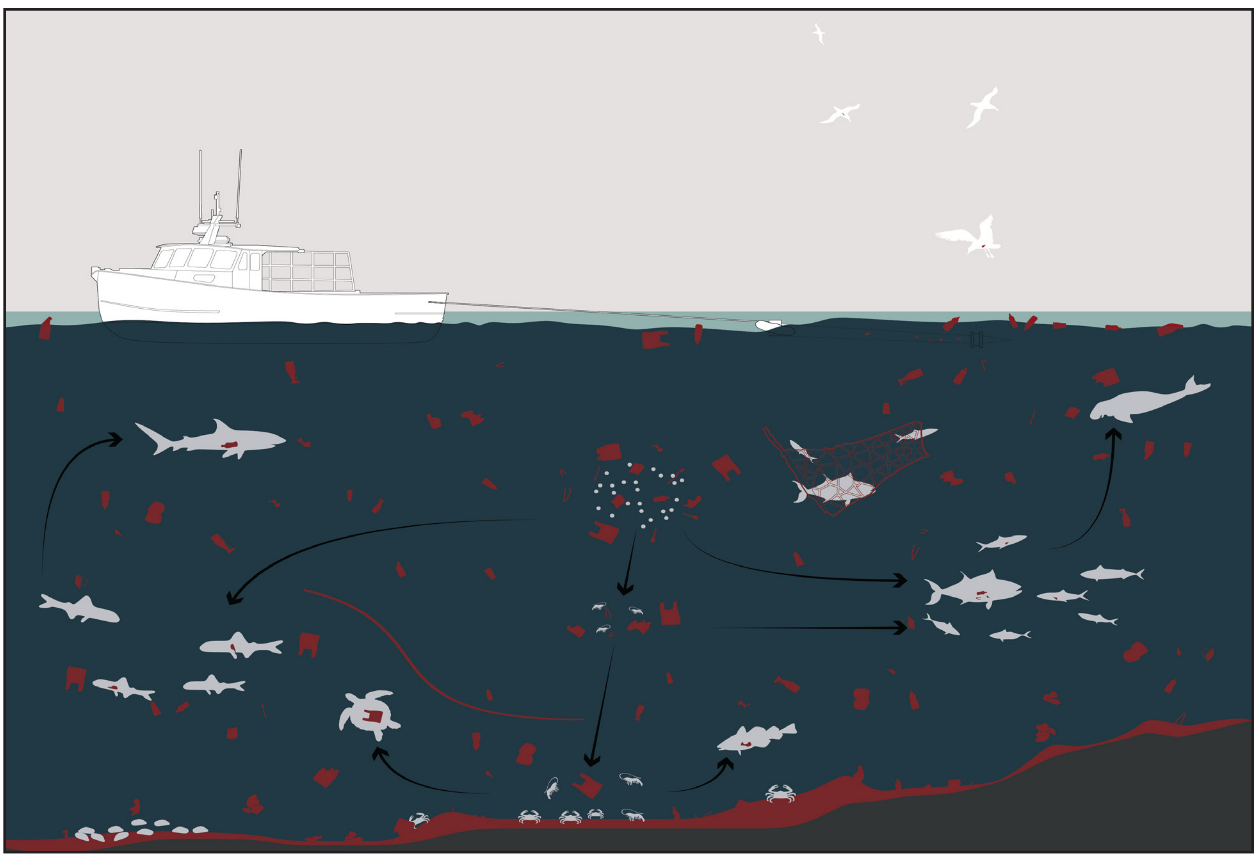

Fig. 3.23 Plastics Entering the Food Chain

21st Century Fossils

Decades-old plastic not only acts as a biotic attractor, but also as an abiotic bonding agent. At both the surface and the bed of the ocean, heat, pressure, and the churning of waves are formulating a new geology: plastiglomerate. Neither a purely geological material nor a product of human manufacturing, this "indurated, multi-composite material made hard by agglutination of rock and molten plastic" is a new, hybrid material.[34] The rock-like substance is an amalgamation of stones, shells, sediments, glass, remnants of fishing gear and smaller brightly coloured synthetic polymers.[35] As seen in the following images (Fig 3.24-3.27), the durability of plastiglomerates can be extrapolated by analysing its most prevalent parts: plastics and stones. As both of those elements have extremely long projected lifespans, plastiglomerate is a geological marker for the Anthropocene.

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34 Graham, James, and Caitlin Blanchfield. *Climates: Architecture and the Planetary Imaginary.* New York, NY: Columbia Books on Architecture and the City, 2016. 69.

35 Graham and Blanchfield, *Climates: Architecture and the Planetary Imaginary.* 69.

Fig. 3.24   Plastiglomerate A

Fig. 3.25   Plastiglomerate B

Fig. 3.26   Plastiglomerate C

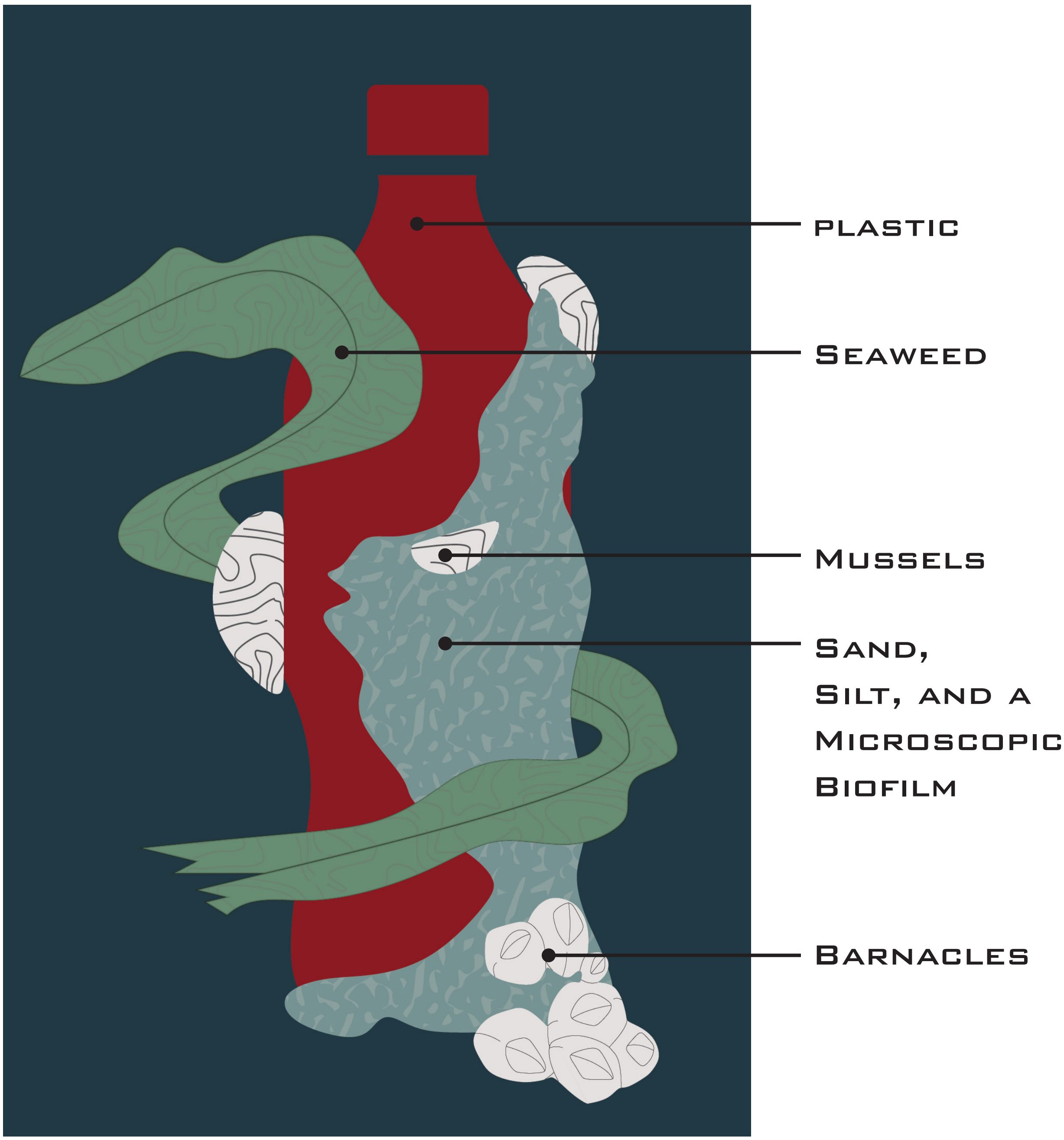

Fig. 3.27 Various Potential Components of Plastiglomerate

03

Chapter 3
Architecture and Water

Arkup 75 - "Livable Yacht"

Schoonschip - Space&Matter

Aircraft Carriers

Adapting Existing Technologies

The Ocean Cleanup Organization

The Pioneering Spirit

Self-Unloading Vessels

R/V Kilo Moana

Architecture and Water

The original intent of architecture was to provide an earthly tethered shelter from the harsh elements. The nature of architecture is that it is an ever-changing field, whose elements are constantly redeveloping themselves to better serve a particular function. These changes evolve generic working forms into a specialized assembly that strongly resists the local climate and provides comfort for the occupants. With most of the earth's surface being water, and sea levels constantly rising, what will architecture look like when it loses its earthly tether? The following subsections are an examination of existing and theoretical precedents that inspire the designs proposed in this thesis.

Arkup 75 – "Livable Yacht"

Florida's increasing prices for beachfront properties coupled with rising water levels has pushed coastal real estate prices to an all-time high. This has led to the partnership between the architecture firm Waterstudio and Arkup to begin designs for a new style of coastal living in Miami. The Arkup Liveable Yachts are self-propelled luxury villas that exist solely on the water, unrestrained by the conventions of terrestrial land. Through the adaptation of the jack-up oil rig's structural design, these floating residences blend the comforts of traditional, terrestrial design with the flexibility of aquatic vessels. In turbulent waters these structures can lift themselves out of the water to assist in negating the harmful effects of large waves.[36] As shown in figure 4.1, these luxury house-shaped yachts have the capacity to mobilize through

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36 Arnaud Luguet, Waterstudio. "Arkup 75 - Livable Yacht." Arkup & Waterstudio. Accessed January 29, 2021

the open water, but it is not recommended for travelling in water deeper than the structural systems allow. The Arkup system has focused on luxury aesthetics, the comfort of the individual, and maintaining the connection to the nearby cities.

By comparison, a larger structure would be able to break away from the dependencies of the city, yet the small size of these yachts restricts them to primarily shallow, coastal areas. Redeveloping an existing jack-up oil rig for a community of 200 or more residents is an entirely feasible endeavour that would create a more autonomous community. The fact that these structures would be able to effectively serve a meaningful purpose, is in question. It would be a wasted opportunity to restrict these structures to an extreme version of ocean-view property.

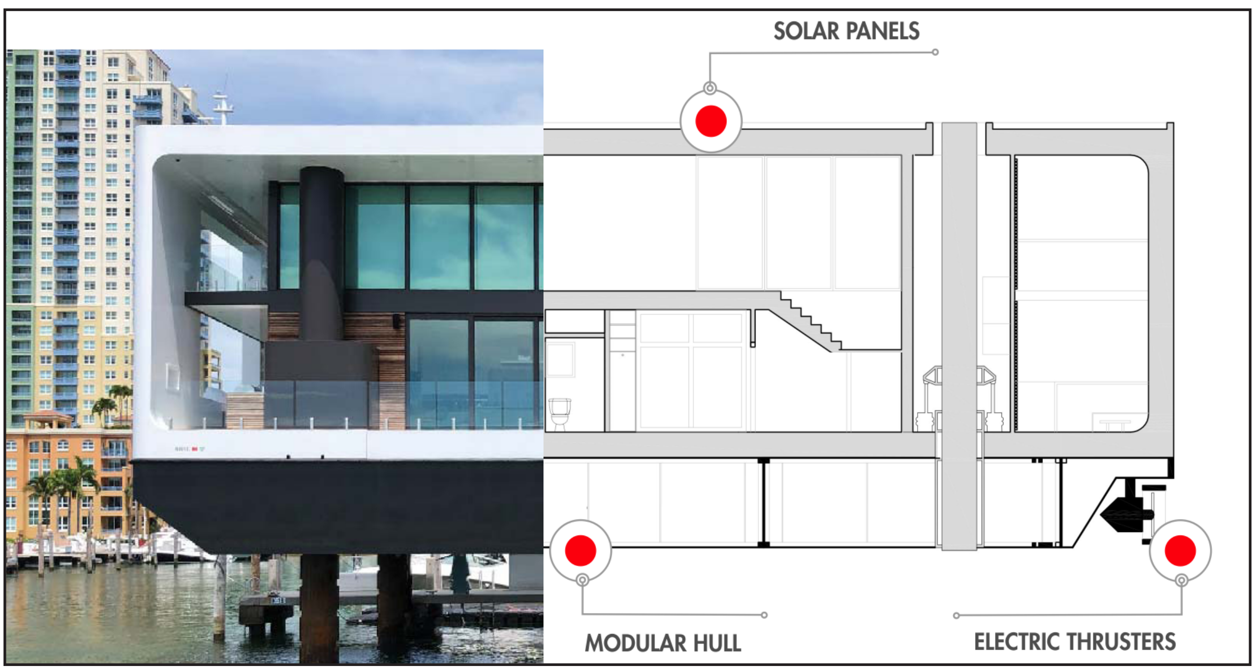

Fig. 4.1 Arkup 75 Technical Features Spliced with a Photograph

Schoonschip

Schoonschip is an Amsterdam based residential area with a unique twist. This aquatic neighbourhood is not a housing arrangement created by a project developer. It has been created and developed as a joint effort from its residents. As shown in figure 4.2, the Space&Matter team has worked with the residents to create a revolutionary, water-based urban plan for a small 46 dwelling community that houses over 100 residents.[37] This floating neighbourhood that first began development in 2011 is still being developed and expanded upon. Each dwelling is energy self-sufficient, capable of growing small amounts of food, and designed with sustainability in mind. The neighbourhood is still connected to the Amsterdam grid which allows them to supply their excess power to the city. This is a relatively small-scale intervention, thus requiring its inhabitants to remain dependent on the city to support a majority of their needs. At a residential-scale, complete self-sufficiency is difficult to properly execute. With its food and power resource generators handled by each resident individually, its potential is overshadowed by the convenience of the surrounding city. What are the requirements of a primarily independent system, and at what scale do the support systems need to be in order to completely sustain life? Is an entirely self-sufficient system reasonable or is there merit to having a dependency on outside resources?

37 de Blok, Marian and Space&Matter. "Schoonschip A Sustainable Floating Community." SPACE&MATTER. Accessed October 17, 2021. https://www.spaceandmatter.nl/work/schoonschip.

Fig. 4.2 An Aerial Photograph of the Aquatic Neighbourhood

Seasteading Institute

The Seasteading Institute is a global research initiative that is focusing on the logistics of initiating autonomous start-up communities that have the ability to float on the ocean. This California based organization is a multidisciplinary hub dedicated to the research of engineering structures on the ocean capable of maintaining permanent inhabitants. Currently, they are working through a series of large-scale independent pods situated in various locations such as Panama, California, and Brazil. By creating site-specific solutions, the Institute has developed an extensive variety of structural solutions. These solutions range from a small dwelling supported by a single structural column embedded into the ocean floor, to creating an ocean-based modular community of apartment-style pods, to a floating settlement that is reminiscent of life onshore.[38] An artist's vision of the floating settlement is pictured in figure 4.3. While some of the key research fields are within the engineering requirements of these ocean-based communities, there is also the probability of seeking political autonomy. This results in a unique living system outside of modern convention. Furthermore, these new societies will require a system of business that can regulate the importing and exporting of materials in order to sustain themselves. Embracing what it means for an architectural form to be unbounded from the conventional, the seasteading movement has the capacity to revolutionize the field of architecture.

38 "Active Projects." The Seasteading Institute. Accessed January 17, 2021. https://www.seasteading.org/active-projects/.

Fig. 4.3 Artist's vision for The Seasteading Institute: An Attempt to Communicate the Essence of Potential Future Ocean Civilizations

Oil Rigs & Offshore Platforms

The uncertainty of the ocean creates the potential for numerous typologies of design. As seen in figure 4.4, there are many unique forms that are specialized to the various conditions that may occur in the ocean environment, each with its own benefits and drawbacks. Oil rigs are semi-permanent structures that can easily be transferred to a new location. Contrastingly, offshore platforms are more permanent structures that cannot be easily moved after installation. Primarily constructed of various types of steel with older structures containing higher compositions of concrete, they are used for the drilling and extensive extraction of oil from vast underground reserves.[39] These platforms are designed for a lifetime of about 25 years of

39 Sadeghi, Kabir. (2007). An Overview of Design, Analysis, Construction, and Installation of Offshore Petroleum Platforms Suitable for Cyprus Oil/Gas Fields. 2. 1-16.

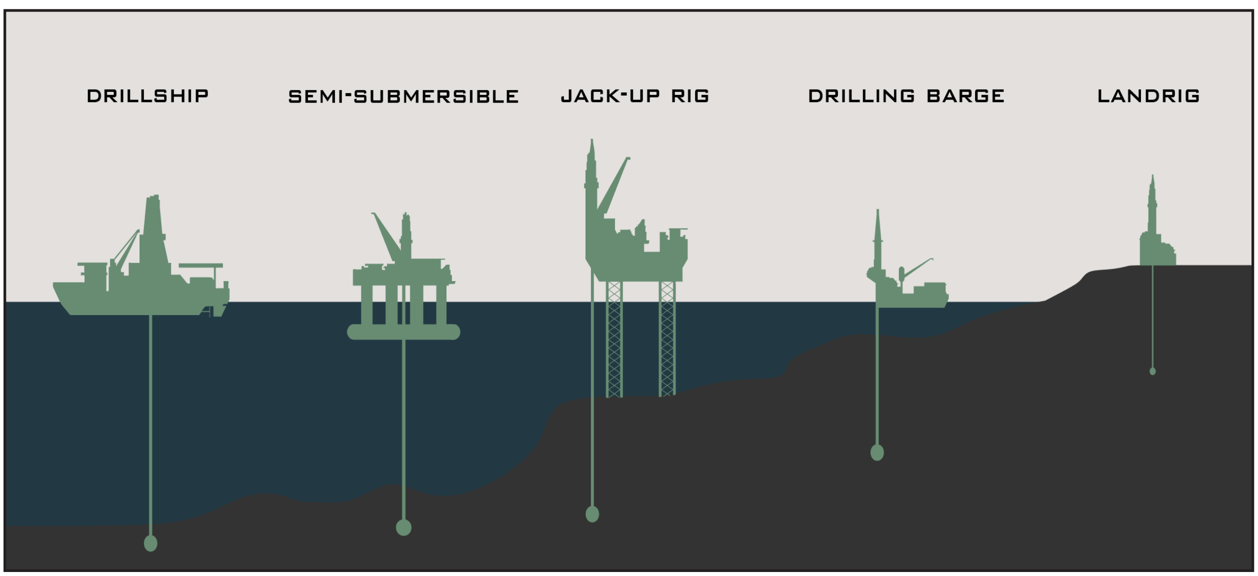

Fig. 4.4 Various Oil Rig Typologies.

constant operation. Offshore platforms are designed with the consideration for the extreme loading by hurricanes and constant, unyielding fatigue loads by the crashing of waves.

Aircraft Carriers

Modern aircraft carriers which are among the largest vessels in the world, are designed to sustain a crew of 6000, and operate continuously for approximately 50 years.[40] As seen in figure 4.5, these vessels are designed to act as a mobile forward operating base. Aircraft carriers are predominantly powered by a nuclear reactor that utilizes the immense heat and high-pressure steam released during fission to produce electricity for the vessel's operation.[41] The departure from standard diesel-powered engines has marked improvements on the vessel's efficiencies. Most notably is the reduction in refuelling requirements, as this system can operate uninterrupted for nearly 20 years without having to return to port for refuelling. There is no core design that these steel behemoths follow; their forms are altered and adjusted to adopt any emerging technological upgrades or to correct any mistakes learned from previous designs. This methodology means that "no two aircraft carriers, even of the same class, are quite alike," and that designs are constantly improving upon the last iteration.[42] The intricacies of an aircraft carrier's functions are facilitated through a strong network of connections that must communicate horizontally (across soldier squadrons),

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40 Aircraft carriers - cvn. (n.d.). Retrieved March 11, 2021, from https://www.navy.mil/Resources/Fact-Files/Display-FactFiles/Article/2169795/aircraft-carriers-cvn/

41 Nuclear submarines and aircraft carriers. (2021, March 03). Retrieved March 11, 2021, from https://www.epa.gov/radtown/nuclear-submarines-and-aircraft-carriers.

42 Rochlin, Gene I., Todd R. La Porte, and Karlene H. Roberts. "The Self-Designing High-Reliability Organization: Aircraft Carrier Flight Operations at Sea." Naval War College Review 40, no. 4 (1987): 76-92. Accessed April 11, 2021. http://www.jstor.org/stable/44637690.

vertically (from maintenance and fuelling, up through facility operations), and across the command structures.[43] This complex choreography is required to keep the day-to-day operations running smoothly. However, with so many moving parts the potential for the entire system to crash is incredibly high. This possibility of failure leads to installing as much redundancy into the system as possible in order to maintain successful day-to-day operations.

Adapting Existing Technologies

In the early eras of technology, horizontal movement has been primarily restricted to land-based caravans pulled by horses or similar beasts of burden. However, as technology advanced, so did humanity advance towards becoming a global community. The advent of maritime travel has dramatically

43 Rochlin, La Porte, Roberts. "The Self-Designing High-Reliability Organization: Aircraft Carrier Flight Operations at Sea." 76-92

Fig. 4.5 USS George H.W. Bush

altered all preconceived notions of transportation. Early maritime travel has consisted of only small vessels that had the capability to traverse across equally small, calm bodies of water with a very limited weight capacity. As time has progressed, so have the ship building techniques, with the size and quality of these vessels directly correlating to the owner's prosperity. Having a larger vessel means that more people and resources can be transported safely across larger bodies of water. Eventually, advancements have led to the ability to sail without concern in all water bodies, even open ocean. These advancements have contributed to the age of discovery, where nearly all major nation's ports have been able to be accessed on a global scale. However, advancements have not stopped after the age of discovery. Fleets of merchant ships have eventually evolved into massive, single vessels that carry thousands of large containers capable of carrying millions of products. These massive specialist ships are currently at the apex of their respective fields and the dramatic leaps of these technological revolutions have thankfully begun to transition into steps taken towards environmental consciousness.

The progression of ships from performing as generalist watercraft into task specialist has resulted in a variety of vessel shapes and forms that accentuate their purpose. This specialist approach to naval design has resulted in significant technological advancements that allow these ships to perform exceptionally well. Ideally, the vessel proposed in this thesis would be able to draw from this wealth of expertise and develop an amalgam that is greater than the sum of its parts.

The Ocean Cleanup Organization

The Ocean Cleanup is an organization that utilises a two-pronged approach to its goal of ocean remediation. Their early work focused on the removal of plastic that is trapped in the Great Pacific Garbage Patch. Now targeting the root of the problem, the organization has developed a river-based collecting boat that will autonomously collect the plastic before it has a chance to make it out to the ocean.[44] By actively targeting some of the most polluted rivers they are working with local governments to spread awareness and educate citizens about the importance of proper waste protocols while reducing the amount of plastic being swept into the open ocean. These preventative measures of removing plastic waste from the rivers before it has a chance to enter the vastness of the ocean is a key step towards a recovery. By combining action with an information distribution campaign, they not only seek to spread awareness but are also actively changing their surroundings.

To combat the plastic that is already in the oceans, they have been developing a series of ocean trawl collection systems. The following image (Fig. 4.6) shows the system 001/B in action. These systems densely consolidate oceanic plastic to be collected and returned to shore by the occasional boat. They are currently working on two approaches to this solution: passive and active collection. Passive trawling units are large, energy-neutral appliances, designed around utilising the ocean's natural currents as a means of consolidating most

44 The Ocean Cleanup. "The Interceptor." The Ocean Cleanup. Accessed September 26, 2021. https://theoceancleanup.com/rivers/.

surface and sub-surface (up to 2m below) plastics.[45] The modular appliance is designed to flow with the plastics on the water's surface at a different speed than the plastic. This differential creates a moving "wall" that ensnares the plastics. This appliance will be ideally released in appropriately spaced groups to cover a larger area in the open ocean. Since this is a passive system that moves at the will of the winds and waves, the appliance will need to be routinely inspected, maintained, and eventually repositioned if it drifts too far off its original course. Furthermore, the appliance is energy-neutral as all of the appliance's sensors and trackers are powered by marine-safe photovoltaic panels. The active system functions similarly to the first: a way of corralling loose plastic into a condensed area by creating an artificial coastline to "catch" the plastic. Contrasting the passive method of the first system, this is designed to be towed behind two small boats causing the

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45 The Ocean Cleanup. "Cleaning the Ocean Garbage Patches." The Ocean Cleanup. Accessed September 26, 2021. https://theoceancleanup.com/oceans/.

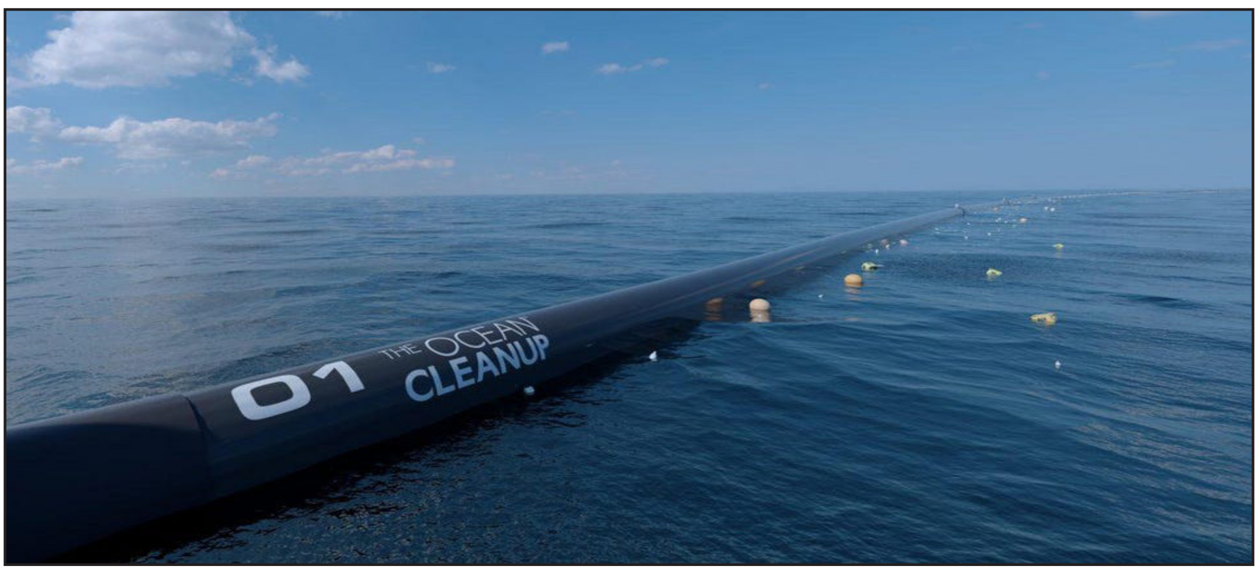

Fig. 4.6 Image of the System 001/B Plastic Collection Appliance

appliance to act as a scoop that will collect the plastic as the vessels move. This method of committing two vessels to work in tandem, is highly effective.

The Pioneering Spirit

The Pioneering Spirit, as seen in the following image (Fig.4.7), is a catamaran vessel that is primarily designed for the installation and removal of large offshore oil rigs. Being able to disassemble, lift, and transport thousands of tons of steel and equipment demands that this vessel is as robust as possible. The twin hull, measuring 382m long and 124m wide provides the ship with extraordinary inherent wave response behaviour.[46] However, the size and shape of the hull are not optimised to completely nullify the actions of the waves; in these instances of turbulence an additional active motion compensation system is engaged. These compensation

46 "Pioneering Spirit." Allseas. Accessed February 19, 2021. https://allseas.com/equipment/pioneering-spirit/.

Fig. 4.7 Arrival of the Pioneering Spirit in Rotterdam

systems, as well as all other systems are powered by eight diesel generators that work together to create a total of 95 megawatts of power used throughout the vessel.[47] The Pioneering Spirit's stability in turbulent waters stems from its dual hull design. In typical monohull vessels, there is always a risk of the craft capsizing in heavy seas, however, this risk is significantly reduced as more points of contact with the water are introduced. By expanding the waterplane surface area across a larger distance a storm surge must be exponentially more dangerous to create capsizing concerns in catamarans that are common in monohull vessels.

Self-Unloading Vessels

Self-unloading vessels are an improvement upon an already existing ship typology, the bulk carrier. A bulk carrier ship's purpose is to transport bulk goods, like rocks, salts, grains, or various ores. Whether ship-mounted or dock-mounted, these ships rely on cranes to scoop up materials, swing a portion of the total load from the ship to the dock, and then distribute it into a container. While the transportation aspect of bulk carriers is effective, their basic offloading system is slow, requires the calm waters of ports to transfer goods, and even then, is still prone to spillage causing environmental hazard. By using a boom-mounted conveyor system, self-unloaders can operate effectively in both ports and in offshore conditions. These conveyor systems are not only able to provide a fast, continuous flow of bulk material than the conventional crane systems, but they are also a completely enclosed system as seen in figure 4.8. An enclosed system

47 Allseas Group S.A. "Pioneering Spirit." Allseas Group S.A. Accessed February 19, 2021. https://allseas.com/equipment/pioneering-spirit/.

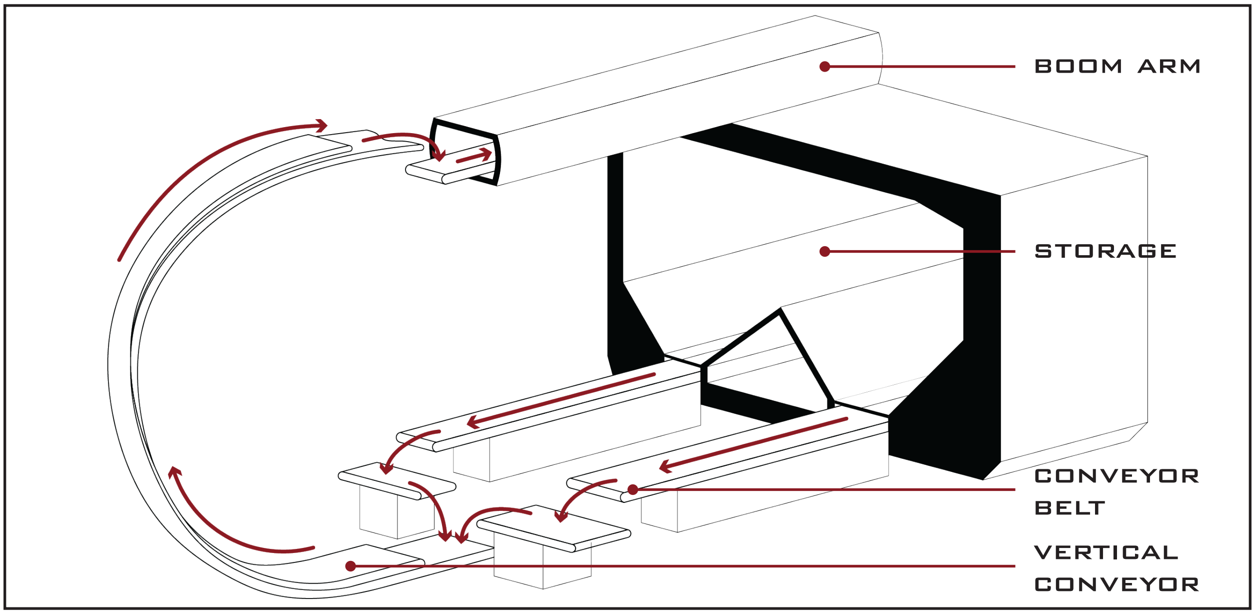

Fig. 4.8 Self-Unloader Conveyor Systems


Fig. 4.9 Self-Unloading Ship

means that there is no dust pollution, significantly reduced chance of accidental spillage, and higher accuracy when discharging material. The self-unloading vessel, pictured in figure 4.9, is a clear improvement on the bulk carrier in terms of efficiency and capability to minimize environmental impacts.

R/V Kilo Moana

The R/V Kilo Moana, pictured in figures 4.10 and 4.11, is a small waterplane area twin hull vessel (S.W.A.T.H.) that is owned by the U.S. Navy and is operated by the University of Hawai'i Marine Centre. This vessel's primary function is to assist the scientific community's exploration and data collection missions at the Marine Centre. The design of the boat is focused on a multi-purpose, oceanographic research vessel that is supplied with an extensive variety of equipment. Its ability to handle turbulent waters while maintaining stability is crucial as the scientific equipment onboard is not particularly robust and is highly susceptible to damage if the boat could not handle choppy water. Over 2500 square feet of space is provided in eight different laboratories and over 4000 square feet of exterior working space is available on the aft main deck and the forward 01 deck.[48] Since the boat is relatively small, the spaces available are optimised for a variety of scientific expeditions and equipment. Nevertheless, the main limiting factors of these expeditions are the small ship's capacity to store the required food and fuel.

48 R/V Kilo Moana. "R/V Kilo Moana." University of Hawai'i at Manoa School of Ocean and Earth Science and Technology. Accessed April 20, 2021. https://www.soest.hawaii.edu/UMC/cms/KiloMoana.php.

Fig. 4.10 R/V Kilo Moana at Sea

Fig. 4.11 R/V Kilo Moana at Port

04

Chapter 4
Design Characteristics

Design Characteristics

There are two primary methodologies when it comes to surviving the open ocean: a fixed offshore platform or a large ship. Where the platform uses brute strength to replicate a familiar, terrestrial landscape, large ships embrace a more flexible and responsive language of design.

Most fixed offshore platforms are static titans of engineering might, straining against the crashing waves often succeeding in replicating the stable conditions of solid ground. However, these static designs require relatively shallow water so that they can either be mechanically affixed to the seafloor or rest upon it due to their excessive mass.[49] Extensive studies, such as geotechnical reports of the intended site, are an installation requirement limiting the flexibility of the platform's placement. These key data figures are time consuming, but essential to decide on the design style as well as discern if extra stability is required.[50] Since most offshore platforms are fixed in shallow waters, they are intended to operate in their immediate area and this increased human activity can be highly disruptive to the surrounding seafloor ecosystems. To be moved to a new location they must be disassembled, carried, and undergo the disruptive installation process each time. To design a static recycling facility would severely limit the facility's sphere of influence, reducing its overall efficacy. Restricted to shallower and coastal areas of the ocean, there will be a need for several long-distance transportation systems working around the clock to keep a

49 Sadeghi, Kabir. "An Overview of Design, Analysis, Construction, and Installation of Offshore Petroleum Platforms Suitable for Cyprus Oil/Gas Fields." (Turkey: Girne American University, Department of Industrial Engineering, 2007), 4.

50 Sadeghi, "An Overview of Design, Analysis, Construction, and Installation of Offshore Petroleum Platforms Suitable for Cyprus Oil/Gas Fields," 10.

continuous flow of collected debris entering the recycling system. To construct a facility several kilometres away from the shore would be a nonsensical exercise. It would be more suitable to create a specialised recycling facility on the shore, close to the port, than to construct one several kilometres into the water. The fixed offshore platform's stability and size are unmatched, however its inability to function in deep water cripples its efficacy and renders these types of design precedents inapplicable.

The next step was to begin investigating ships that could remain on the move for extended periods of time and sustain a full crew. A ship is a highly mobile, hyper-specialised feat of engineering that is designed to efficiently serve the specific purpose of traversing the waves. From the humble fishing boat to hulking aircraft carrier warships, each vessel has a primary objective, to survive in the open ocean. After this initial requirement, there are nearly endless adaptations that allow them to fill a variety of nautical niches. The size of the vessel is also important as small boats are essential for navigating tight corners and shallow waters, however, they lack the deep-sea capabilities of larger ships. A large ship easily houses several small boats, and therefore, acts as a hub to and from which these smaller boats deploy. Since the small boats can be deployed at will, they do not need to be weighed down by long-term life-support items freeing up extra space for the task at hand. Smaller vessels have much higher manoeuvrability compared to large vessels, are closer to the water's surface, and will be able to interact with the Passive Trawl System with ease. Like a surgeon's scalpel, these boats would function as one of the ship's tools rather than a main habitation vessel.

There are many examples of large ships that have the capacity to deploy smaller boats effectively, however the autonomy, mobility, and variety of onboard instruments of aircraft carriers often places them in a tier all their own. These hyperdense vessels routinely prowl the seas through all weather conditions and can house heavy armaments and munitions, air and water vehicles, and sustain thousands of crew members at once. To emphasize long-term performance, these vessels are over-designed to perform effectively in even the most strenuous of situations. However, this is not a perfectly isolated system that is able to function entirely independent of outside help. While able to subsist for months without the need for a resupply, a trip to port or a supply ship exchange is inevitable. Military aircraft carriers are designed with a specialized nuclear reactor to surpass all the vessel's power needs. These highly refined reactors can last for upwards of 25 years without needing to refuel and many modern vessels are retired after a half century of service. Being able to repurpose a decommissioned aircraft carrier would allow for a long-lasting and durable recycling vessel. However, the carriers are very long and thin vessels which cannot turn or manoeuvre very easily and are susceptible to capsizing if a particularly strong wave were to hit the broadside of the vessel. There are both positives and negatives to repurposing an aircraft carrier, yet the creation of nuclear waste to remediate ocean plastic is highly counter-productive to the result of waste removal.

Blurring the line between ship and offshore platform, semi-submersible platforms are relatively mobile and capable of independently maintaining or altering positioning while able to be highly stable in deep sea conditions. These deep-sea platforms utilize a series of columns and pontoons that fill with water to control the depth of the platform similar to a ship's ballast tanks.[51] When the lower hull is submerged and filled with water, extra anchors can deploy to further increase stability in especially turbulent waters.[52] Since the stability requirements of a drilling platform are more significant than a large-scale recycling facility, it is possible to utilize an existing platform typology and adapt it to fit the nuances of its new role of a recycling facility. The adaptation of a large, semi-submersible platform was the original point of inspiration for the recycling facility's design. As these platforms are designed for a lifetime of about 25 years of constant operation in the deep ocean, there is thoughtful consideration for the harmful loading caused by extreme weather events and constant, unyielding fatigue loads by the crashing of waves. These highly stable structures can crawl across the ocean's surface but prefer to stay in the same location as much as possible. The design of these oil rigs are focused on creating a stable surface that remains primarily static over an oil well to allow for reliable extraction. It is highly unconventional to move them for long distances other than to position them over an immediately neighbouring well. While more stable than similarly sized ships and more mobile than its fixed platform counterpart, this inability to travel long distances severely impedes a deep-sea platform's ability to work effectively across the vastness of the ocean.

While the semi-submersible platforms are able to mobilize, they cannot traverse the open ocean as efficiently as their inspiration, the Small-Waterplane-Area Twin Hull (S.W.A.T.H.) Vessel. The unyielding effects of waves against a vessel's hull is a constant reminder that the ocean does not welcome

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51 Sadeghi, "An Overview of Design, Analysis, Construction, and Installation of Offshore Petroleum Platforms Suitable for Cyprus Oil/Gas Fields," 2-3.

52 Speight, James G. Handbook of Offshore Oil and Gas Operations. Amsterdam: Elsevier, 2015. 78.

our presence. Unlike typical monohull vessels, the design of S.W.A.T.H. vessels limit the cross-section of their hull that meets the water. This reduction in the waterplane area to dynamic wave action greatly improves its seakeeping performance, stability, and lowers speed reduction caused by rough water.[53] The wave's power is severely diminished below the surface and like submarines, the SWATH vessel also capitalizes on this fact. Waves are in constant motion and their strength directly correlates to their size above the water's surface. As seen in figure 5.1, the vessel's main platform is above the water's surface with most of the vessel resting on two stilt-like struts that connect to sub-surface pontoons. By moving most of the boat's displacement into submarine-like compartments the majority of the vessel rides out of reach of the turbulence caused by the waves. In so doing, this creates a compounding effect further increasing the vessel's stability without sacrificing significant amounts of mobility. Therefore, a SWATH vessel will become the foundation, a lightweight skeleton, upon which strategies from other nautical niches can be adapted to work towards a possible solution to the global plastic crisis.

Vessel Objective

What is the Vessel?

Our stoicism in the face of a global environmental collapse is founded upon our willing ignorance of the alternative. This thesis is a manifestation of a willingness to acknowledge our global scale of ignorant harm and to propose change

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53 Djatmiko, Eko budi. "Hydro-Structural Studies on Swath Type Vessels." (Thesis, University of Glasgow Department of Naval Architecture and Ocean Engineering, 1992), 26.

before the point of no return has been reached. An emerging seafaring vessel, this mobile, ocean-based recycling facility will monitor, collect, and recycle the plastic waste in the Pacific Ocean. Applying already existing technologies and naval designs will bring a breath of realism into this design and attempt to anchor it in the realm of immediate future possibility. My design for a mobile, ocean-based recycling facility will be able to cover large distances and basing the design in the style of a small-waterplane-area twin hull (S.W.A.T.H.) vessel will provide a stable experience in all but the worst of weather conditions. A stable environment is critical for the operations of the interior machinery as well as the long-term comfort of its occupants. Actively seeking out and removing the plastic with just a fleet of ships is incredibly difficult due to the relationship between the dynamic nature of the ocean's currents, the designed resiliency of plastic, and the vastness of the impacted area. The ocean can harbour many scenarios where the plastic can hide. The plastic is also very adaptable and alters its forms depending on how it is interacting with the surrounding area. The most buoyant plastics float to the surface while others hang in between the surface and ocean floor.[54] To actively track, capture, and remove the plastic in all forms at all levels of the ocean would require a perpetual effort. Therefore, a perpetual passive collection system coupled with an active recycling vessel will compound the already large-scale of the sphere of influence without rapidly exhausting resources. As seen in figure 5.2, there are seven key points that influenced the overall design of the vessel: structure, future growth, purpose, design, production, power, and autonomy. Each of these sections influenced the design of the vessel and together, are greater than the sum of their parts.

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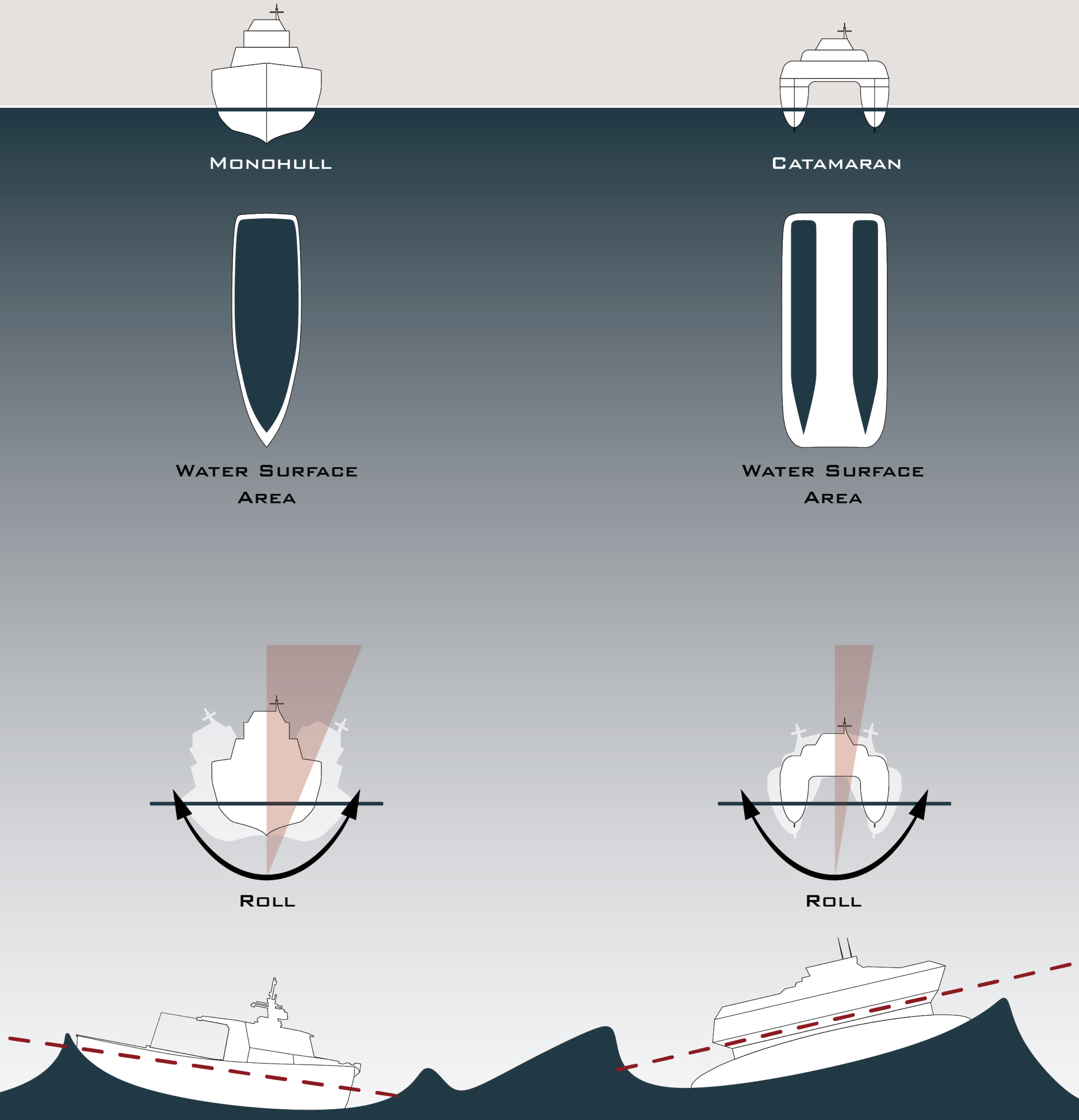
54 Andrady, "Microplastics in the Marine Environment." 1599

Fig. 5.1   Comparison of different hull designs.



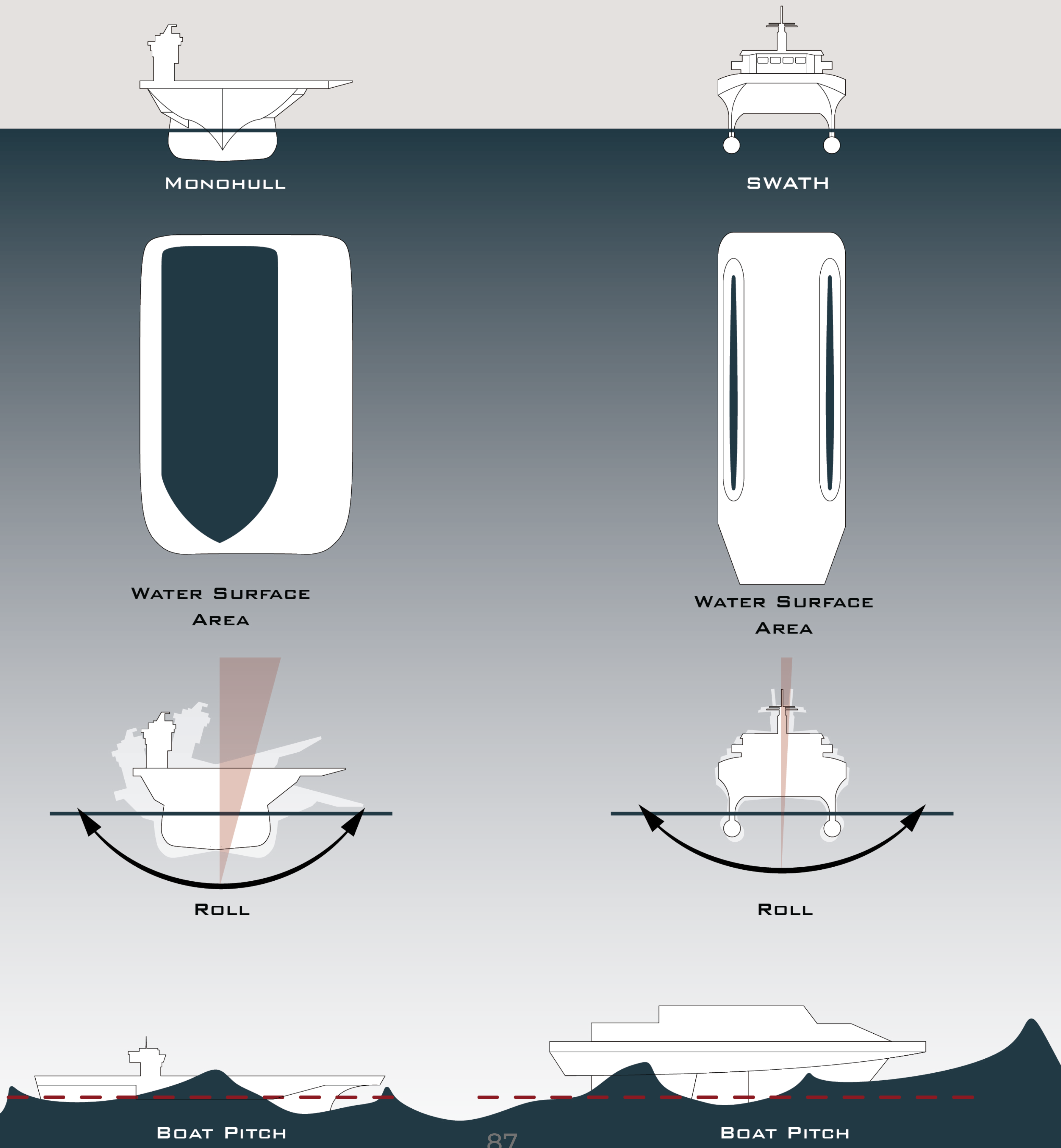
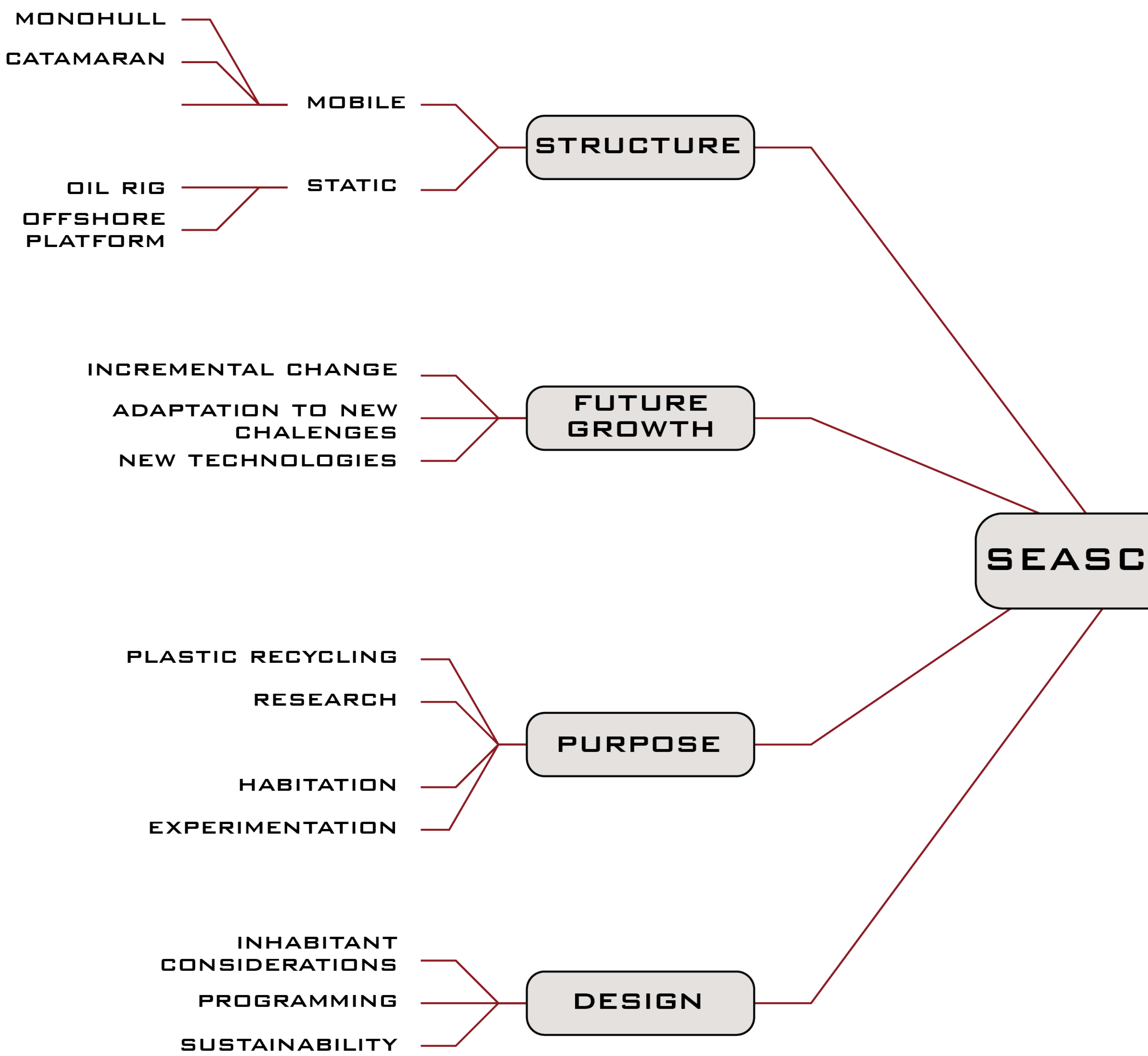
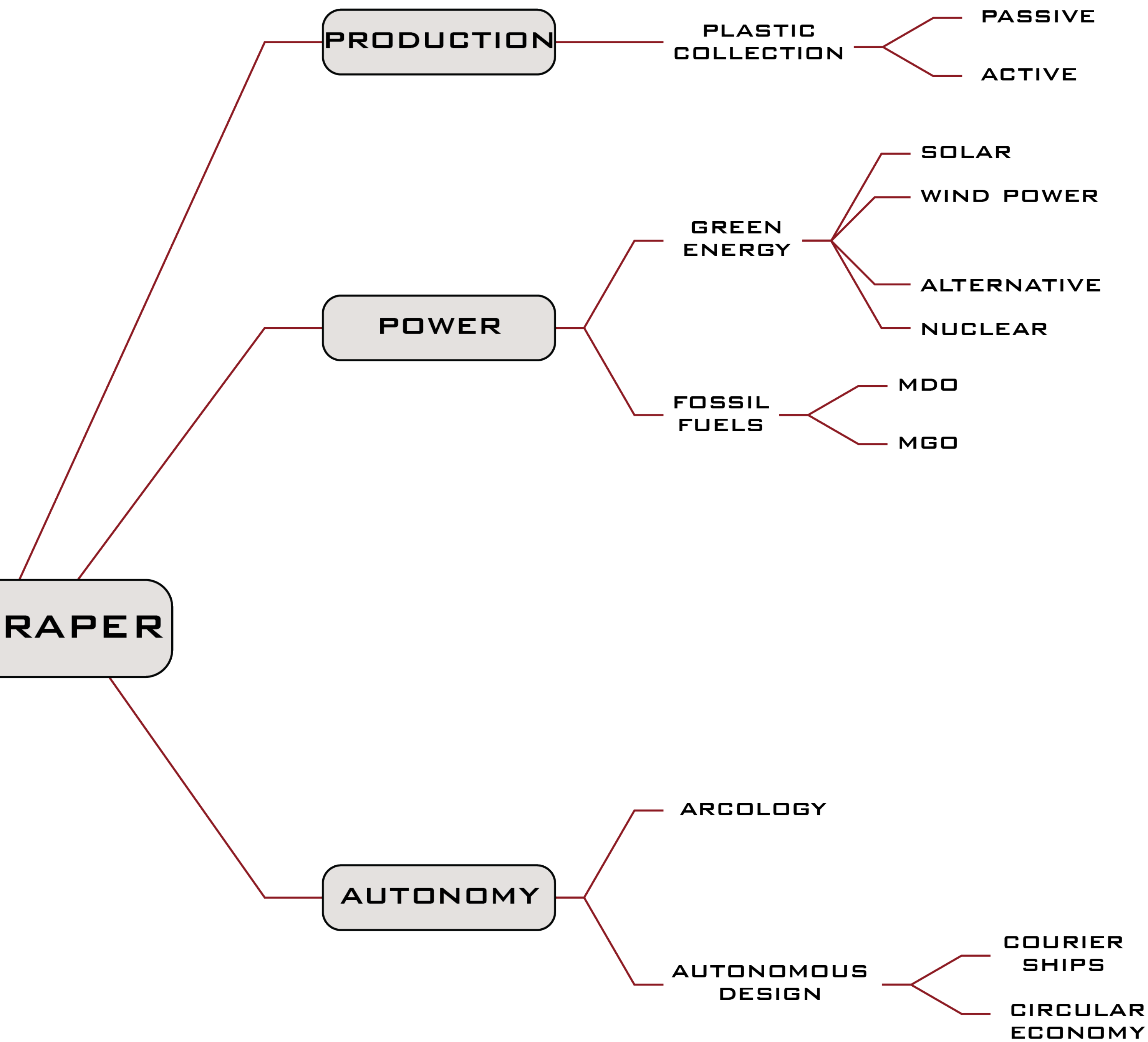

Monohull
SWATH
Water Surface Area
Water Surface Area
Roll
Roll
Boat Pitch
Boat Pitch

Fig. 5.2 Design Characteristics




RAPER
PRODUCTION
PLASTIC COLLECTION
PASSIVE
ACTIVE
POWER
GREEN ENERGY
SOLAR
WIND POWER
ALTERNATIVE
NUCLEAR
FOSSIL FUELS
MDO
MGO
AUTONOMY
ARCOLOGY
AUTONOMOUS DESIGN
COURIER SHIPS
CIRCULAR ECONOMY

Since this vessel will be out at sea for extended periods of time, it is important to incorporate elements of self-sufficiency to reduce its dependency on the resources acquired from the shore. Some of these elements will take the form of on-site power generation, food production and water desalination. The plastic collection systems will be adopted from the brilliant work of The Ocean Cleanup Organization's Ocean Trawl Systems. This method capitalizes on the cyclical nature of the Plastic Purgatory Principle, skimming the surface and immediate subsurface for plastic, corralling it until it can be collected.

What can the Vessel do?

Since this is a prototype vessel design, the recycling infrastructure will be the primary focus of the vessel with a majority of the functions focused on the collection, cleaning, and appropriate disposal of ocean plastics. Harvesting plastic from the vast ocean is no easy task. Therefore, a series of passive and active ocean-plastic collection systems inspired by the designs of Boyan Slat will be used as the primary harvesting tools. Smaller, more manoeuvrable boats will be deployed to interact with these collection systems, functioning as worker bees, collecting resources, and returning to the "hive." Through the use of clever manipulation of ballast tanks, SWATH vessels can control their height above the water's surface. This ability to alter the ship's height above the water's surface will make the interactions between the large vessel and its smaller support vessels easier. The recycling aspect of the vessel will consist of full-sized and partially automated recycling systems to handle the constant depositing of collected plastics. All plastic that undergoes mechanical recycling into a pelletized state will be stored until a large quantity can be unloaded onto a courier ship. Adopting the self-unloading style crane system for ship-to-ship recycled plastic transference in the open ocean will ensure that discharging operations occur quickly and without spillage. Left to the churning sea for many decades, some plastics have deteriorated so much that they have become unrecyclable, however this does not mean that it is entirely useless. Plastic that is unrecoverable will be cleaned and used as feed stock for energy recovery through pyrolysis. This will require significant space for the large processing equipment as well as storage for the plastic and post-plastic resources.

The scientists and researchers are a parallel community aboard the vessel that will focus on data collection and experimentation. Monitoring and tracking not only the plastic debris' behaviour but also its impacts on wildlife over extended periods of time. Due to the vessel's extended periods at sea, the deployment of drones, monitor buoys, and diving expeditions can occur freely and frequently. Between the data collected through satellites, deployed equipment, and onboard sensors, it is an invaluable asset to have on-site observers to analyse this data in real time.

The scientific community will be able to access interior and exterior staging spaces to prepare equipment as well as examine collected materials and specimens. Climate-controlled laboratory spaces are essential as the salty sea air can be damaging to the delicate equipment. The permanent and semi-permanent positions of researchers onboard the vessel will provide opportunities for post-secondary student engagement. Graduate researchers can spend extended periods aboard the vessel to obtain invaluable first-hand experience working alongside marine scientists in the field such as marine biologists, oceanographers, and environmental scientists. This mixture of professionals and students working together will create an intergenerational workforce that are physically present striving not only to understand and record the current conditions, but also experiment on possible solutions to expedite the remediation of the problem.

As seen in figure 5.3 the recycling teams and the scientific community are not the only crew members aboard the ship. Without the tireless efforts of the operational staff the vessel would not be able to function effectively and would surely fail. These crew members are the backbone of the ship, keeping the operations streamlined and the plastic, food, and people flowing. The operational staff are tasked with the locating and collecting of ocean plastic. A task requiring constant vigilance, they must track the shifting concentrations of plastic, plot an efficient course, and operate the collection boats to obtain the plastic. The coordination of main vessel and the recycling boats is not this teams only concern. Since this vessel is not a pure arcology it will require an additional supply line in the form of courier vessels.[55,56] These couriers will act as the vessel's main connection to the shore restoring its depleted food stocks, changing out personnel, and removing its waste. Moreover, the operational staff are responsible for the ongoing maintenance of the vessel as well as taking care of the needs of its occupants. These tasks ensure that the day-to-day operation of the vessel runs smoothly and

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55 Paolo Soleri introduces a new perspective for urban living: The Arcology. An arcology is represented as a combination of architecture and ecology, a city sized organism that is intended to exist in harmony with nature. Where in nature, evolving organisms increase in complexity and become a compact system, a city should evolve and densify in a similar fashion.

56 Soleri, Paolo. Arcology: The City in the Image of Man. Cambridge: The MIT Press, 1969.

Fig. 5.3 Potential Resident Distribution

allows the primary and secondary functions of recycling and scientific research to continue, unencumbered.

Design Framework

Plastic Collection

The Ocean Cleanup Organization is constantly designing, testing, and redesigning new ways to collect the waste plastics from the ocean. With two iterations of their ocean trawl systems comes two different methods of collection. The first method is a passive system where, once set up, can function independently for some time. A modular system will float along the currents of the ocean, passively corralling the surface plastics. A cross-section of this design is illustrated in figure 5.4. The second method builds off the ideas of the first, while taking a different approach to collection. Rather than being a purely passive system, it is instead pulled by two boats. As it scrapes across the ocean's surface, plastic is collected in a similar style to that of fishing nets. Once enough plastic is captured, the containment unit is sealed, hoisted onto one of the boats, and everything that was collected is sorted while the whole process begins again. Plastic collection trawls will target surface plastics. Their vertically compact design allows the surface-dwelling wildlife to easily avoid these mechanisms and swim beneath.

Both methods can be employed to function in unison towards the ultimate goal of plastic removal. Autonomously floating throughout the waters, large arrays of passive collection trawls can be left to collect plastic. While the bulk of the collection trawls is passive, the main Seascraper vessel is able to equip up to three separately operating active trawls that can be

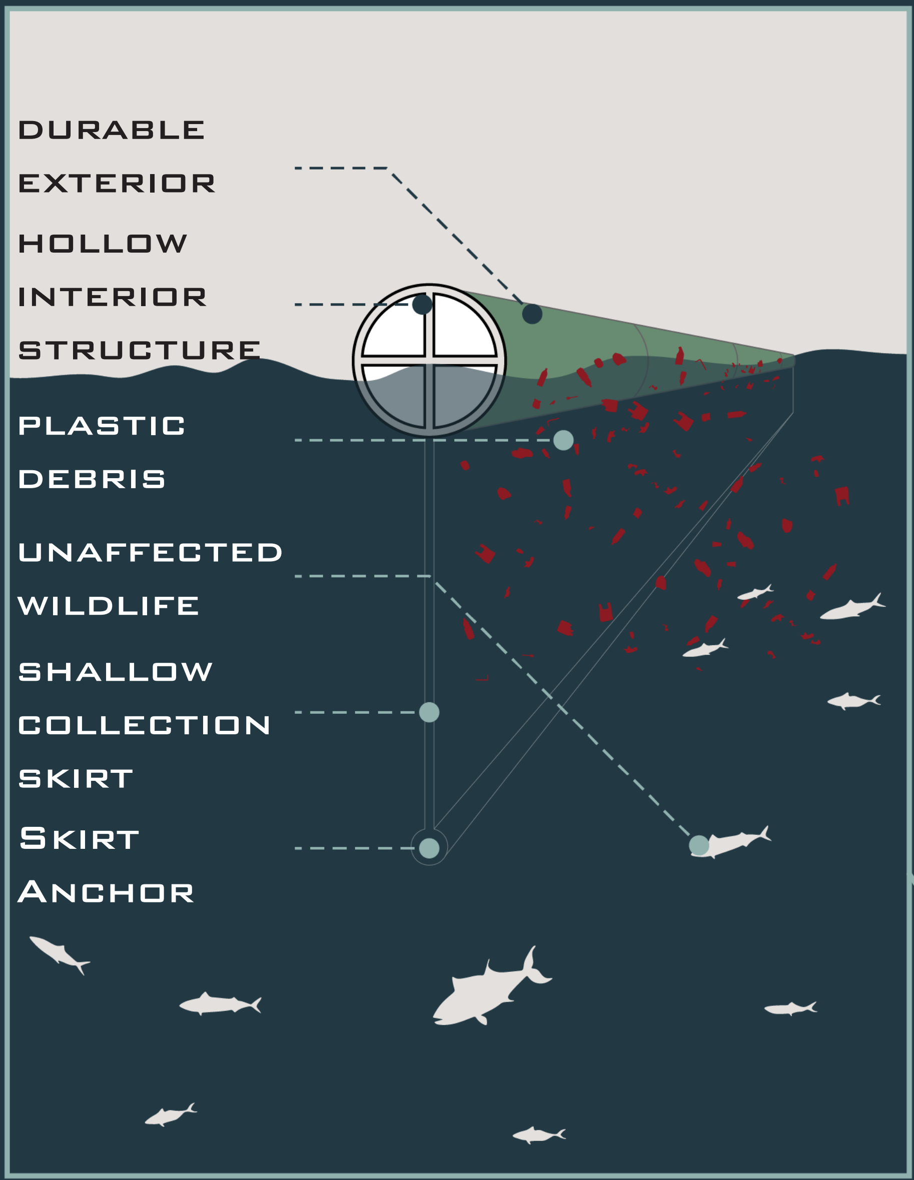
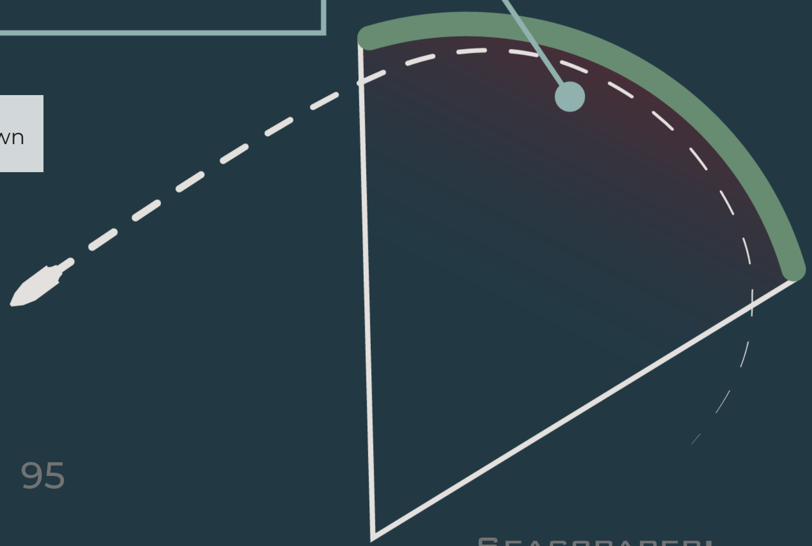


Fig. 5.4 Plastic Collection Trawl Component Breakdown



deployed between array fields. Moreover, the Seascraper and its deployed vessels will greatly benefit from an onboard mechanic and workshop for at-sea maintenance and repair needs. This asset should not be limited to just the vessels. By storing spare components, the collection equipment can be repaired at sea by the very same mechanics and fabricators. This would dramatically reduce the collection equipment's dependency on the original facilities where they were made.

The collection zones, illustrated in figures 5.5 and 5.6, are intended to create a circuit for the Seascraper to navigate through the Great Pacific Garbage Patch. Since ocean plastics are not restrained to the Great Pacific Garbage Patch the Seascraper vessel must also plan to expand its area of influence outside of the Patch. Time spent traveling to a new location can be used for recharging the collection boats, conducting inspections, or even actively collecting plastic in the formation shown in figure 5.7. Figure 5.8 illustrates that, when not in use, the collection boats are typically stored on the rear deck of the Seascraper. As seen in figures 5.9-5.11, once among the trawls, the smaller collection boats are deployed and begin to collect plastics, inspect the trawls for damage, and reposition them if necessary. The smaller boats are able to easily interact with the surface plastics and temporarily store them until they can be offloaded. Once the plastic is collected by the ship's boats, it undergoes very basic sorting to ensure that no wildlife has accidentally been caught. Afterwards, it is placed into containers that are then hoisted up to the main ship through the extendible conveyors on the rear of the vessel and emptied onto the pre-screen platform. Large, bulky plastics that are ensnared in netting are manually cut loose as well as any remaining organic or nonrecyclable matter is removed. The plastic is then rinsed of any residual salt water, dried and then sent off to the next stages of sorting.

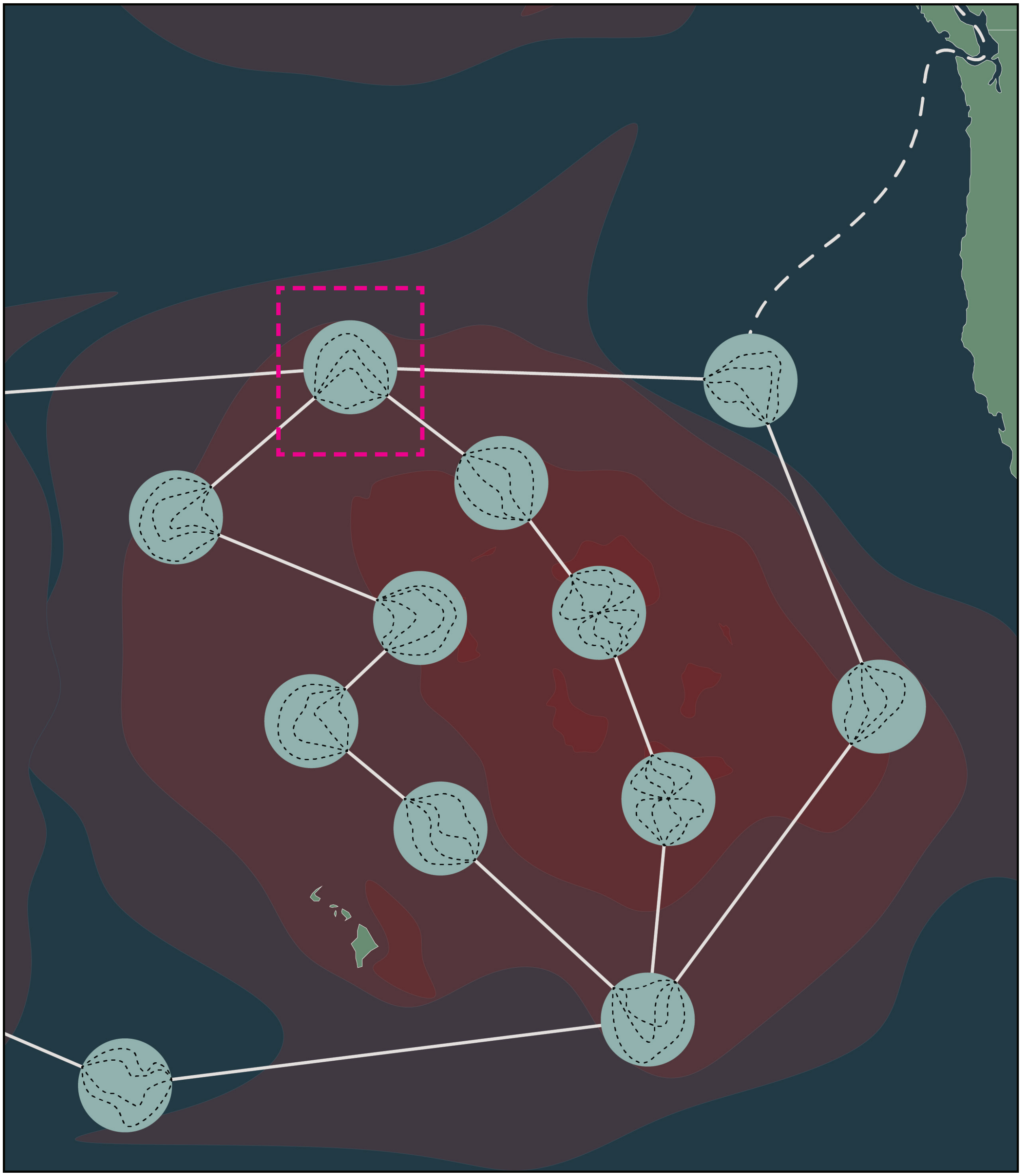


Fig. 5.5 Concentrated Collection Points in the Patch

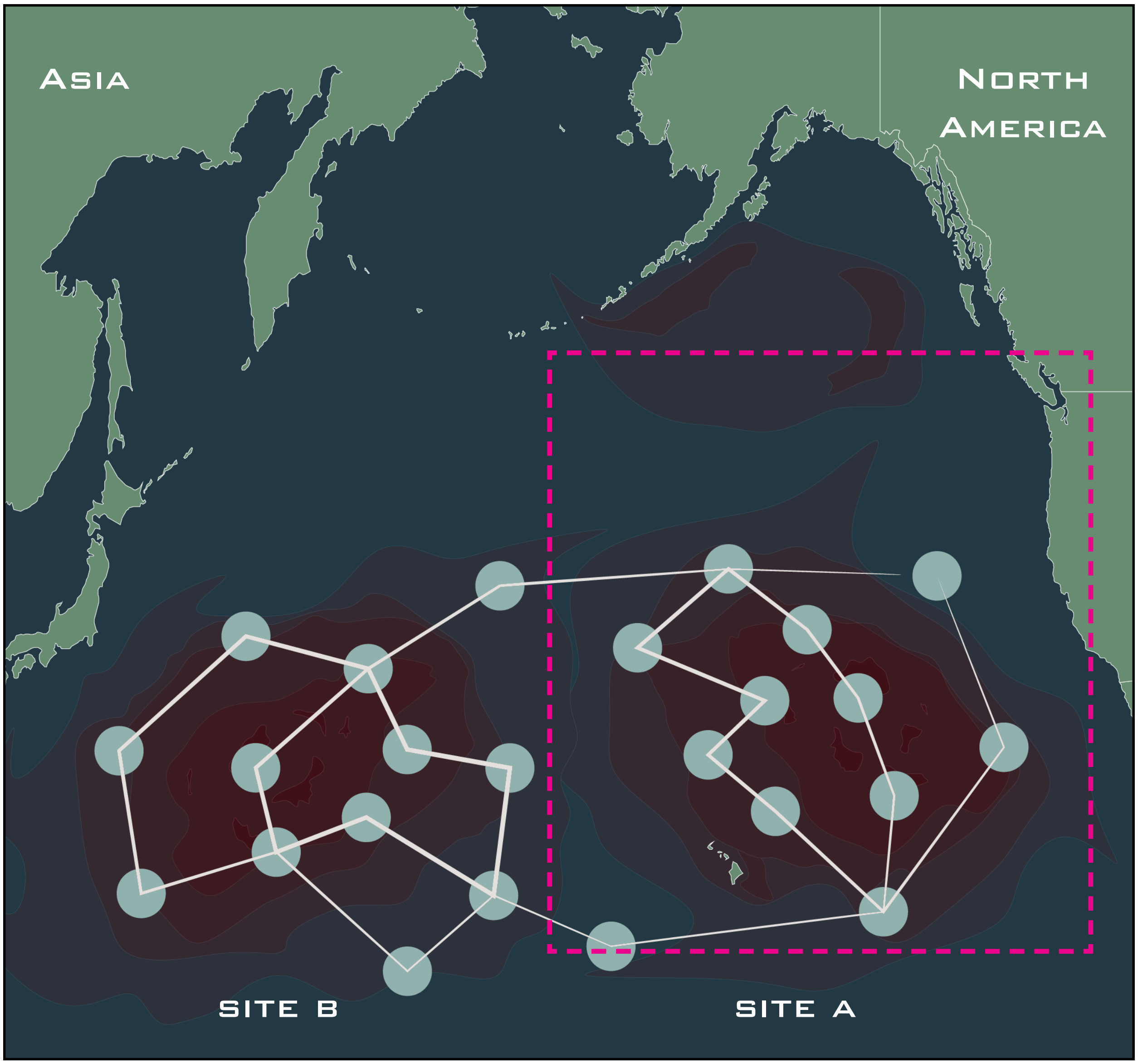


Fig. 5.6 Concentrated Collection Points in the Pacific Ocean

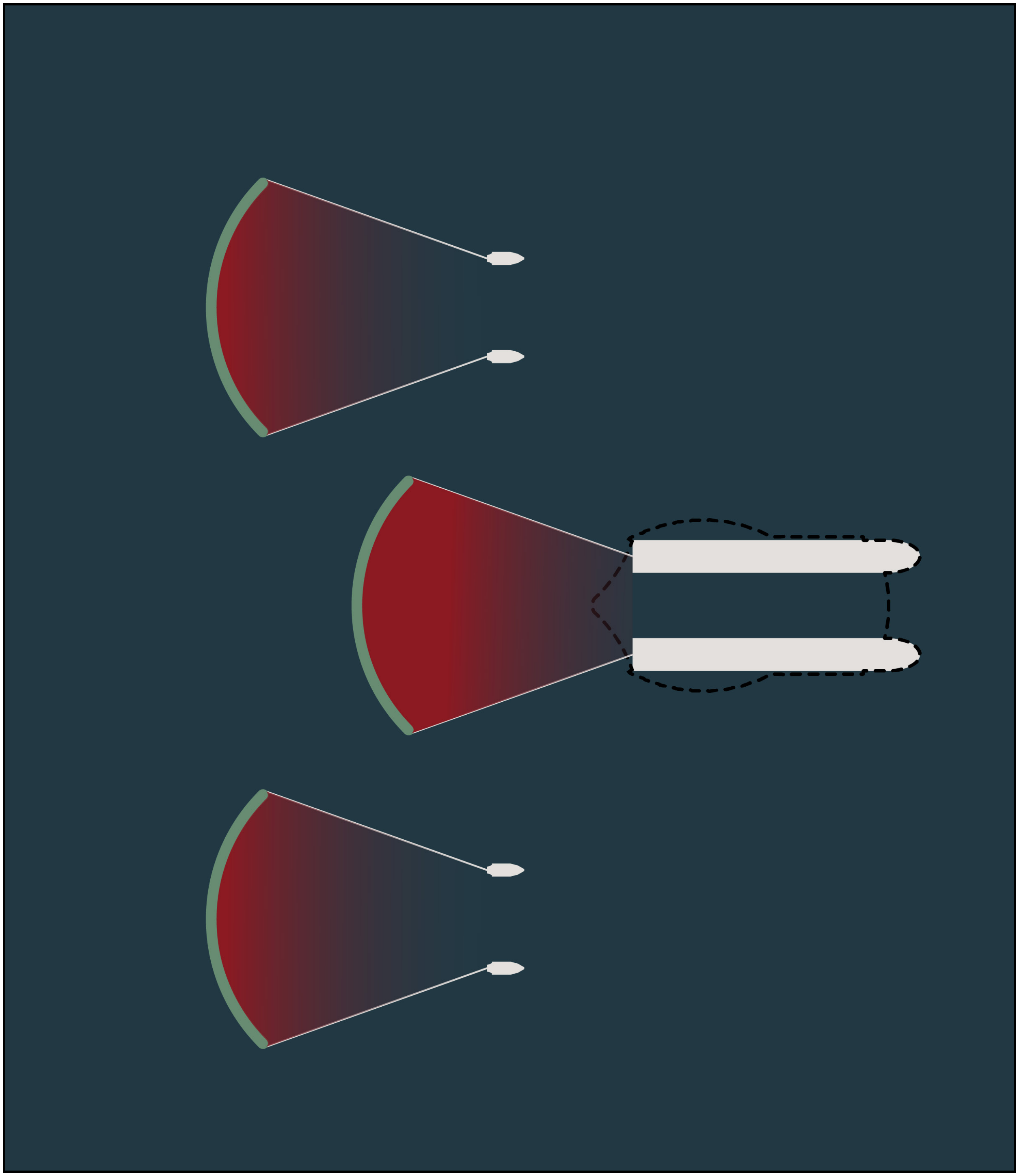


Fig. 5.7 Pictured is the active collection process.

Fig. 5.8 The Seascraper vessel circulates the pacific ocean.

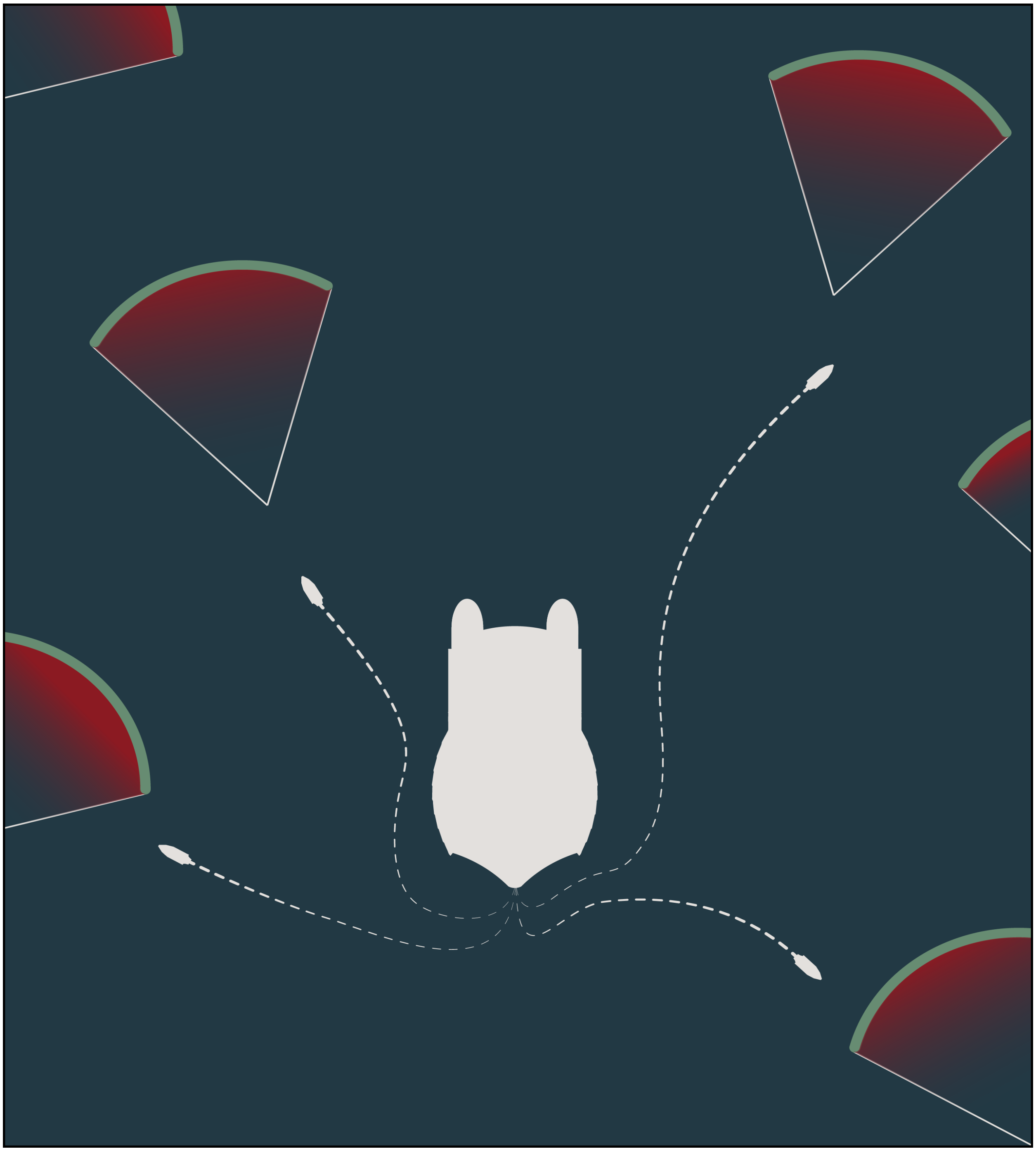


Fig. 5.9 Collection Vessels are deployed from the main ship.

Fig. 5.10 Smaller boats interact with the trawls without risking damage.

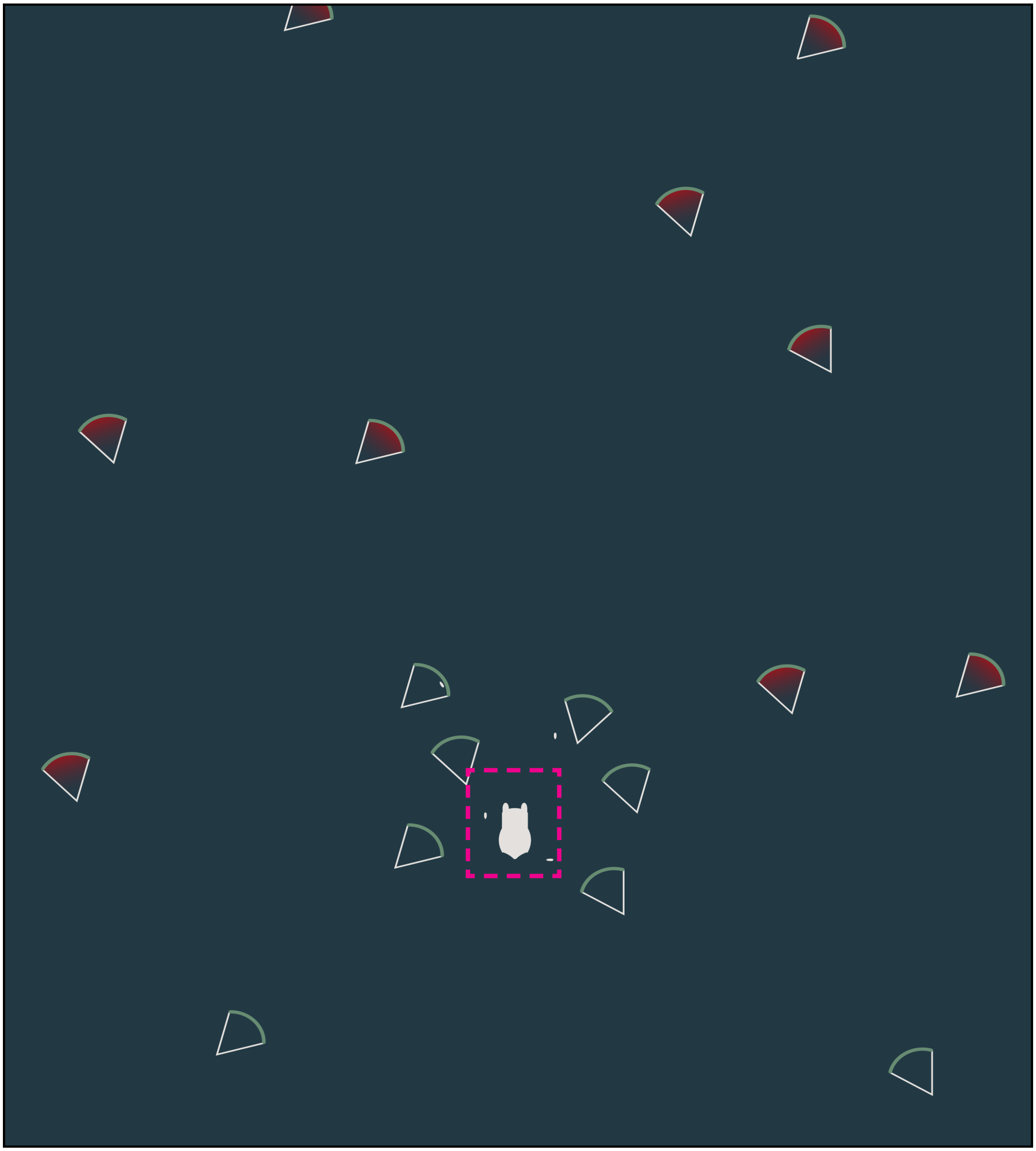


Fig. 5.11 The collection trawls will be deployed far apart.

The Ship's Boats

The ship's boats play an essential role in the collection of plastics. Deployed from the large main vessel, these boats are the larger ship's primary means of interacting with the water's surface. Smaller monohull boats are more capable of deftly manoeuvring through the water than their larger counterpart. This sea-faring dexterity allows them to close the gap and collect directly from the trawls. However, there is no universally proven method that can perfectly optimise the collection of plastic from the water. Just like a tradesman does not solely rely on a single tool to complete their job, I believe that the ship's boats must be equipped for a variety of collection methods. Since there are many different forms of plastic in the ocean, relying on a "one size fits all" approach is short-sighted. Therefore, there is a demand for several unique approaches to the removal of plastic. First, by adopting the seiner style of fishing vessel we can utilize existing fishing practices and apply them to the newly aggregated surface plastic.[57] Pictured in figure 5.12, this strategy of using nets and vessel manoeuvring would be ideal for collecting large quantities of higher grade plastic waste, however some plastic would inevitably fail to be collected as its plastic retention capacity is directly related to the size of the net's holes. Alternatively, the Ocean Cleanup Organization has created a plastic interceptor. Primarily utilized to prevent the plastic deposited into some of the most polluted rivers around the world from entering the ocean, this mostly stationary design can be altered to accommodate travelling on the open seas. This boat uses a conveyer belt system, as seen in figure 5.13, that constantly pulls plastic from the

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57 Seine fishing, an ancient fishing technique, is when the fish are captured by a net that hangs vertically in the water.

water into on board storage containers. While this design is ideal for small to medium sized plastic waste, dense clusters of plastic enmeshed in discarded fishing nets may be too large to be collected by this method. A third option is to use a series of modified skimmers that can pump a slurry of water and plastic onto a sluice system that will separate the water from microplastics, as seen in figure 5.14. The skimmer draws in a mixture of water and plastics and uses increasingly finer filters to separate the water from the plastic. The plastic collection capabilities of the pump skimmer are more appropriately suited towards removing the smaller particulates and is even capable of collecting micro plastics. Like worker bees foraging for resources and returning to the hive, these smaller boats are vital to the collection, storage, and transfer of plastic to the larger vessel's recycling system.

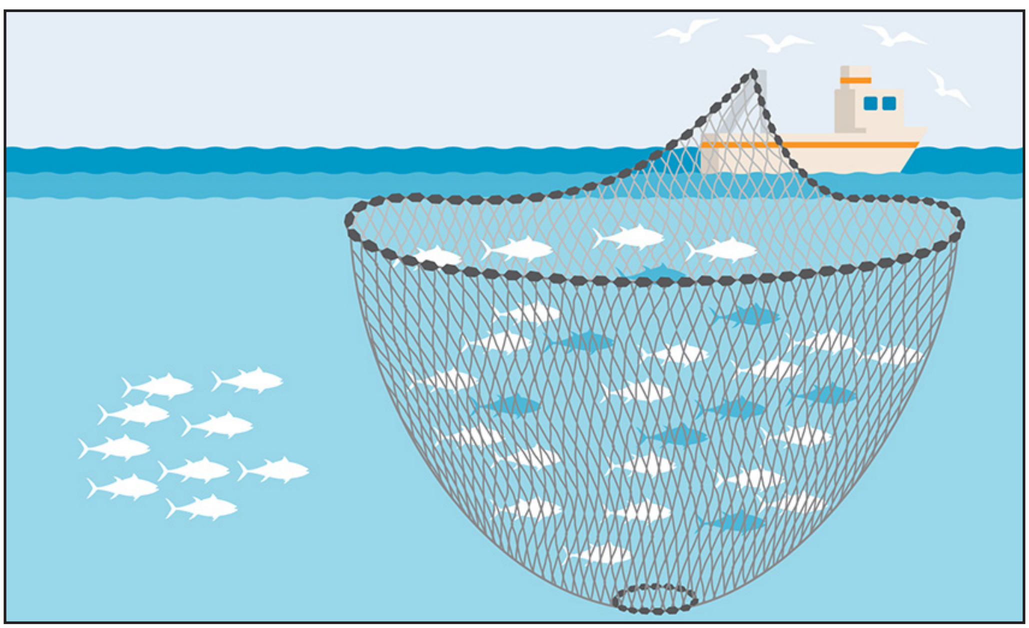

Fig. 5.12 Ship's Boat Picture 1: Purse Seine

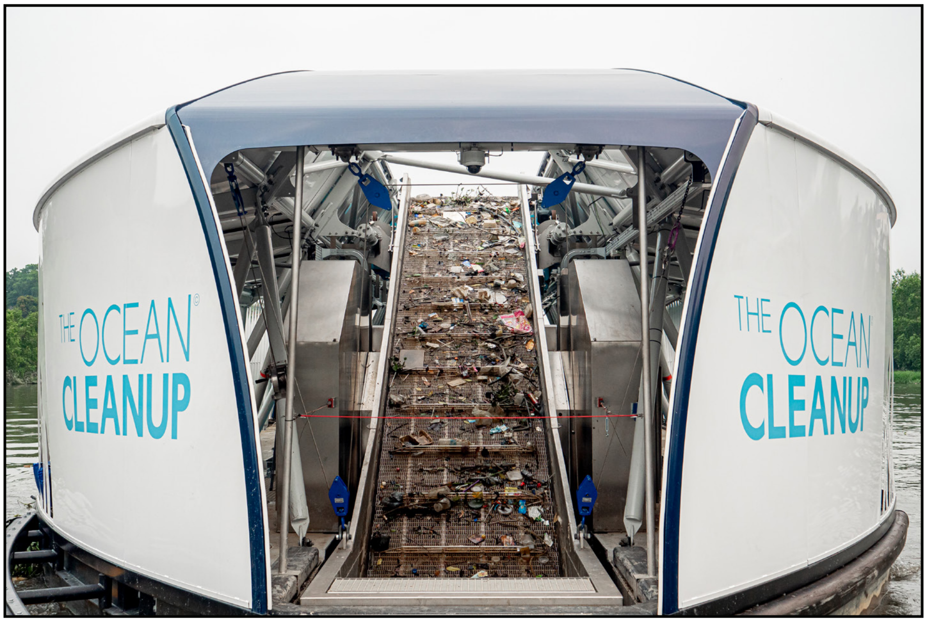

Fig. 5.13   Ship's Boat Picture 2: River Interceptor

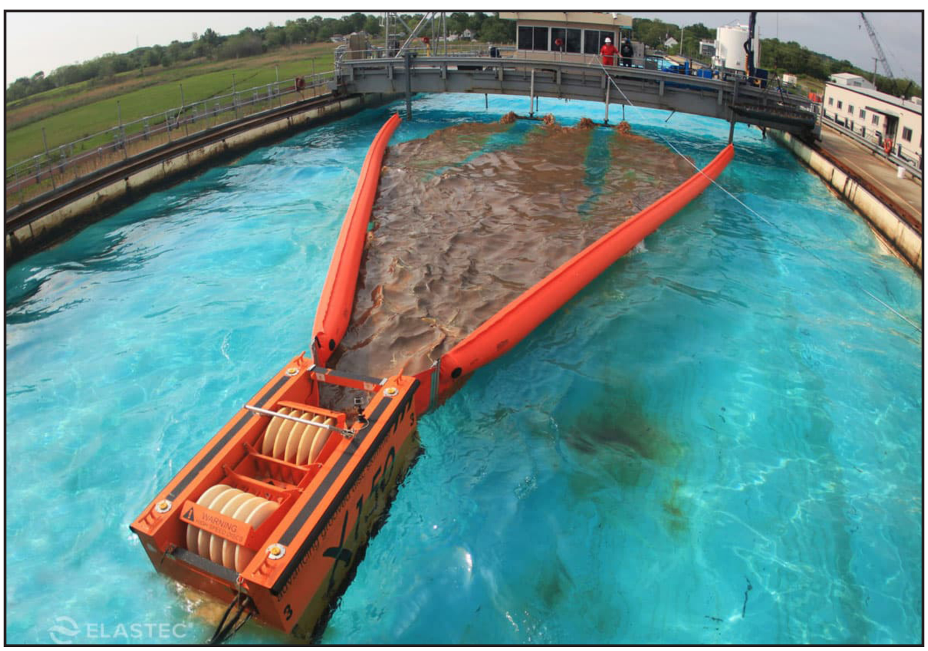

Fig. 5.14   Ship's Boat Picture 3: X150 from ELASTEC - Base for the Skimmer Pump.

Recycling Process

The ocean is a harsh environment that immediately begins to alter anything that enters its waters. After spending up to several decades in the churning water the plastic becomes ensnared in either a biotic or an abiotic contaminant. This contaminant must be removed otherwise it will compromise the final recycled product. Plastic waste is a broad term that encompasses a myriad of variations such as high-density polyethylene (HDPE), low-density polyethylene (LDPE), polypropylene (PP), polystyrene (PS), and polyvinyl chloride (PVC). Each of these variations are designed with specific strengths and weaknesses. To blindly recycle all the types together would result in a poor-quality product that cannot be used and would be immediately discarded. Furthermore, the collection of waste materials from the ocean does not guarantee that particular plastic variations are collected evenly or of suitable quality to be safe for reuse. Therefore, there must be a duality in the approach of recycling this waste with an emphasis on proper sorting. Figures 5.15-5.18 are schematic renderings of the collection and sorting process.

The complex recycling processes begin after the plastics have been cleaned and dried. Sorting can be achieved through tribo-electric separation for materials smaller than 5mm (micro plastics), froth floatation in order to separate PVC and PET, and FT-IR (Fourier transformed infrared technique)[58] for the remainder.[59]

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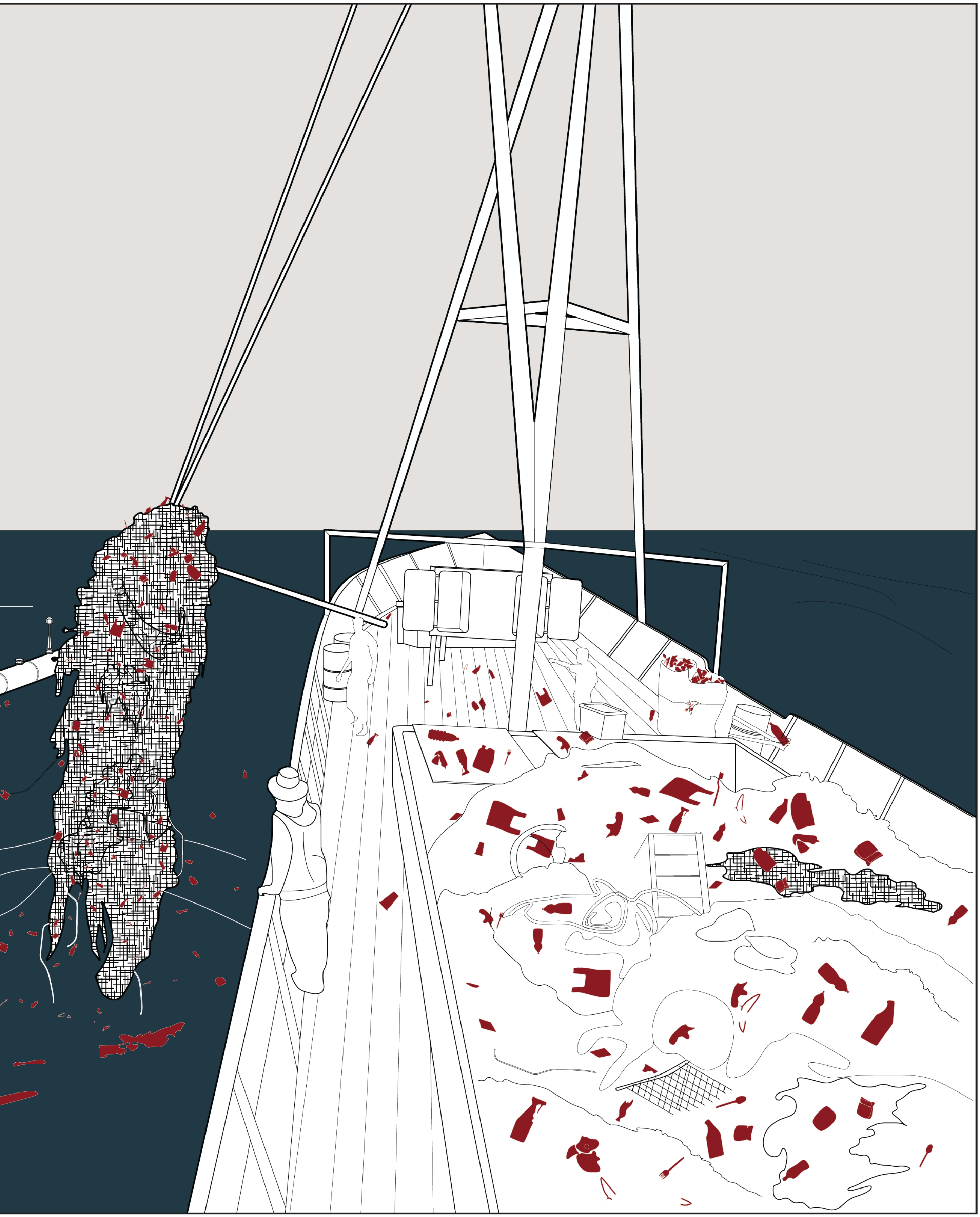
58 FTIR spectroscopy is used to identify compounds such as compounded plastics, blends, fillers, paints, rubbers, coatings, resins, and adhesives.

59 Singh, Hui, Singh, Ahuja, Feo, and Fraternali. "Recycling of Plastic Solid Waste: A State of Art Review and Future Applications." 413.

Fig. 5.15 Waste Collection from the Ocean



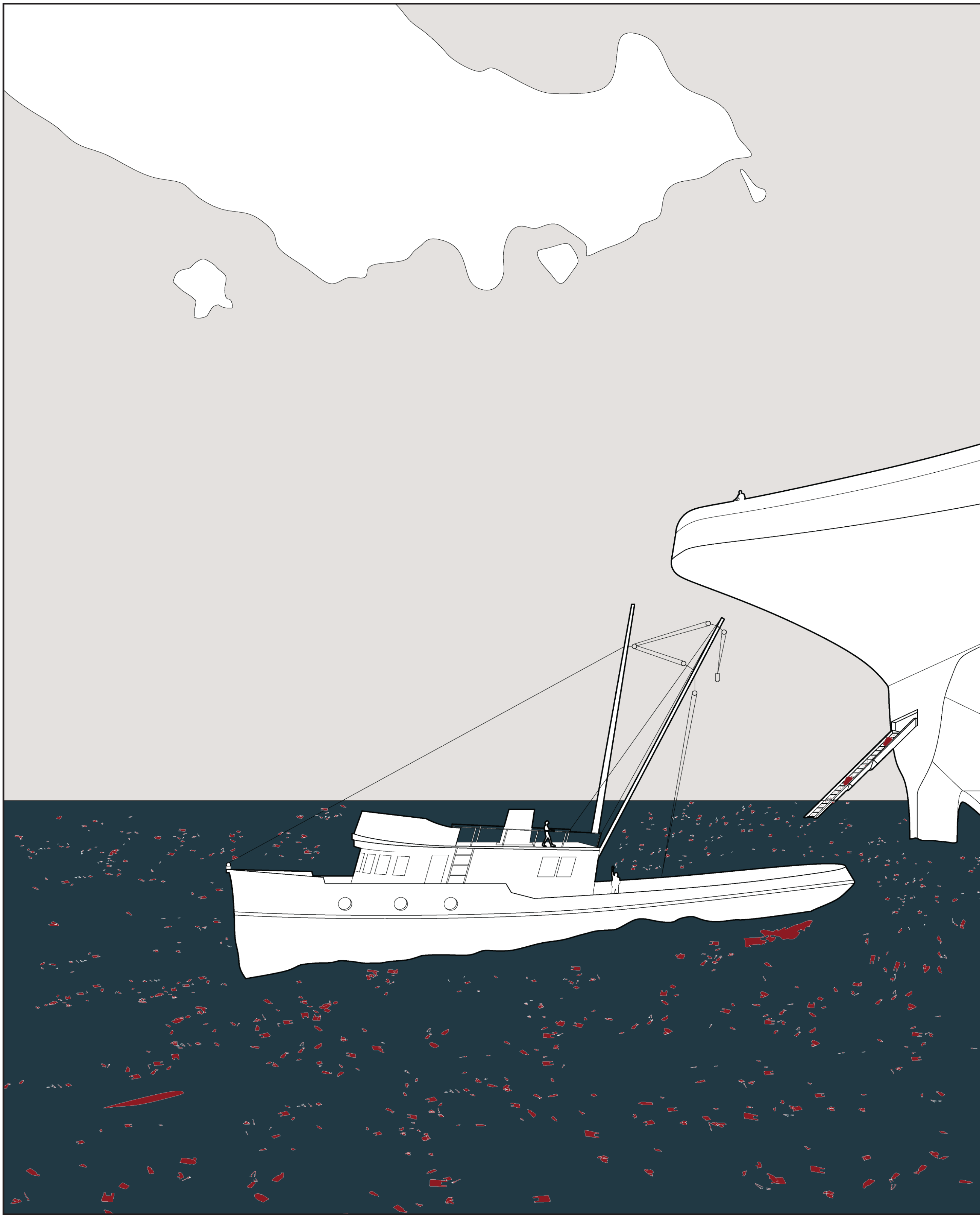
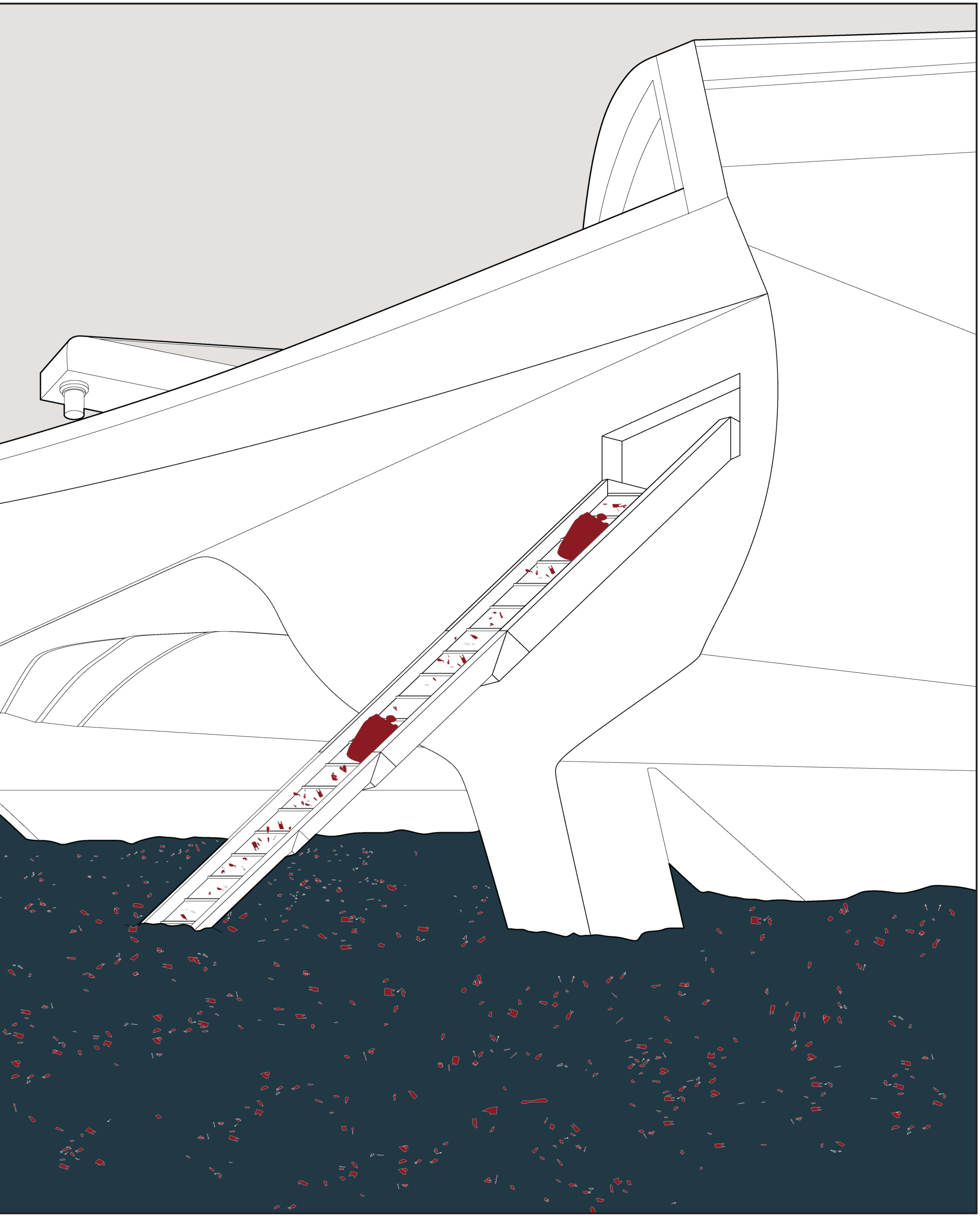


Fig. 5.16 Rear Plastic Conveyor Belts



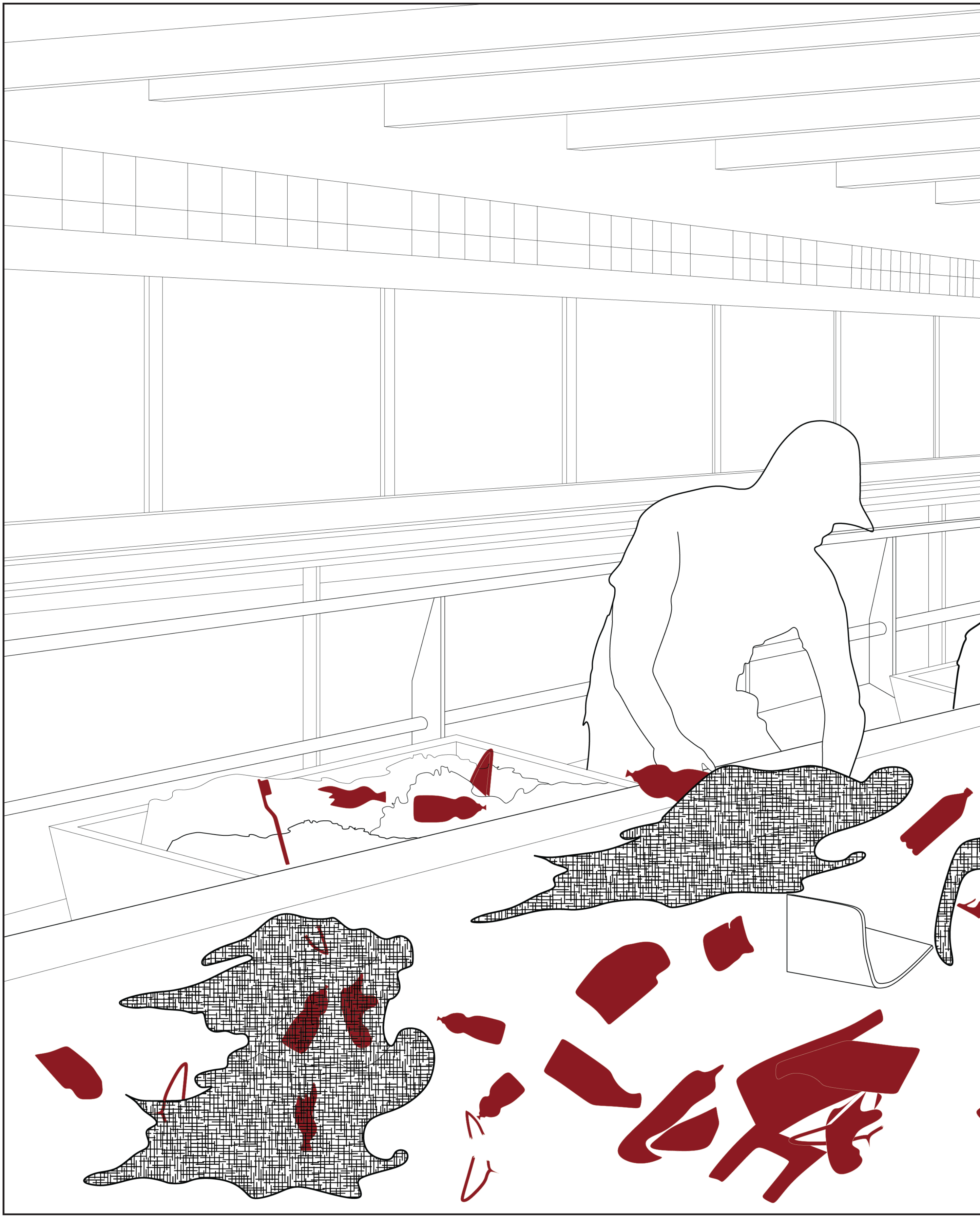
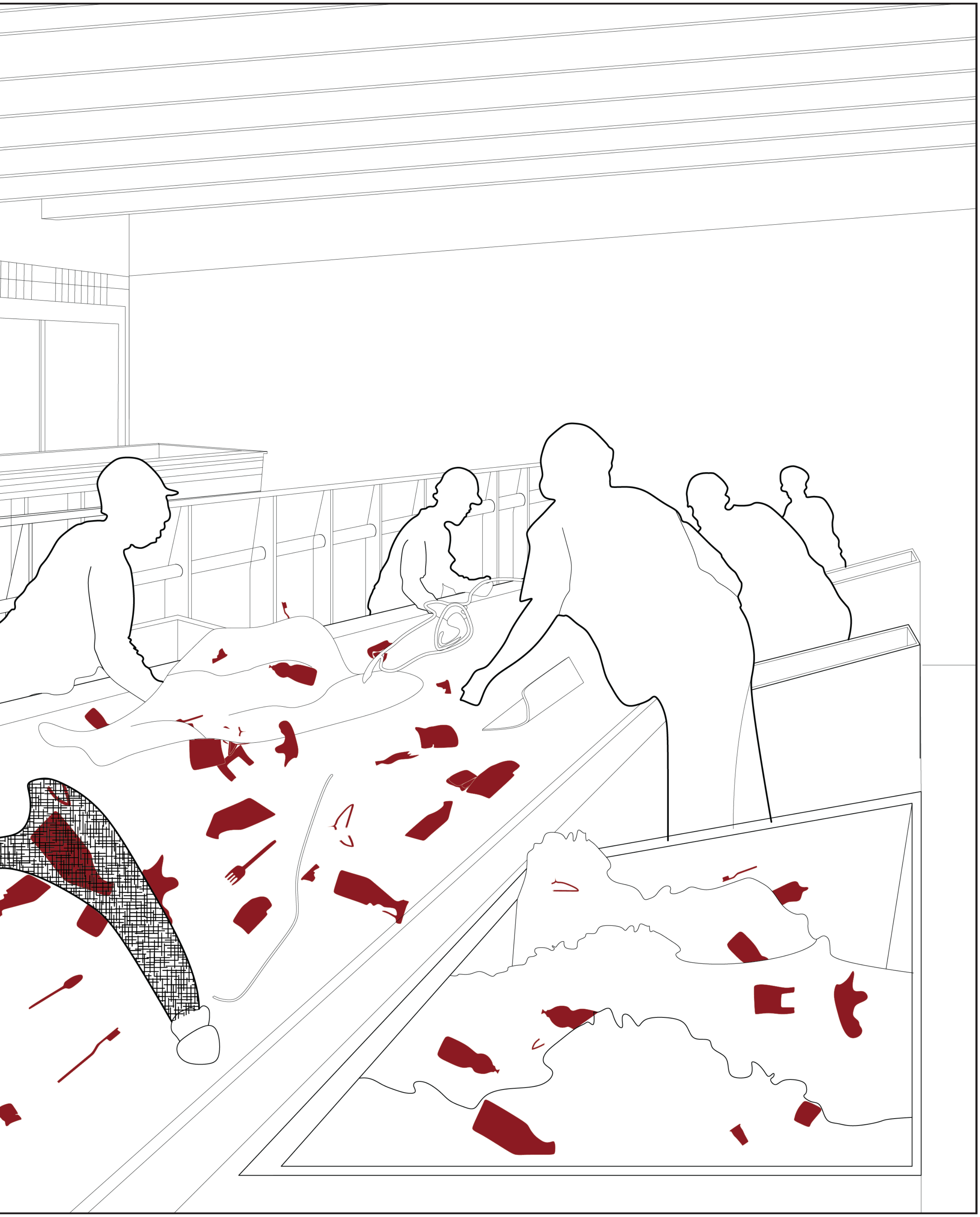


Fig. 5.17 Primary Recycling Sorting



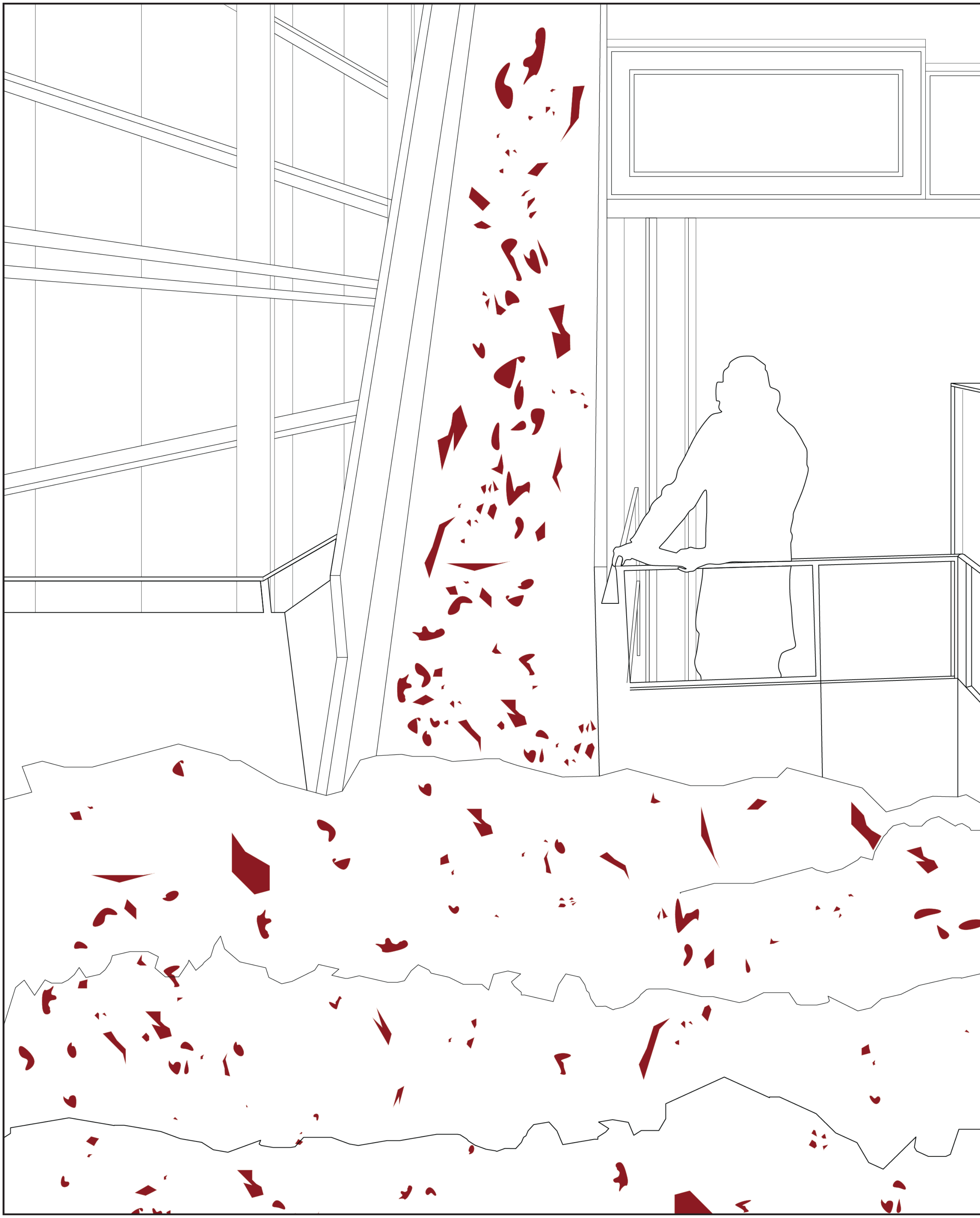


Fig. 5.18 Secondary Recycling Sorting

This sorting and separation stage is a critical step that cannot be skipped as neglecting to do so would cause the final product, whether plastic pellets or biofuel, to be extremely poor quality and nearly unusable. With the initial sorting and separation stages completed, any remaining large plastics are shredded into smaller, similar sized pieces. After the shredding process, the plastics undergo another round of sorting and examination to ensure that there are no contaminants. The plastic is then deposited into temporary storage containers according to the plastic's type and the level of recycling integrity.

Once enough plastic feedstock has been accumulated it will undergo a mechanical recycling process. These shredded fragments of plastic are then melted down and extruded into the form of easily manageable pellets (Figure 5.19). Pelletising the plastic ensures that this recycled product can be efficiently transferred to courier ships and be easily manufactured into consumer products. Shown in figure

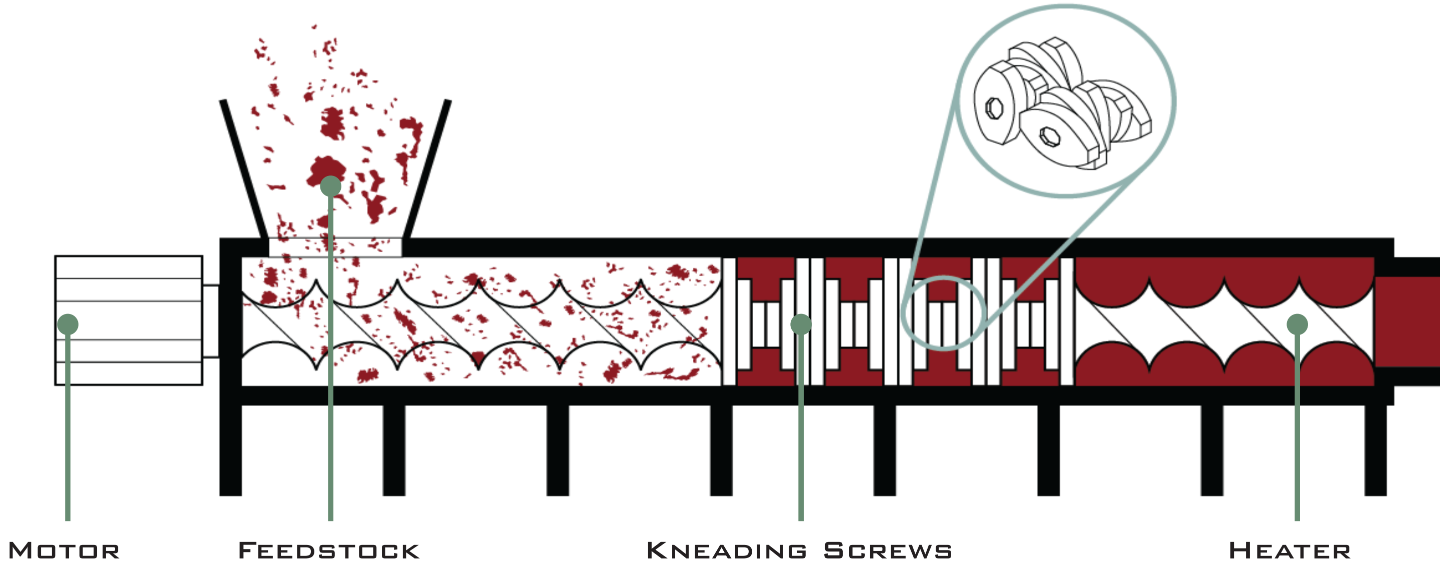
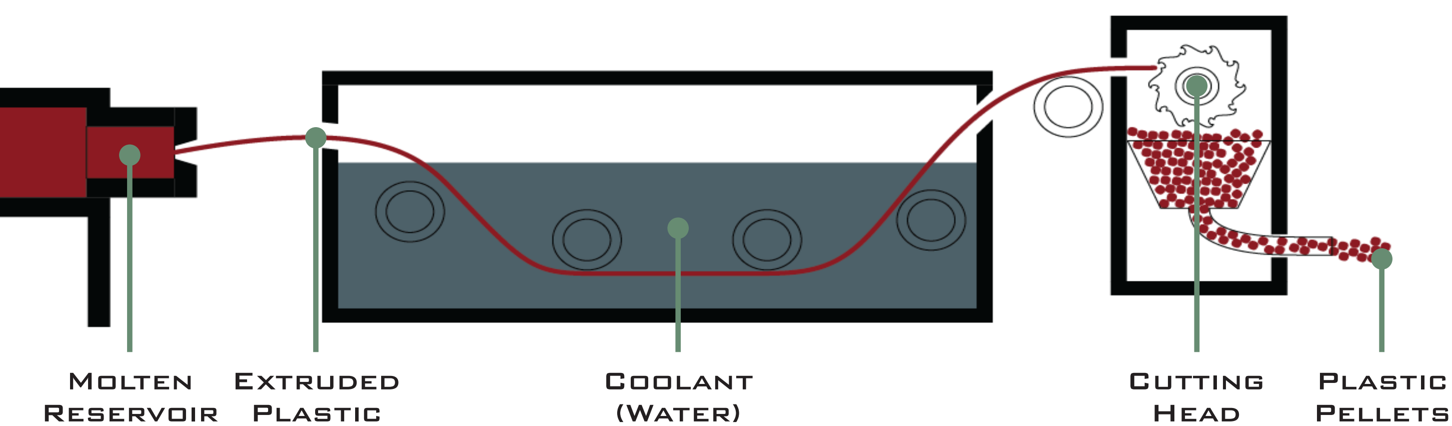


Fig. 5.19 Mechanical Recycling of Waste Plastics

5.20, plastic that is unsuitable for pelletising is separated and used in pyrolysis. The vessel is equipped with a massive storage room where the pelletised plastic that is suitable for re-entry into the production stream will be stored until it can be offloaded onto a courier vessel. In the style of self-unloading vessels, a technology used for decades by dry-bulk cargo freighters, the recycling facility will be able to carry out ship-to-ship cargo transfers in open ocean water with little-to-no spillage. While the ship is offloading the plastic pellets, the ballast tanks, depending on which side they are on, will either be emptied or filled in order to balance the ship while the load is being redistributed.



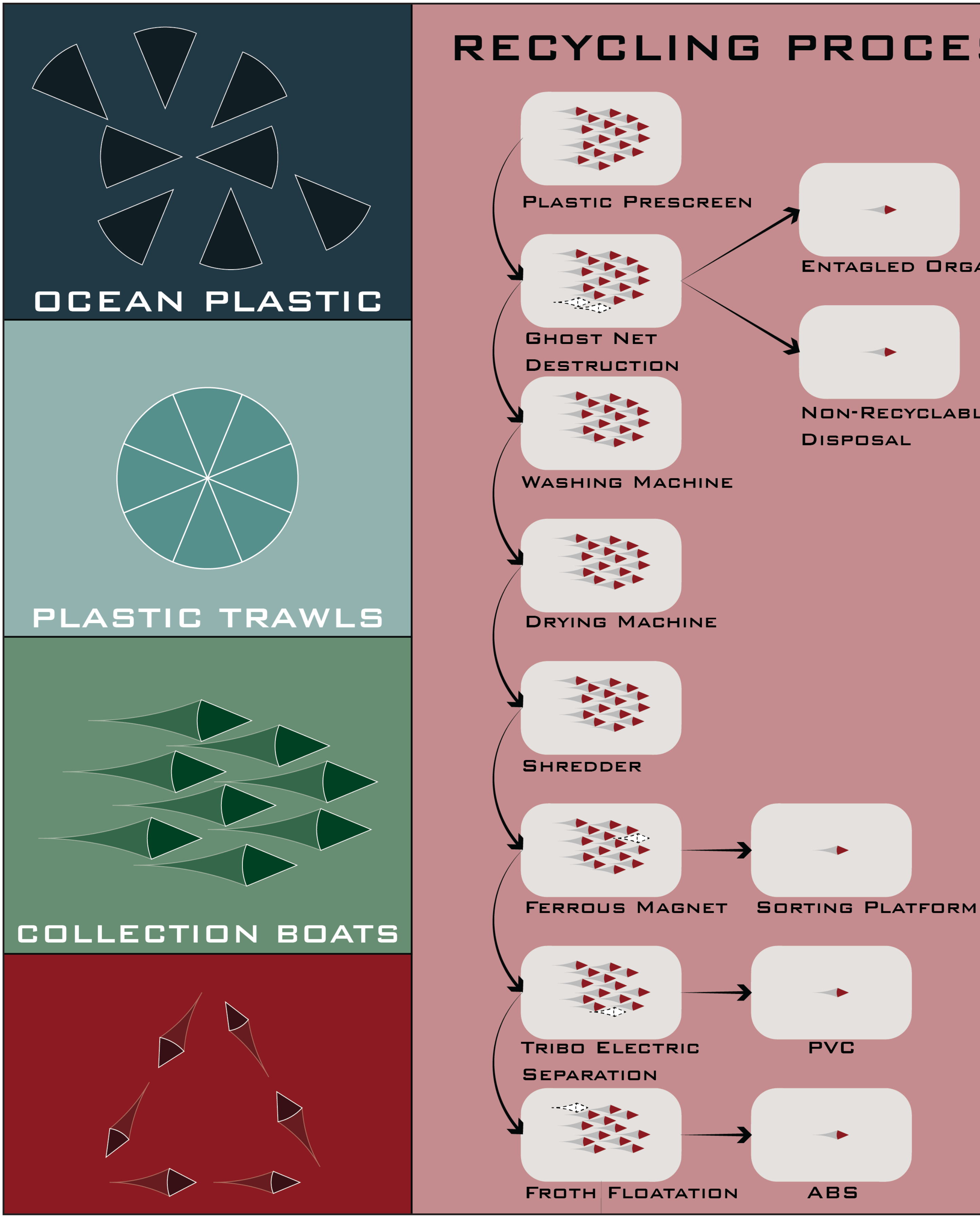
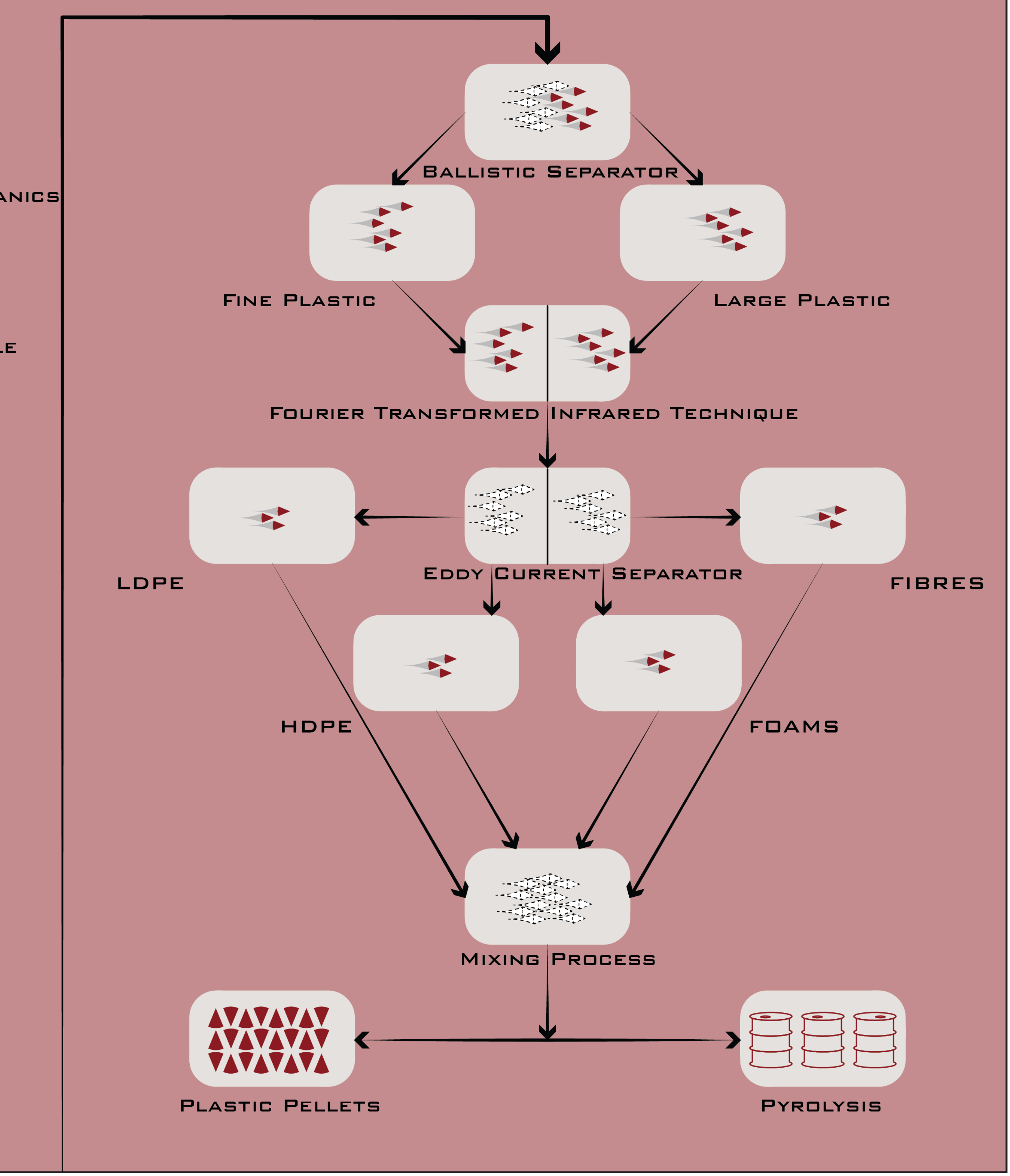


Fig. 5.20 Recycling Processes

SSES


Ballistic Separator
Fine Plastic
Large Plastic
Fourier Transformed Infrared Technique
Eddy Current Separator
LDPE
FIBRES
HDPE
FOAMS
Mixing Process
Plastic Pellets
Pyrolysis
ANICS
LE

Plastic that is unsuitable for mechanical recycling will be processed through pyrolysis, shown in figure 5.21, to create an alternative fuel source that is comparable to standard petrol products. The pyrolysis of plastic waste is considered one of the most effective ways to permanently remove plastic from the environmental equation as standard recycling processes do not eliminate the plastic; rather, the latter just allow it to re-enter the consumer world. The process of pyrolysis is the heating of plastic waste between 300 degrees Celsius up to 650 degrees Celsius in the absence of oxygen.[60] This environment which lacks oxygen disables the plastic's ability to combust. Rather, a controlled thermal decomposition of the component chemical compounds results in the creation of combustible gases, liquids and bio-charcoal.[61] There are two main types of pyrolysis processes: fast pyrolysis and slow pyrolysis. Slow pyrolysis typically generates an approximately even amount of liquid (30%), solid (35%), and gas by-products (35%).[62] Whereas fast pyrolysis results in a significantly higher yield of liquid by-product (75%), compared to solid (12%) and gas (13%).[63] This thesis focuses on the utilization of fast pyrolysis as a method to process the waste plastic found in the ocean since the liquid fuel produced is easily stored and can be used as supplemental power. However, some plastic variants such as PET and PVC are generally excluded from pyrolysis due to their harmful properties. The degradation of

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60 Anuar Sharuddin, Shafferina Dayana, Faisal Abnisa, Wan Mohd Wan Daud, and Mohamed Kheireddine Aroua. "A Review on Pyrolysis of Plastic Wastes." Energy Conversion and Management 115 (2016): 308–26. https://doi.org/10.1016/j.enconman.2016.02.037.

61 "What Is Pyrolysis?" Biomass Pyrolysis Research at the Eastern Regional Research Centre: Usda ARS. Accessed May 28, 2021. https://www.ars.usda.gov/northeast-area/wyndmoor-pa/eastern-regional-research-center/docs/biomass-pyrolysis-research-1/what-is-pyrolysis/.

62 Ringer, M., V. Putsche, and J. Scahill. "Large-Scale Pyrolysis Oil Production: A Technology Assessment and Economic Analysis." The National Renewable Energy Laboratory (NREL), 2006. 5. https://doi.org/10.2172/894989.

63 Ringer, Putsche, and Scahill. "Large-Scale Pyrolysis Oil Production: A Technology Assessment and Economic Analysis." 5.

PET creates benzoic acid, a harmful product that affects the performance of the processing equipment.[64] Pyrolysis of PVC releases hydrogen chloride, which not only deteriorates the processing equipment, but also negatively impacts the fuel quality.[65] Therefore, the pyrolysis of consumable plastics must be tailored to a specific feedstock of HDPE, LDPE, PP, and PS plastics for the process to be successful. It is important to monitor the percentages of the plastic mixtures as increasing amounts of a particular plastic influence the production of more or less of the multiple types of fuels. The heating temperature and feedstock of plastic significantly influence the output of usable alternative fuels, with some yields as high as 80% weight.[66] It is ideal to maximize the yields as the process of pyrolysis can become partially self-sustained by using the recently created fuel sources to supplement the required energy for future reactions.[67] These alternative fuel sources can be stored and consumed on-site as a means to reduce the overall power demands of the vessel.

Even with the high energy requirement of initially heating the reaction chamber, the rate of heat transferred to the feedstock must be high to achieve an effective reaction. However, once this temperature level is reached, the energy to breakdown the feedstock is not as significant. A portion of the energy needed to fuel this transformation can be

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64 Abnisa, Faisal, Abnisa, Shafferina, bin Zanil, Wan Daud, and Indra Mahlia. "The Yield Prediction of Synthetic Fuel Production from Pyrolysis of Plastic Waste by LEVENBERG–MARQUARDT Approach IN Feedforward Neural Networks Model." Polymers 11, no. 11 (2019): 1853, 3. https://doi.org/10.3390/polym11111853.

65 Abnisa, Shafferina, bin Zanil, Wan Daud, and Indra Mahlia. "The Yield Prediction of Synthetic Fuel Production from Pyrolysis of Plastic Waste by LEVENBERG–MARQUARDT Approach IN Feedforward Neural Networks Model." 3.

66 Abnisa, Shafferina, bin Zanil, Wan Daud, and Indra Mahlia. "The Yield Prediction of Synthetic Fuel Production from Pyrolysis of Plastic Waste by LEVENBERG–MARQUARDT Approach IN Feedforward Neural Networks Model." 2.

67 Usda ARS. "What Is Pyrolysis?"

acquired using the coproducts of pyrolysis.[68] Correctly utilising the process of pyrolysis is considered a form of green energy production since unlike recycling, pyrolysis does not contaminate any water sources and its by-product can be reused to compensate the facility's overall energy requirement.[69] The API gravity method, established by the American Petroleum Institute (API), measures the density of petroleum relative to water. The API Gravity of HDPE, PP, and PVC all have approached values of diesel's API gravity value: 38.98.[70] However, LDPE has surpassed diesel and has resulted in a cleaner product approaching gasoline quality at 47.75.[71] This by-product is so similar to conventional fuels that machinery such as furnaces, boilers, turbines, and diesel engines do not require any upgrades to utilize this new fuel source.[72] The pyrolysis process requires venting of residual gases that cannot be used in the fuel production process. An extensive scrubber system is used to ensure that there are no harmful fumes exhausted into the atmosphere.

Energy Requirement

The energy requirement for the recycling of plastic wastes is a disputed topic, where every aspect from the collection to the sorting, to the actual processing of plastics varies

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68 Ringer, Putsche, and Scahill. "Large-Scale Pyrolysis Oil Production: A Technology Assessment and Economic Analysis." 5.

69 Abnisa, Shafferina, bin Zanil, Wan Daud, and Indra Mahlia. "The Yield Prediction of Synthetic Fuel Production from Pyrolysis of Plastic Waste by LEVENBERG–MARQUARDT Approach IN Feedforward Neural Networks Model." 5. Polymers 11, no. 11 (2019): 1853, 309. https://doi.org/10.3390/polym11111853

70 Anuar, Shafferina, Abnisa, Wan Daud, and Kheireddine Aroua. "A Review on Pyrolysis of Plastic Wastes." 308–26.

71 Anuar, Shafferina, Abnisa, Wan Daud, and Kheireddine Aroua. "A Review on Pyrolysis of Plastic Wastes." 308–26.

72 Abnisa, Shafferina, bin Zanil, Wan Daud, and Indra Mahlia. "The Yield Prediction of Synthetic Fuel Production from Pyrolysis of Plastic Waste by LEVENBERG–MARQUARDT Approach IN Feedforward Neural Networks Model." 3.

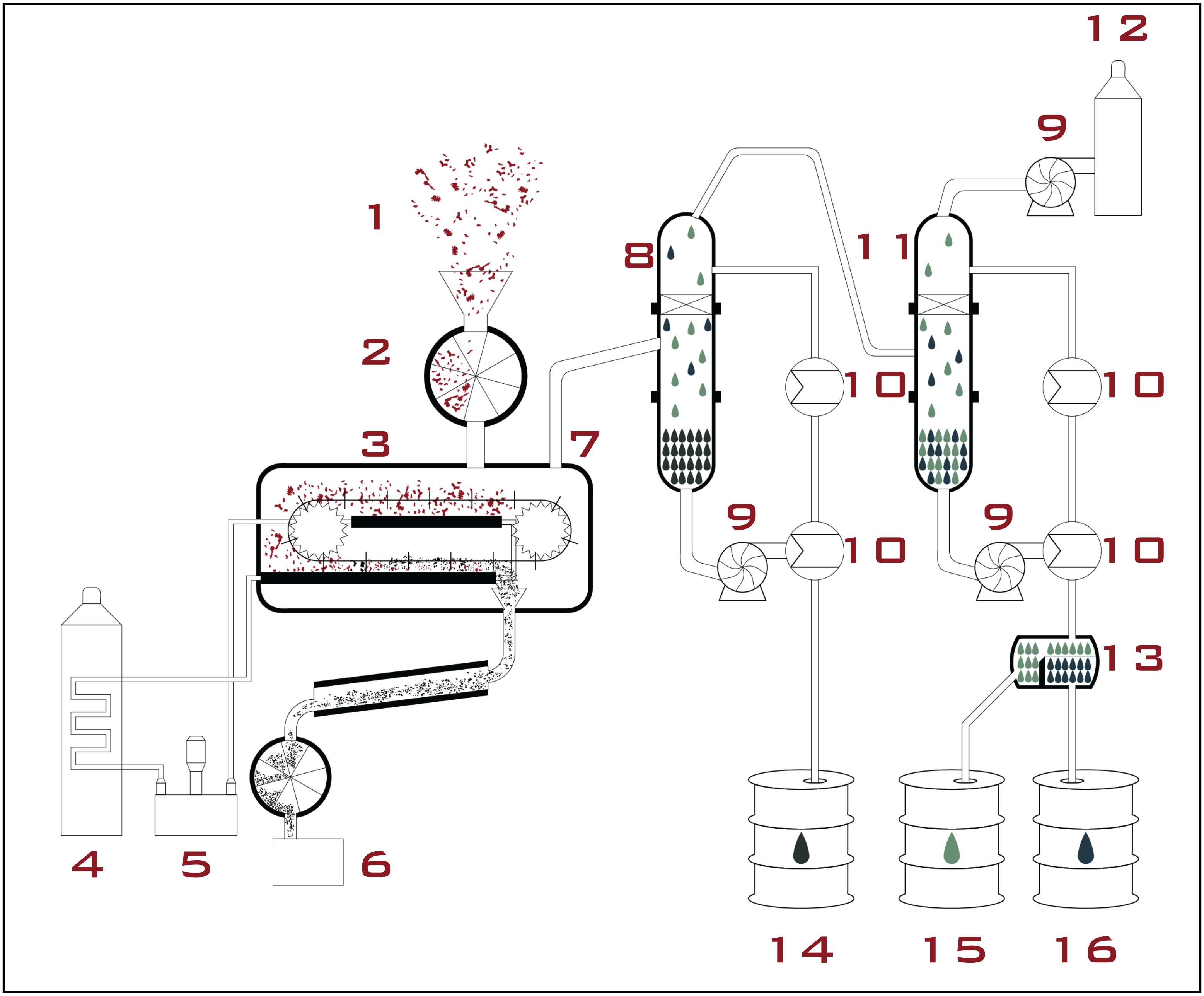

Fig. 5.21 Plastic Pyrolysis Process

1 PLASTIC FEEDSTOCK
2 VACUUM VALVE
3 PYROLYSER
4 ELECTRIC FURNACE
5 MOLTEN SALT
6 PLASTIC CHAR
7 VAPOURS
8 CHAMBER 1
9 PUMP/VACUUM PUMP
10 HEAT EXCHANGER
11 CHAMBER 2
12 COMBUSTIBLE GAS
13 WATER/OIL SEPARATOR
14 HEAVY OILS
15 LIGHT OILS
16 WATER

from facility to facility. This variety of information often leads to researchers making assumptions based on the limited information available in their country. For example, a study on the recycling of plastics in Germany that has been conducted by Martin Patel and his associates, has extrapolated the gross energy requirements for the primary production of feedstocks, secondary energies, intermediates and materials. However, they also mention that "the technical standards of German municipal waste incineration plants vary greatly. An inventory of the existing facilities in Germany including the net efficiencies for the generation of electricity and district heat is not available."[73] A separate study focusing on the cost-effectiveness of incineration or recycling in the Netherlands conducted by R.H.J.M. Gradus and Associates mentions an inaccessibility of information stating: "There is no publicly-available information regarding the costs of collection, separation, sorting, and recycling of plastic waste in the Netherlands."[74] In Japan a study on incinerating plastic bottles takes approximately 327,024 kJ per ton (approximately 91 kWh of electricity).[75] However it does not take into account the energy requirements of the collection, sorting, and other preparatory processes. Furthermore, incineration of plastic waste is a different process than that of pyrolysis, but is often preferred due to the facility needing to maintain a quantity over quality approach to dealing with plastic waste.

Due to the wildly varying regulations of a country's recycling

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73 Marten Patel, Norbert von Thienen, Eberhard Jochem, Ernst Worrell. "Recycling of Plastics in Germany" Conservation and Recycling, 2000, 29, 74. https://doi.org/10.1016/S0921-3449(99)00058-0

74 Raymond Gradus, Paul Nillesen, Elbert Dijkgraaf, Rick van Koppen. "A Cost-effectiveness Analysis for Incineration or Recycling of Dutch Household Plastic Waste" Ecological Economics, 2017, 24. https://doi.org/10.1016/j.ecolecon.2016.12.021

75 Masakazu Yamashita, Shin-ichiro Matsumoto. Status of Recycling Plastic Bottles in Japan and a Comparison of the Energy Costs of Different Recycling Methods. International Journal of Environmental Protection and Policy. Vol. 2, No. 4, 2014, pp. 132-137. doi: 10.11648/j.ijepp.20140204.12

standards, processes and capabilities, there are too many variables to develop an accurate benchmark of recycling energy cost. This complexity is compounded further by the lack of universal standards which results in unreliable standards at the scale of each facility, the overall city, and even at the scale of the countries around the world. Since the collection methods on-shore are drastically different than that of collecting at-sea, yet another layer of complexity is introduced. The value stated above of 91 kWh/ton of plastic bottles can act as a baseline energy requirement for the recycling aspects of the vessel, whereas additional power requirements can be extrapolated from the data of similarly sized ships. In lieu of an exact power requirement an estimation of an acceptable power range is substituted.

For example, the Oasis of the Seas is a large cruise ship that houses close to 5,500 total people as well as extravagant amenities and entertainment venues. The vessel proposed in this thesis is smaller than this cruise ship which is capable of producing more than 96 megawatts (MW) of power through its 6 Wartsila diesel engines and an additional 22MW through its bow thrusters.[76] [77] Furthermore, the Trillium Panamax technical specifications mention that this specific bulk carrier uses a relatively small amount of total power. At an operational requirement of just 10,430 Kilowatts (KW) the power requirements of a bulk carrier and its small crew are nearly negligible relative to larger, multi-use vessels.[78] Moreover, the research undertaken by physicist Brendan

76 Holmlund-Sund, Marit. "Wärtsilä Powers Royal Caribbean's Oasis of the Seas - the Largest and Most Revolutionary Cruise Ship in the World." Wartsila. Wartsila, November 29, 2009. Wärtsilä powers Royal Caribbean's Oasis of the Seas - the largest and most revolutionary cruise ship in the world.

77 A bow thruster is a secondary propulsion device located at the front of the ship to aid in manoeuvring

78 CSL Americas. "Trillium Panamax Specifications." Accessed April 11, 2022. https://www.cslships.com/sites/default/files/csl_trillium_panamax_brochure_en.pdf

Hanlon averages that a Nimitz-class aircraft carrier is capable of generating an average of 500MW of power per reactor.[79] However, not all power generated has been used for the purpose of propulsion. The power requirement to propel a vessel is a portion of the total power and is proportionate to the vessel's size, weight, and the shape of its hull. The remaining power requirements are influenced by the additional processes onboard.

Since the values presented by Masakazu Yamashita and Shin-ichiro Matsumoto do not explore the additional power requirements of the collection of waste plastics from the ocean, the cleaning and sorting of soiled plastics, nor the differences between incineration and pyrolysis, the energy cost per ton of plastic will be significantly higher than 91kWh/ton. Since the programming requirements of an ocean-based recycling facility are a unique and unprecedented purpose the expected power requirement would result in an approximate range of values. I believe that a range of 75MW to 125MW would be appropriate for a vessel of this size.

Power Generation

Early maritime vessels have utilized the physical strength of the oarsmen or large sails propelled by the winds to travel large distances relatively easily. However, with the evolution of mechanical technologies, sails have been quickly abandoned in favour of the more reliable, albeit fossil fuel dependant, engine propulsion systems.

Actively patrolling the open waters requires a consistent and

79 Hanlon. "Validation of the Use of Low Enriched Uranium as a Replacement for Highly Enriched Uranium in US Submarine Reactors" (2015): 19.

reliable power source not only to propel the vessel, but also to run the extensive industrial equipment onboard. Using typical fuel sources such as marine gas oil (MGO) and marine diesel oil (MDO) require large amounts of onboard space which on a ship is very limited. These fuels not only create a proportionate ratio of volume to power generation which require frequent refilling, but also actively contribute to energy-based pollution. Whether this refuelling period occurs using a courier ship, or through frequent stops at global ports there is significant time spent travelling to and from a fuel source as well as increased opportunities for hazardous spills to occur. Hydrogen as a fuel source could eventually replace fossil fuels as its consumption for energy production does not contribute to greenhouse gas creation.[80] However, hydrogen as a fuel source is an emerging technology and there is a distinct lack of infrastructure to support its use. Furthermore, its large-scale production is fuelled by the energy produced through the burning of the very same fossil feedstock that it seeks to make obsolete.[81] Water electrolysis is an alternative to the requirement of burning fossil fuels however, the high cost and energy consumption of this process has restricted its progress. These high energy costs can be negated by solar or wind power contributions, however the power provided by these sources are inconsistent and unable to wholly support the production of hydrogen. Additionally, a storage leak coupled with the inherent volatility of hydrogen could cause significant environmental hazards ranging from a localised explosion to a release of significant amounts of gas into the atmosphere, potentially leading to the creation of radicals

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80 Gahleitner, Gerda. "Hydrogen from Renewable Electricity: An International Review of Power-to-Gas Pilot Plants for Stationary Applications." International Journal of Hydrogen Energy 38, no. 5 (2013): 2051. https://doi.org/10.1016/j.ijhydene.2012.12.010.

81 Gahleitner, Gerda. "Hydrogen from Renewable Electricity: An International Review of Power-to-Gas Pilot Plants for Stationary Applications." 2043.

that magnify the effects of ozone depletion.[82] Hydrogen as an emerging fuel source has incredible future potential to fully replace fossil fuels, but at this time the technology is not advanced enough to make it a viable option. Therefore, to achieve a reduced dependency on the mainland, the vessel proposed in this thesis uses a variety of renewable alternatives such as wind propulsion, solar arrays, and biofuel generators to generate on-site power.

Harnessing solar energy has existed since the 7th century, however not in the conventional sense of using photovoltaics (P/V) to generate sustainable power. These ancient methods have focused on how the passive capabilities of solar energy could be manipulated to perform basic functions. In more modern times passive energy design and the use of the sun's energy to power buildings have started to become popular during the energy scare that surrounded the second World War. As a result, extensive research and funding from that point have resulted in the modern photovoltaic systems. Unlike fossil fuel or coal energy systems, solar energy systems do not actively produce air pollution or greenhouse gasses. However, some of the materials and chemicals used in P/V panels are toxic if leaked into the environment making their creation, use, and disposal a regulated field. Since these P/V systems do not actively contribute negatively to the environment, they are an ideal replacement for fossil fuels. Large-scale implementation of solar energy creates a dramatic reduction of energy-based pollution. As shown in figure 5.22, there is placement space for approximately 20,000 square metres of opaque and transparent panels mounted on the exterior surfaces of the vessel. While the sun

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82 Gahleitner, Gerda. "Hydrogen from Renewable Electricity: An International Review of Power-to-Gas Pilot Plants for Stationary Applications." 2051.

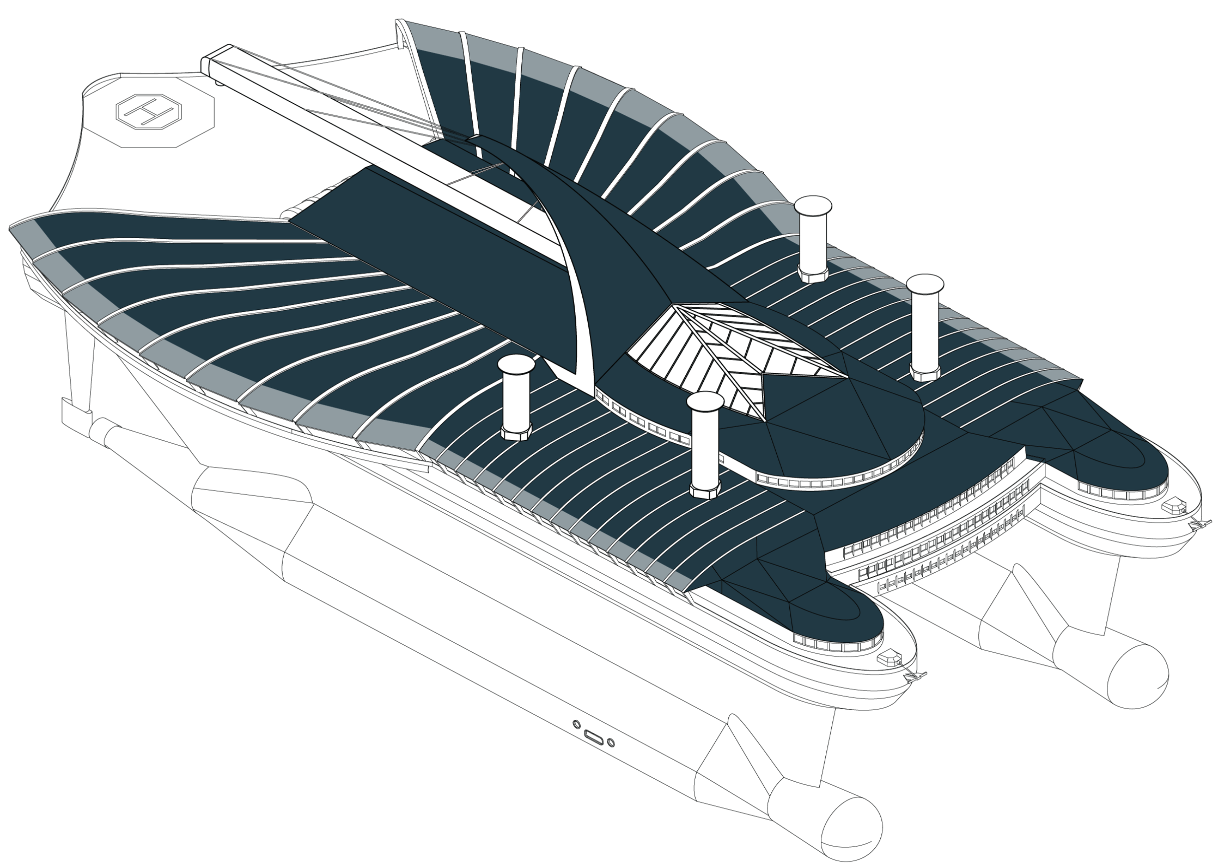

Fig. 5.22   Photovoltaic Panel Distribution on the Seascraper

is shining and under perfect conditions the large amount of installed PV panels have the capacity to contribute large amounts of power.

Additionally, in the event of excess power being created, it can be temporarily stored in large on-site batteries for periods during which the sun is obstructed. The capabilities of photovoltaic (P/V) systems are dependent on many factors, such as the global position of the panel, environmental interference, and the amount of time spent in direct sunlight. Since the vessel is in a state of near-constant circulation it is impossible to constantly meet the perfect reception angle for all the P/V panels simultaneously. The current performance of the P/V panels fluctuates between 10% and 22% (where 22% is mostly found in laboratory applications).[83] Essentially, this means that a single square metre of panel would produce between 100W-220W of power. As a result, large amounts of unobstructed surface area are required to support a solar array capable of powering the vessel. Furthermore, the degree of solar density impacts the P/V panel's energy production, with high densities being preferable. Figure 5.23 illustrates that the power output is derived from the number of active panels and the density of solar radiation in that specific operating area. As seen in figure 5.24, the earth has been divided into six sections of varying solar density, where NASA has performed studies in order to estimate the power generation capacity of a P/V system in an area without local meteorological data, such as in the deep ocean.[84] The vessel proposed in this thesis would be able to sustain approximately 20,000 square

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83 Glykas, Alexandros, George Papaioannou, and Stylianos Perissakis. "Application and Cost–Benefit Analysis of Solar Hybrid Power Installation on Merchant Marine Vessels." Ocean Engineering 37, no. 7 (February 6, 2010): 593. https://doi.org/10.1016/j.oceaneng.2010.01.019

84 Glykas, Papaioannou, and Perissakis. "Application and Cost–Benefit Analysis of Solar Hybrid Power Installation on Merchant Marine Vessels." 593.

Surface of Panels (m^2)	Zone 3 Solar Radiation Density π=2.34 (kWh/m^2 per day)		Zone 2 Solar Radiation Density π=3.72 (kWh/m^2 per day)		Zone 1 Solar Radiation Density π=5.61 (kWh/m^2 per day)	
	kWh/day	kWh/year	kWh/day	kWh/year	kWh/day	kWh/year
500	127	46442	202	73,878	305	111402
1000	254	92884	405	147756	610	222805
1500	382	139325	607	221634	916	334207
2000	509	185767	810	295512	1221	445610
2500	636	232209	1012	369389	1526	557012
3000	763	278651	12114	443267	1831	668414
3500	891	325092	1417	517145	2136	779817
4000	1018	372534	1619	591023	2442	891219
4500	1145	417976	1822	664901	2747	1002622
5000	1272	464418	2024	738779	3052	1114024
5500	1400	510859	2226	812657	3357	1225426
6000	1527	557301	2429	886535	3663	1336829
6500	1654	603743	2631	960412	3968	1448231
7000	1781	650185	2834	1034290	4273	1559634
7500	1909	696626	3036	1108168	4578	1671036
8000	2036	743068	3238	1182046	4883	1782438
8500	2163	789510	3441	1255924	5189	1893841
9000	2290	835952	3643	1329802	5494	2005243
9500	2418	882393	3846	1403860	5799	2116646
10000	2545	928835	4048	1477558	6104	2228048

Fig. 5.23 Table of Global Solar Density.

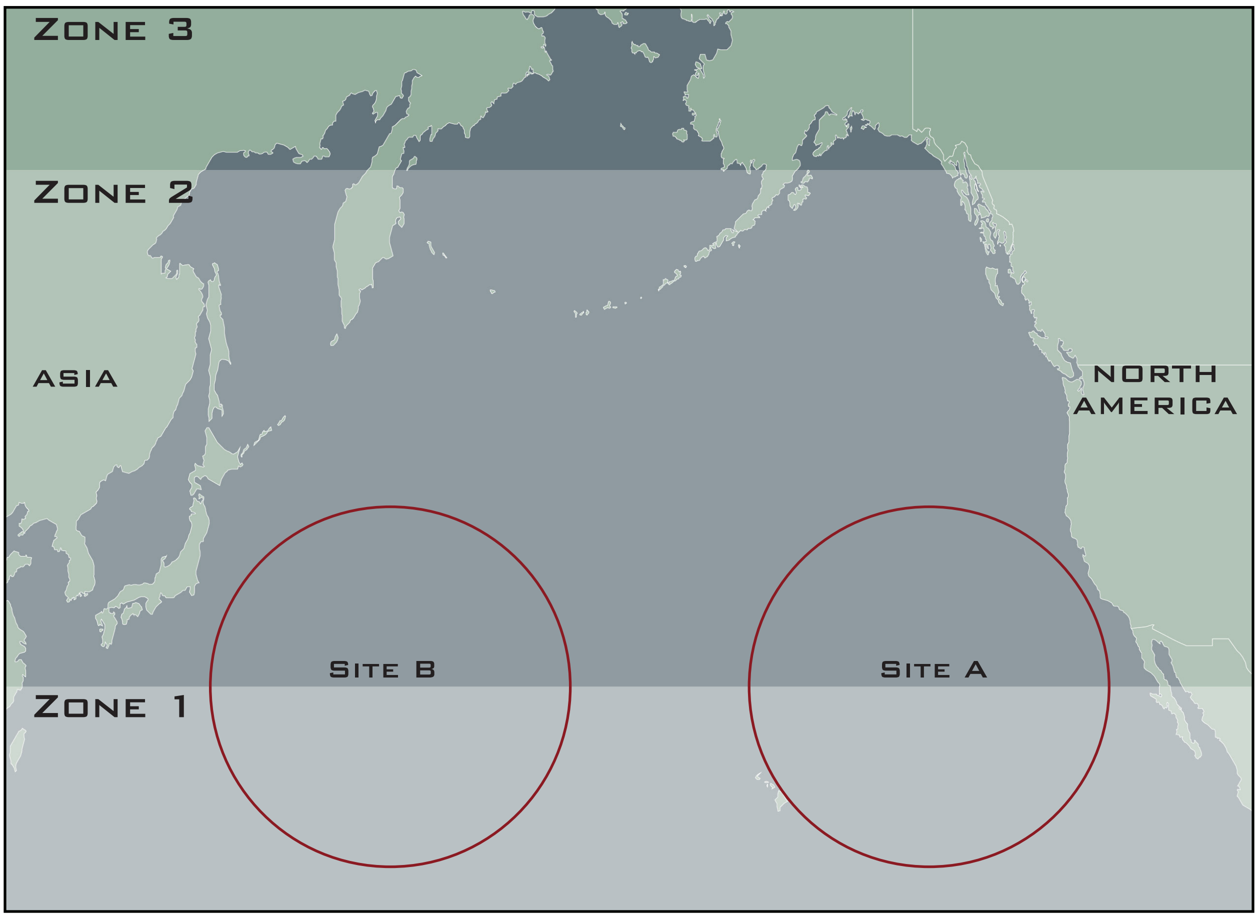

Fig. 5.24 Zones of Solar Density in the Northern Hemisphere

meters of solar panels providing a potential power output ranging between 2,200,000W and 4,400,000W, although the expected output would be less due the previously stated hindrances. Additionally, this vessel's primary operating area coincides with the two highest solar density locations further increasing its likelihood of producing large amounts of solar power. As green technology further increases in its capabilities, there is a potential for the entirety of the vessel to function exclusively through solar power. The capabilities of solar technology have progressed significantly, however, at this time it is not yet a perfect solution and requires other methods of power generation to supplement it.

Flettner Rotors

The same principle that puts the curve in a curveball is responsible for the propulsion of Anton Flettner's first rotor ship the Buckau. Figure 5.25 is a photograph of the vessel built in 1924. It is one of the first vessels to use the flettner rotor design that exploits the Magnus effect, a physics principle that generates thrust many times that of an equivalent sail area.[85] As illustrated in figure 5.26, the flettner rotor is a rotating cylinder mounted vertically on the ship; the act of rotation creates a varying degree of flow on either side of the cylinder resulting in a similar form of lift that would be seen in aerofoils. A theory first explored dating back to the mid 1800's by a professor at the University of Berlin, Gustav Magnus, the magnus effect is a phenomenon that informs how a spinning object moving through a fluid such as air deviates from its original trajectory due to the differences in pressure. In the case of the flettner rotor, the turning cylinder pulls some of

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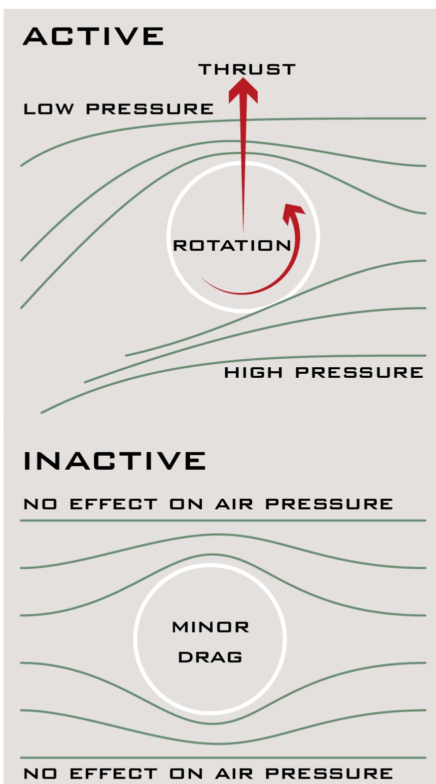
85 Seifert, Jost. "A Review of the Magnus Effect in Aeronautics." Progress in Aerospace Sciences 55 (2012): 17–45. https://doi.org/10.1016/j.paerosci.2012.07.001.

Fig. 5.25 Photograph of the Buckau, 1925



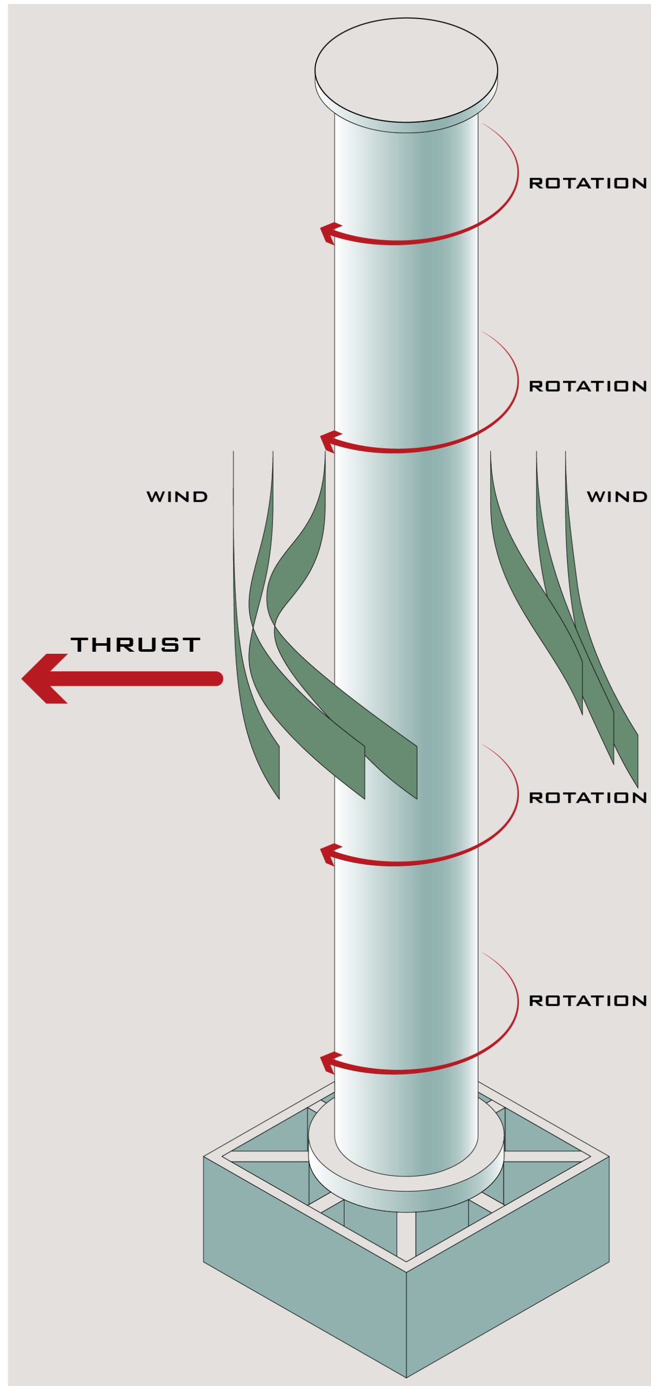


Fig. 5.26 Diagrams of Flettner Rotors Utilizing the Magnus Effect

the air around with it as it rotates creating difference in air pressure. There have been many proposed possibilities to use this effect in naval and aeronautic applications, however very few of these concepts have been built, tested, and performed as effectively as Anton Flettner's designs.

While travelling on the ocean there are two ways for wind to manifest: induced wind and true wind. Induced wind is the airflow that is felt as a result of the ships forward motion while true wind is the current direction of naturally blowing wind affecting the ship.[86] As illustrated in the following diagram, figure 5.27, the combined result of these two forces contribute to the total apparent windspeed that is used in velocity calculations. While there is no significant source of wind, the rotor stands idle to save energy and reduce any potential drag. However, when there is a beneficial wind blowing, the small motors controlling the rotor's rotation engage and begin to rotate the cylinders to match the speed of the blowing wind, rotating in whichever direction is the most efficient. Utilizing wind energy in the open ocean will directly correlate to a reduced demand on the other power sources to contribute to the propulsion of the vessel. As effective as these rotors are, they do have some restrictions; they must be securely mounted to a clear deck space without any immediately adjacent structures.[87] Several meters of uninterrupted airflow around the rotor are essential to obtain peak efficiency and reduce any possibility of damage. A return to sustainable wind power, flettner rotors are an innovation of the historic sails billowing in the wind.

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86 Pearson, David R. "The Use of Flettner Rotors in Efficient Ship Design." Influence of EEDI on Ship Design 2014, 5. https://doi.org/10.3940/rina.eedi.2014.14.

87 Pearson, "The Use of Flettner Rotors in Efficient Ship Design. 2-9.

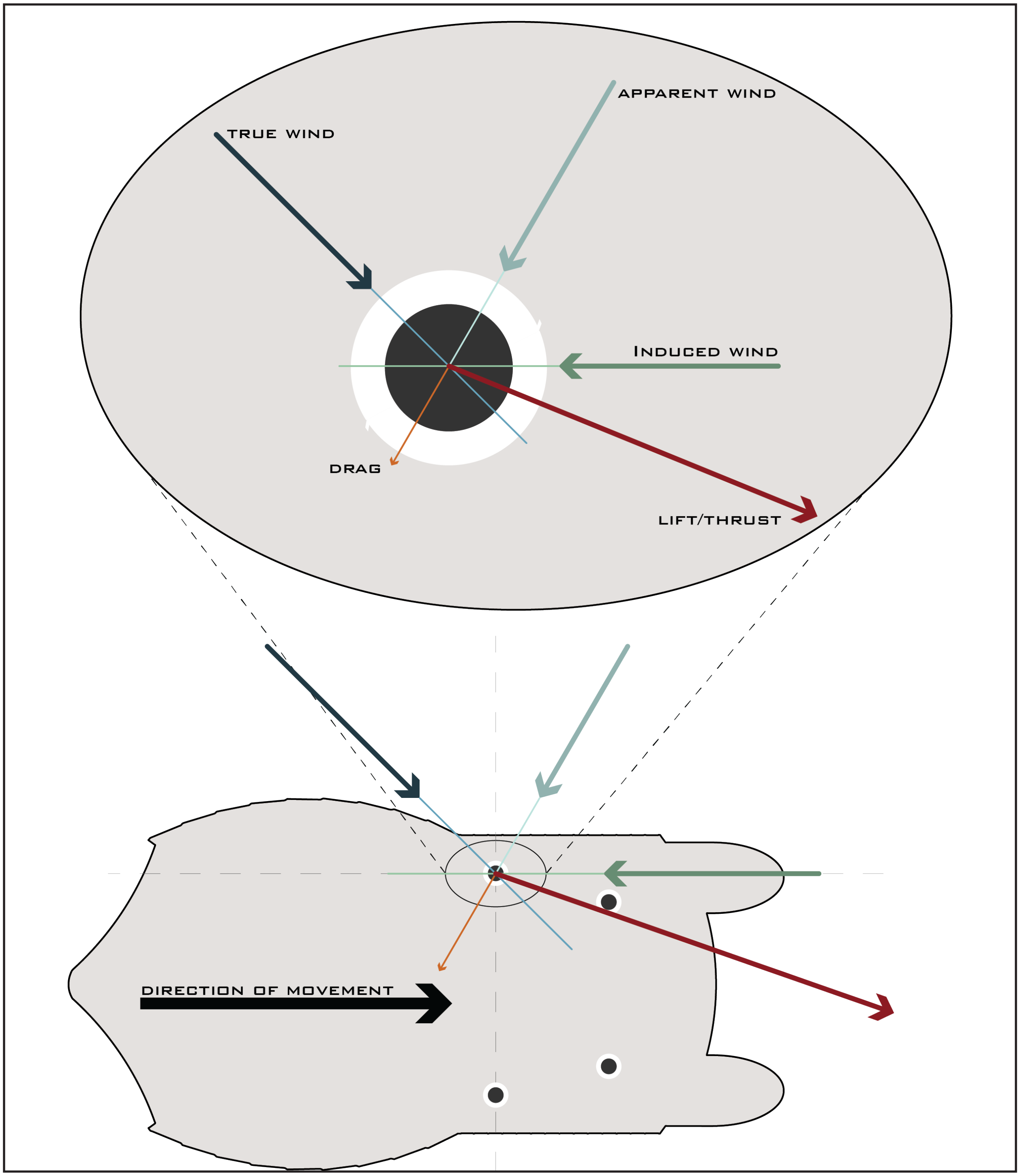

Fig. 5.27 Flettner Rotors Turning True Wind into Thrust

The data that have been observed from the use of the Buckau, have shown that the rotors were a success, effectively decreasing the operational cost and increasing the energy effectiveness of the vessel. The creation of this innovative design has been a response to the post WWI energy crisis of the 1920s. Despite the proven data from the voyages of the Buckau, this technological innovation has been eclipsed by the prices of oil dropping to their lowest ever level by the end of the decade.[88] At this time there have been only a few ships equipped with Flettner rotors but the emerging technology could not compete with the existing steam and diesel ships of the time; thus, it has been promptly abandoned.[89] By the mid-1980s, we see the low fuel prices soaring to 15 times their post-WWI prices and become a concerning factor for maritime shipping costs. This concern quickly fades as the price of fuel drops to post-WWII levels and maritime fuel-saving technology has been, once again, forgotten. However, the ever-increasing fuel prices have sparked a resurgence in the interest and experimentation of alternative propulsion methods. The UK NPO research group, Greenwave, has conducted a series of wind tunnel tests in 2006 that have explored the thrust developed by a Flettner rotor on a medium size bulk carrier.[90] Based on the results of these trials, Greenwave has been able to predict the reduction of an average of 13% of harmful exhaust emissions or 1000 tons of fuel. Nearly a century after its debut, the efficiency and validity of these wind propulsion systems as a method of reducing the fuel required for maritime travel is still relevant.

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88 Nuttal, Peter.; Kaitu, John. “The Magnus Effect and the Flettner Rotor: Potential Application for Future Oceanic Shipping.” The Journal of Pacific Studies 2017. 162

89 Traut, Michael.; Gilbert, Paul.; Walsh, Conor.; Bows, Alice. Propulsive Power Contribution of a Kite and a Flettner Rotor on Selected Shipping Routes “Applied Energy 2013. 364.

90 Nuttal, Peter.; Kaitu, John. “The Magnus Effect and the Flettner Rotor: Potential Application for Future Oceanic Shipping.” 2017. 172.

However, relying purely on green energy is unpredictable as the current technology is not at a high enough level to consistently harness enough power in all conditions to operate without interruption. Whether the sun is hidden behind the clouds, or the wind is not blowing at an ideal speed or angle, the vessel will still need to function. Therefore, a more reliable source of power is required in order for the vessel to function consistently. The petrol alternative that is generated as a by product of pyrolysis can be utilised as a power supplement when green energy supply is especially lean.

This generated fuel-source has comparable properties to MDO and MGO in terms of proportionate volume-to-power output. Utilizing this fuel source is the final stage of eliminating ocean plastic waste, turning an environmental hazard into a purposefully unsustainable resource. This essentially allows the vessel to “run” on the plastic it collects with the goal to exhaust this “resource” of ocean plastic. During times of high solar yield and strong winds this petrol alternative is not required and can be stockpiled onboard to act as a backup power source until there is the capacity to utilize the extensive green energy systems.

Nuclear Power

An immediately available alternative, nuclear powered vessels are finely tuned machines that are the apex of autonomously fuelled vessels. However, the stigma of nuclear energy obscures their functionality under a fog of fear and ignorance. Nuclear fission requires an atom to be split, as a result an enormous amount of energy is released. However, the devastation caused by weaponizing this technology strikes terror in those who discuss its possible alternative uses. A nuclear bomb is a violent burst of brilliant light as all the energy is released in an instant, rampaging across anything in its radius at the speed of light. This is not the case with nuclear reactors. Nuclear reactors control the energy generated by splitting the atom and releasing its energy slowly over a longer timeline. The production of nuclear power has been deemed safe enough to reside in many densely populated residential areas such as the reactor at McMaster University, the uranium fuel production facility in Toronto, and the nuclear generating station located in Pickering. Nuclear power can be considered a scary concept when there are failures, however this is a very clearly understood risk and is therefore one of the most highly regulated fields. When it is used for power generation purposes it can cleanly generate power at an enormous scale compared to the size required to house the reactor and fuel. For example, a single uranium fuel pellet has the capacity to generate energy comparable to one ton of coal, 149 gallons of oil, or 17,000 cubic feet of natural gas.[91] These pellets are then loaded into metal casings that act as the foundation of the consolidated fuel assembly. Like all methods of generating large-scale energy, nuclear energy generates waste as a by-product. The generation of nearly limitless power comes at the cost of generating small amounts of potentially highly volatile waste. However, unlike most energy generation methods, all nuclear waste is accounted for and stored properly. All processes are regulated throughout the life of a nuclear component. This attention given to the materials at their production phase carries on through their intended use phase, finally culminating in the

91 Nuclear Energy Institute. "Nuclear Fuel." Nuclear Energy Institute Washington. Accessed April 21, 2022, 2022. https://www.nei.org/fundamentals/nuclear-fuel.

end-of-life processes that are in place to reduce any chance of environmental pollution. There are four main types of nuclear waste created: very-low-level waste (VLLW), low-level waste (LLW), intermediate-level waste (ILW), and high-level waste (HLW). Unlike other industrial toxic wastes, the principal hazard associated with nuclear waste – radioactivity – diminishes with time.[92] A commission from the European Union inventories the quantities of radioactive waste and spent fuel in the Community's territory. At the end of 2013 the estimated total inventory of radioactive waste in the European Union was 3 313 000 cubic meters.[93] The document goes on to outline that of the 3 313 000 cubic meters of waste, roughly 74% of the overall waste is comprised of LLW, while the remaining quantities of VLLW, ILW, and HLW are approximately 15%, 10%, and 0.2%, respectively.

Uranium is a commonly used fuel in nuclear reactors globally and undergoes two changes during the fission process. First, the uranium atoms split, and this energy is used to generate electricity. This splitting results in the creation of isotopes such as cesium-137 and strontium-90. These isotopes, called "fission products," account for most of the heat and penetrating radiation in high-level waste.[94] These resultant isotopes may be high-level waste, but their radiotoxicity will decay to safe levels as the unstable element naturally stabilizes. For example, the half-life of strontium-90 is approximately 29 years, this unstable element then decays, transforming into

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92 "Radioactive Waste – Myths and Realities." Radioactive Wastes - Myths and Realities: World Nuclear Association - World Nuclear Association, February 2021. https://world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-wastes/radioactive-wastes-myths-and-realities.aspx.

93 European Commission. "Inventory of Radioactive Waste and Spent Fuel Present in the Community's Territory and the Future Prospects" 2017. 10.

94 United States Nuclear Regulatory Commission. "Backgrounder on Radioactive Waste" Accessed April 12, 2022. 5. https://www.nrc.gov/docs/ML0501/ML050110277.pdf

yttrium-90.[95] Yttrium-90 is a well-established radionuclide within medical applications such as targeted cancer therapy. With a half-life of only 64 hours this unstable element then decays into stable zirconium.[96] These elements that decay relatively quickly are often monitored and stored temporarily on-site until they can be permanently stored or used for other applications. The second event that occurs is the creation of trace amounts of plutonium, a transuranic element that will remain for beyond 1000 years.[97] The reprocessing of fission products before storage allows for the extraction of uranium and plutonium that can once again be used as a fuel source. However, storage of radioactive materials is not a new concept. According to the EPA records "more than 55,000 containers of radioactive wastes have been dumped at three ocean sites in the Pacific Ocean between 1946 and 1970.[98] Almost 34,000 containers of radioactive wastes have been dumped at three ocean sites off the East Coast of the United States from 1951 to 1962."[99] The management of spent nuclear fuel has been one of the greatest concerns of this fuel source as the processes vary according to the perspectives and capabilities of different countries. However, there are strong parallels that can be observed within each process: the need of a deep geological repository, the requirement to reduce the burden of the radiotoxic elements to be disposed in it,

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95 Pichestapong, Pipat, Wiranee Sriwiang, and Uthaiwan Injarean. "Separation of Yttrium-90 from Strontium-90 by Extraction Chromatography Using Combined SR Resin and RE Resin." Energy Procedia 89 (2016): 367. https://doi.org/10.1016/j.egypro.2016.05.048.

96 Pichestapong, Pipat, Wiranee Sriwiang, and Uthaiwan Injarean. "Separation of Yttrium-90 from Strontium-90 by Extraction Chromatography Using Combined SR Resin and RE Resin." 367.

97 United States Nuclear Regulatory Commission. "Backgrounder on Radioactive Waste" 5.

98 United States Environmental Protection Agency. "Learn about Ocean Dumping." Accessed Feb 15, 2021. https://www.epa.gov/ocean-dumping/learn-about-ocean-dumping.

99 United States Environmental Protection Agency. "Learn about Ocean Dumping." Accessed Feb 15, 2021. https://www.epa.gov/ocean-dumping/learn-about-ocean-dumping.

non-proliferation issues, etc.)[100] These commonalities have influenced the development of a series of research programs between the world's leading nuclear nations. The greatest hazards of spent nuclear fuel are from a few of the resultant chemical elements: plutonium, neptunium, americium, curium, and some long-lived fission products such as iodine and technetium at concentration levels of grams per ton of fuel.[101] [102] After initial treatments the spent fuel pellets are buried up to 5000 meters below the surface in highly specialized containers as to reduce any risk of leakage into the environment. Working in unison with the surrounding natural rock environment, these are specialized, multi-layer containers that are often a combination of graphite, copper, and steel.[103] The protection capabilities of these cannisters are of the utmost importance. Therefore, they are robust enough to continue to shield effectively for approximately 100 000 years, over four times the length it would take for plutonium to degrade to safe levels (24 000 years).[104] However, the disposal process is not as simple as a container arbitrarily placed underground. There are multiple studies completed to ensure the safety and validity of a potential storage facility. The building's infrastructure is meticulously developed to provide multiple layers of natural and man-made fail-safes to ensure that the devastation brought about by the negligence and flawed design of the soviet-era Chernobyl reactor will never happen again.

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100 Salvatores, M. "Nuclear Fuel Cycle Strategies Including Partitioning and Transmutation." Nuclear Engineering and Design 235, no. 7 (2005): 805–16. https://doi.org/10.1016/j.nucengdes.2004.10.009.

101 Salvatores, M. "Nuclear Fuel Cycle Strategies Including Partitioning and Transmutation." 806.

102 1 US ton = 907,185 grams

103 Hedman, Tommy.; Nystrom, Anders.; Thegerstrom, Claes. "Swedish Containers for Disposal of Spent Nuclear Fuel and Radioactive Waste." Comptes Rendus Physique 2002. https://doi.org/10.1016/S1631-0705(02)01378-6. 906-907.

104 Hedman, Nystrom, Thegerstrom. "Swedish Containers for Disposal of Spent Nuclear Fuel and Radioactive Waste." 910.

Nuclear marine propulsion is not a new concept. It began in the 1940s, and by the mid-1950s the first nuclear powered submarines were built and tested successfully. Nuclear power is particularly suitable for vessels that need to be at sea for long periods as it produces consistent, reliable power for decades without the need for refuelling. Nuclear power generation can be scaled to the requirements of its ship, being able to generate between 3 and 550 megawatts of power depending on the size and number of reactors.[105] Initially, nuclear power was reserved for submarines, however it quickly spread its utility to other types of military, and even civilian, vessels. Currently over 160 ships are powered by more than 200 small nuclear reactors, with over 700 ships having been used at sea since the 1950s.[106] The designs of the more common marine reactors are based off the submarine reactors that are required to withstand shock and vibration during service from either the turbulent ocean or an enemy's assault. If nuclear power has been deemed safe enough for active combat in a warzone, then I believe it will be safe enough to be used in a more beneficial manner through the remediation of our world's oceans. The exaggerated fears about safety have caused political restrictions on port access for nuclear ships. Yet as the restrictions on fossil fuel use tighten, marine nuclear propulsion will begin to see an even more widespread use in the coming years.

Although the vessel proposed in this thesis is primarily centred around the use of green energy, it is unlikely that

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105 1 megawatt (MW) is equal to 1000 kilowatts. 1 kilowatt (kW) is equal to 1000 watts.

106 "Nuclear-Powered Ships." Nuclear, November 2021. https://world-nuclear.org/information-library/non-power-nuclear-applications/transport/nuclear-powered-ships.aspx.

the solar or wind technology of today can compete with a typical fossil fuel vessel, let alone a marine nuclear reactor. Future advancements of green technology have the potential to out-perform nuclear reactors; on the specifics of this matter, however, we are left to conjecture. Nonetheless, the infrastructure to fulfil the vessel's energy requirements through nuclear fission is available immediately, effectively, and safely. It is unfortunate that the cost of remediating the atrocity of potentially millions of tonnes of ocean plastics is the creation of comparatively small amounts of nuclear waste. However, in my opinion the cost of permanently losing the ocean as a resource is far greater.

Habitation & the Human Element

Being out at sea for extended periods of time means that the vessel must have the capacity to meet the needs of its occupants. In the simplest terms this means that there must be a reliable stockpile of food and water and protection from the elements. However, any time spent travelling to and from port, as well as docking to load and unload would be time not spent working on the issue at hand. An alternative to the lost time constantly travelling to and from ports is to embrace elements of autonomy.

Desalination Plant

The first step to becoming more autonomous is to secure a reliable source of water. Conveniently, the ocean has a nearly endless supply. Yet, humans are not capable of drinking ocean water directly, it must be processed to be potable. Rather than depending solely on water that is purified on land, packaged, and transported to the vessel. The Seascraper desalinates its own water from the surrounding ocean and store excess fresh water on-site.

Access to fresh water onboard the Seascraper is essential for the residents and functions of the vessel. It is not only used for drinking and bathing, but also for cooking, doing laundry, and even the routine cleaning of the vessel. Having a constant supply of fresh water for cleaning is essential as the corrosive nature of seawater is highly damaging. The deep-sea water that the ship sails through is ideal for onboard reverse osmosis filtration. Figure 5.28 illustrates how this process uses a series of fine filters that will separate the salt from the water. Unlike the process of creating distilled water,

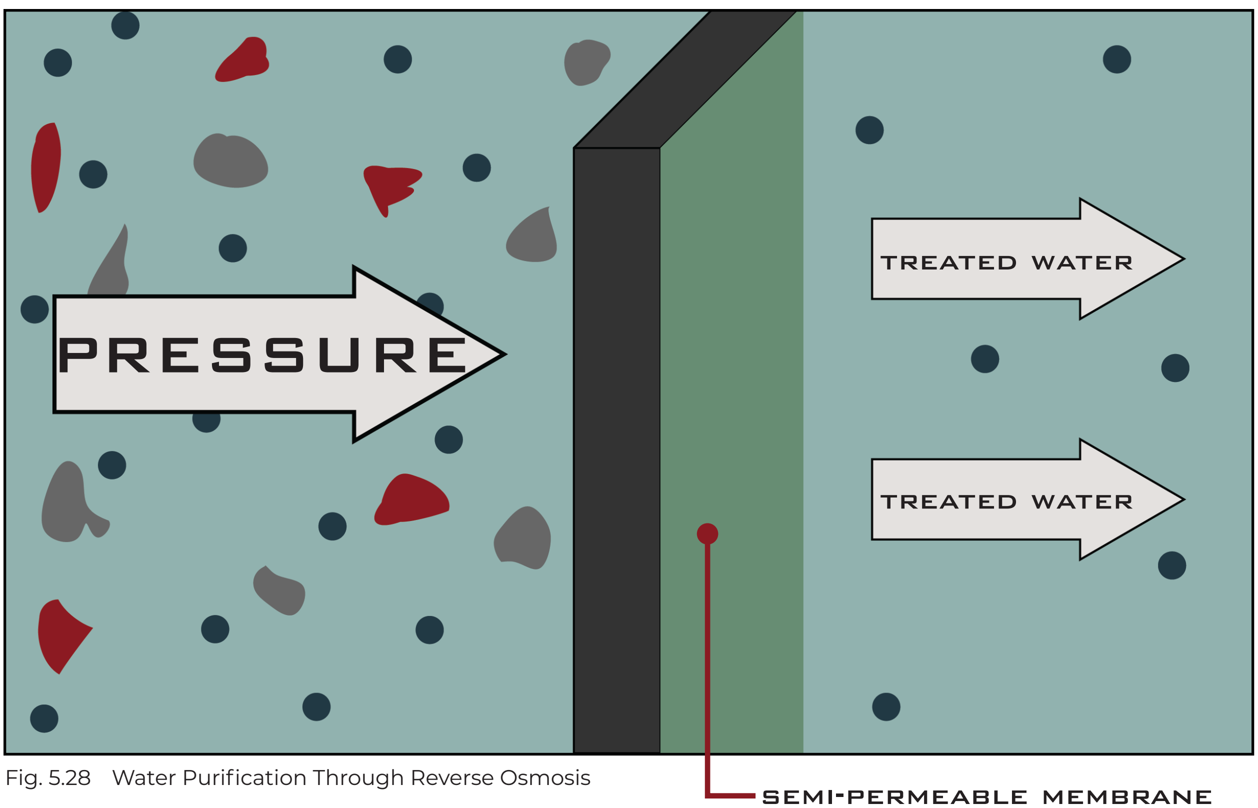


Fig. 5.28 Water Purification Through Reverse Osmosis

which extracts nearly all the minerals, the physical processes of reverse osmosis only remove select minerals resulting in less additives required for dosing the water to bring it up to potable standards. Reverse osmosis filtration is so effective at removing particulates that some trace amounts of minerals must be reintroduced to obtain the highest quality water. This purification process does not work as effectively in shallow water as there are significantly more biotic and abiotic contaminants that can ruin the filters. It is essential that an autonomous vessel has the capability to generate its own supply of fresh water, since water is a building block of survival.

Food Management

The primary restraining factor of the recycling facility is the requirements of its occupants. With a desalination plant, the supply of water is nearly endless, however maintaining a steady supply of food is a different story. Aside from fishing, food is hard to come by in the ocean, especially since the salinity of the water and air would ruin any ideals of depending on a micro farm that directly utilizes sunlight. Therefore, there must be large storage spaces to ensure that food supplies do not run low very often. Modern storage techniques and long-term planning can dramatically extend the freshness of the food onboard. By equipping the vessel with an extensive pantry space and freezer storage the number of food resupply trips to port can be reduced. However, since the time spent travelling to port is not ideal, courier vessels will be able to handle resupplies to reduce the need to travel to port. Shelf-stable and frozen foods are a staple for long trips as the food will not spoil quickly and can be transferred easily.

To reduce further the need for resupply and simultaneously increase the available food stores, a series of hydroponic systems are installed and maintained inside the vessel. Rather than risking the harmful effects of the ocean's salty breeze, these systems function in the underdeck levels. By controlling the temperature in the under-deck space as well as installing specialty lighting, fresh vegetables can be obtained with minimal effort. Fruits and vegetables grown in hydroponic systems do not explicitly require energy directly from the sun or nutrients from soil to grow. Light from full spectrum LED's and a nutrient cocktail injected into the closed loop water supply is all that is required for these plants to flourish. There are a variety of proprietary systems that are designed to compactly produce a bounty of food in a short time frame. Figure 2.29 illustrates the method used in the NFT system. It is an ideal system for small, quick growing plants such as leafy greens. While not every fruit or vegetable

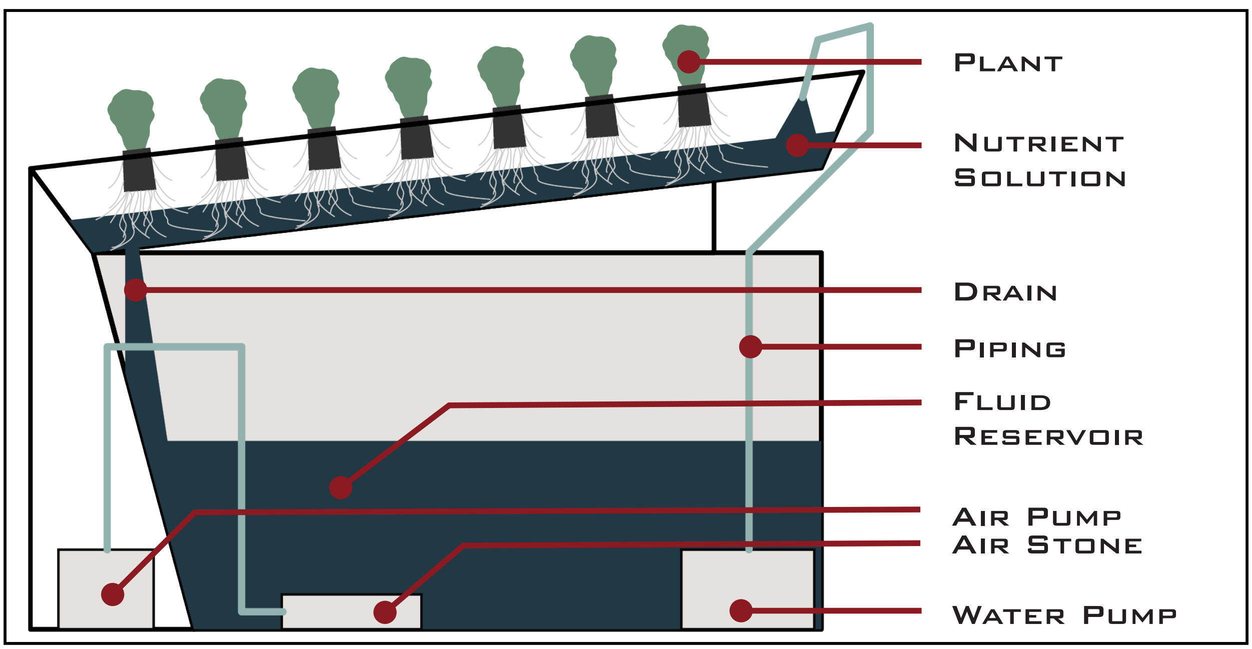


Fig. 5.29 Pictured is a version of the NFT (Nutrient Film Technique) hydroponic system.

is able to be grown effectively in these systems, there is still a large variety that thrive in these conditions: most leafy greens, nightshades, and even some fruits can be grown in these conditions.[107]

Eventually when the frozen and dry food storages become low it will need to be replenished, however the food grown onsite will be able to supplement the courier items and require less trips overall. Since the vessel will spend most of its time navigating between clusters of floating trawls it can plot a route so that when the food stores begin dwindling it will be ideally positioned for a resupply ship to meet it at a shorter distance from land.

Waste Management

Any substantial human community, whether on land or in the ocean, will inevitably create waste, and dumping raw garbage and sewage into the ocean is unacceptable. Coastal communities have dumped waste into the ocean for centuries, however these elements have been either natural, inert, or in small enough quantities that the harm could not be seen in the surrounding ecosystems. However, ships and governments have been haphazardly dumping industrial waste into the ocean for decades. As the ocean is so vast, they must have thought that a few boat loads of refuse would surely not cause significant backlash in the ecosystem. However, in the mid-20th century it has been found that this practice of dumping became the norm and has been incredibly harmful to the fragile ocean ecosystems. Since then, ocean dumping

107 Leafy greens: basil, bok choy, various lettuces, kale, spinach, cabbages, some types of onions, and even various herbs. Nightshades: Tomatoes and peppers. Fruits: Strawberries, blueberries, grapes, and melons can be grown under the right support

has become regulated under the London Convention, a global agreement to protect the marine environment from human activities.[108] On a typical ship wastewater can be divided into three categories: grey water from sinks, laundries, and drains; black water from toilets and galleys; and bilge water which may contain detergents, oils, and solvents. To purify these fluids to an acceptable state they must undergo an on-site waste management process that separates the harmful contaminants and purifies the water.

Since there are harmful bacteria and contaminants in the wastewater, it must undergo a cleaning process using an integrated treatment system. A highly effective system filters the waste and concentrates two key elements: wastewater that has been cleaned enough that it can be safely discharged in the ocean, and a dense sludge that can be cleanly incinerated in accordance with proper marine waste guidelines. Wastewater is fed through an aeration chamber where conditions are ideal for the kinds of bacteria that begin to break down any organic matter in the wastewater. Afterwards the water is passed through a filtration system to gradually remove increasingly finer particulates. Eventually the water enters a chamber where it is allowed to settle. While water accumulates at the top, heavier solids sink to the bottom forming into a type of condensed sludge. This sludge is then looped back into the previous system for reprocessing with any persistent solid materials to be disposed of in low-emission incinerators. The water that separates to the surface enters a chamber where it is bombarded with sterilizing UV radiation to eradicate any hazardous pathogens. At this point the cleaned, bacteria-

108 "Ocean Dumping: International Treaties." EPA. Environmental Protection Agency. Accessed December 15, 2021. https://www.epa.gov/ocean-dumping/ocean-dumping-international-treaties.

free water is at potable levels of cleanliness and is used for the regular cleaning of the exteriors. This water is stored until it can be used or responsibly discharged into the ocean when there is an excess. However, as vast as the ocean is, there are areas that are designated environmentally sensitive. These protected zones limit the ship's capacity to discharge even the cleanliest of waters in order to prevent further disruption to the fragile ecosystem below.

Courier Ships

The use of courier ships to transport resources to and from larger vessels is not a new concept and the practice of replenishment at sea (RAS) has been in practice for many decades. Much like the variety found in the ship's boats, different methods of transferring between ships are also required to serve different purposes. When the supplies are running low, rather than travel several days to port, the main vessel requisitions a resupply from the shore and coordinates a location to meet the resupply ship. The resupply vessel's crew accumulates the required supplies, resources, and even people. In this time the main vessel is able to get closer to shore to reduce the resupply ship's total travel time.

A ship-to-ship resupply in the open ocean is entirely different from a simple port resupply. While in the calm waters of the port, ships are tied down to points on land and relative stability is achieved. In the ocean, attempting to recreate the stability found in ports is nearly impossible since the motion of the waves cause idle ships to sway. However, the lateral intensity of wave action is reduced if the ships are actively sailing. By having the two ships sail in parallel, and in relatively calmer waters they can perform S.T.R.E.A.M. effectively. The STREAM, or standard tension replenishment alongside method, is the preferred method of at-sea replenishment as this keeps the vessels more stable and farther apart.[109] The following images show the two main types of at-sea resupply methods: CONREP (Fig. 5.30) and VERTREP (Fig. 5.31 & 5.32). CONREP, short for alongside connected replenishment, is primarily designed to transport fluids such as water, oils, and fuel through piping between ships. To properly transfer resources the vessels will launch a structurally sound guide wire. This wiring system is affixed to both vessels and supports the long-distance deployment of the piping systems. VERTREP, or vertical replenishment, is when a helicopter is used to ferry solid cargo from the supply ship onto the main vessel. VERTREP is an ideal complement to CONREP as the former specializes in the transport of solid cargo and the latter can only transport fluids.

The methods of CONREP and VERTREP are highly effective for transferring items that are essential for the functions of the ship. Yet, to unload the massive stores of plastic pellets on board using VERTREP is entirely unsuitable due to the accumulated volume of recycled plastic pellets. By adopting the methods used by self-unloading vessels, the large quantities of recycled plastics can be unloaded quickly. This process involves utilising a series of gravity fed hoppers that transfer the pellets from storage onto conveyer belts that allow the plastic to be carried up from the middle of the ship and out the top. From the top of the ship a large crane arm can be adjusted to match the position of the nearby vessel that the pellets are being deposited into. Ideally, the ships

109 Lukacs, John. "A Century of Replenishment at the Sea." Naval History and Heritage Command. Naval History, August 8, 2018. https://www.history.navy.mil/get-involved/essay-contest/2017-winners/additional-essay-contest-submissions/a-century-of-replenishment-at-the-sea.html.

Fig. 5.30 USS Charleston, right, receiving a fuel probe from the USNS Guadalupe.

Fig. 5.31 An MH-60F Sea Hawk helicopter transfers supplies to a Nimitz-class vessel.

receiving the load are also self-unloading bulk carriers as they are specialty made ships for receiving, carrying, and offloading large quantities of dry goods.

The human element of this floating structure is much more than just the basic necessities required to sustain human life. This structure is a framework upon which an emerging community can grow and support the ongoing evolution of the spaces. While unable to sprawl to the same extent as a terrestrial city, the public spaces of the Seascraper act as the heart of this ocean-dwelling community. These spaces are designed to be engaging to the senses and create a bond between the occupants and the space itself. If there is a strong connection between the people and the structures that they share, then this connection can eventually be extended out to the surrounding natural environment.

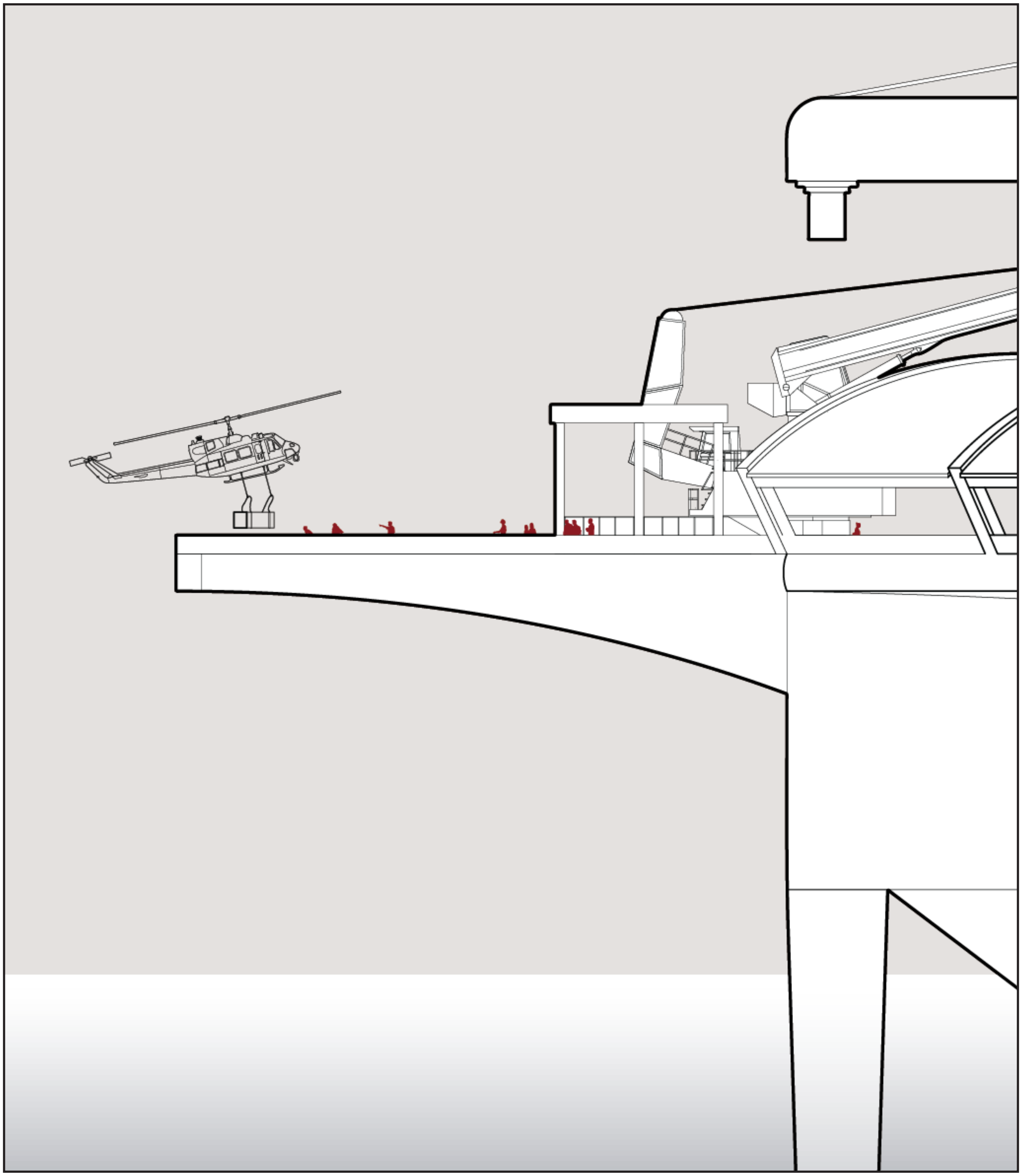


Fig. 5.32   A UH-1H Huey helicopter transfers supplies to Seascraper vessel.

05

Chapter 5
Design Images and Commentary

The Bridge

Living Areas

Main Deck

Atrium

Interactive Green Space

Library

Gym

Dining Hall

Lower Decks

Pontoon Levels

Ocean Space-Making and Community Building

The underlying design philosophy for the vessel created in this thesis is to advance the creation of a harmonious union of the architectural form, the vessel's purpose, and a high quality of life for the on-board residents. The design of the exterior of the vessel is inspired by architectural zoomorphism championed by Santiago Calatrava. This is a belief that animals and plants have an ideal form that provide a wealth of design opportunities when combined with the rhythms of human life. Within the designs of the brisé soleil of the Quadracci Pavilion at the Milwaukee Art Museum, pictured in figure 6.1, it can be seen that Santiago Calatrava has furthered his zoomorphic designs from a static form of architecture with animalistic notions to a dynamic harmony of engineering and nature-inspired design. Likewise, the zoomorphic inspiration for the vessel in this thesis has been the manta ray, as seen in figure 6.2, which is often found far from land and travelling with the currents. An incredibly intelligent and highly threatened species, manta rays deftly navigate through the pelagic and mesopelagic zones of the ocean searching for food. The broad wingspan of these creatures allows them to glide effortlessly throughout the ocean and it is this effortless horizontal movement that has inspired the vessel's exterior "wings" and its development of the rhythmic rib patterns. The design of a zoomorphic architectural form has been chosen as a way to embrace an oceanic architectural identity that has yet to be established.

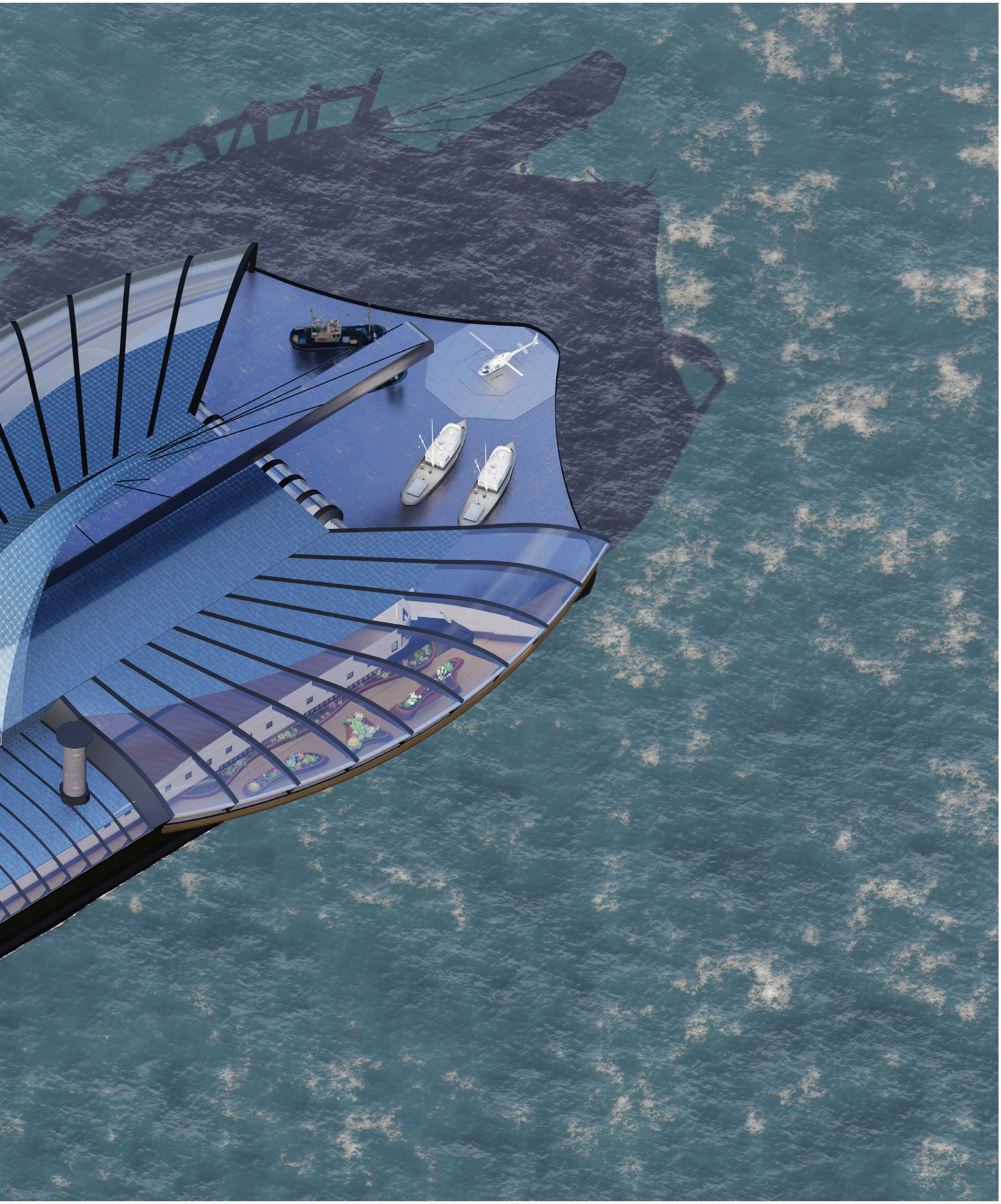
The proposed vessel in this thesis, the Seascraper, boasts organic-like slopes that define this superstructure instead of harsh, perpendicular exterior walls and flat roof surfaces.

The sloped exterior surfaces, seen in figures 6.3-6.7, create an aerodynamic form that reduce wind resistance, increase the available mounting area for photovoltaic panels, and supply opportunities for rain shedding or collection. Having an aerodynamic vessel sailing through the water is essential to reduce the amount of drag created. As a result of less drag, there is less propulsion force required to drive the vessel forward. This means that the thrust derived from wind energy can also have a more significant contribution in reducing the vessel's dependency on mechanical propulsion. Additionally, the angles of the sloped exterior walls are beneficial to the reception angles of photovoltaic panels which increases their overall effectiveness. The harsh vertical nature of typical exterior walls severely limits the amount of direct sunlight that the panels would receive. By contrast, mounting these panels to the angled superstructure increases the total surface area; a higher quantity of panels correlates with an increase in the amount of power generated. The large slopes of the roof structures can also be used as a means to collect rainwater. During significant rainfall events, the approximate 20,000 square metres of surface area can collect significant amounts of water. This extra water can be processed through the standard purification system to become potable water, or it can be used in the cleaning of the exterior of the vessel as non-purified water.

Fig. 6.1 Photograph of the Brise Soleil at the Milwaukee Art Museum

Fig. 6.2 Photograph of a Manta Ray


Fig. 6.3   Exterior Render 01



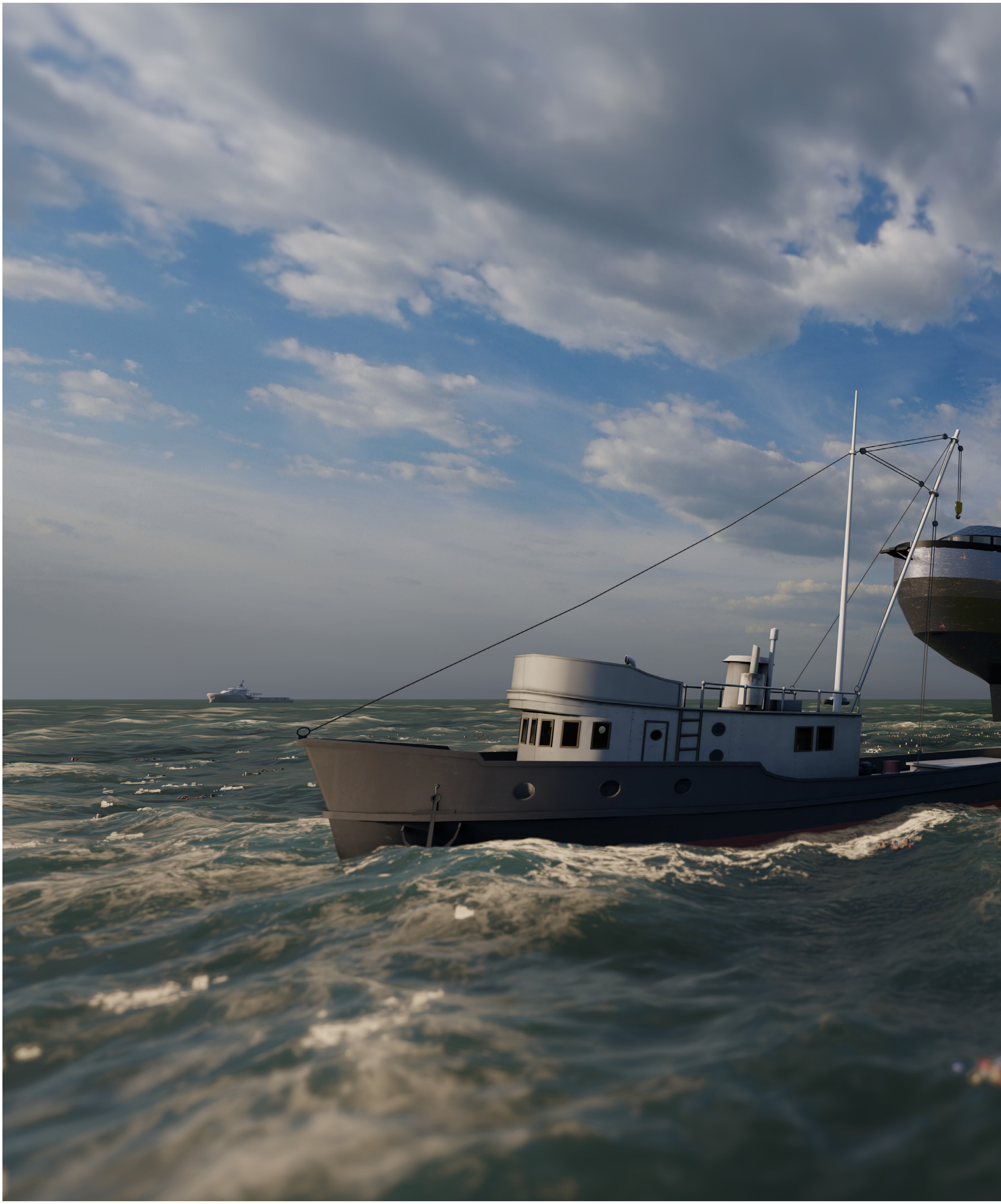
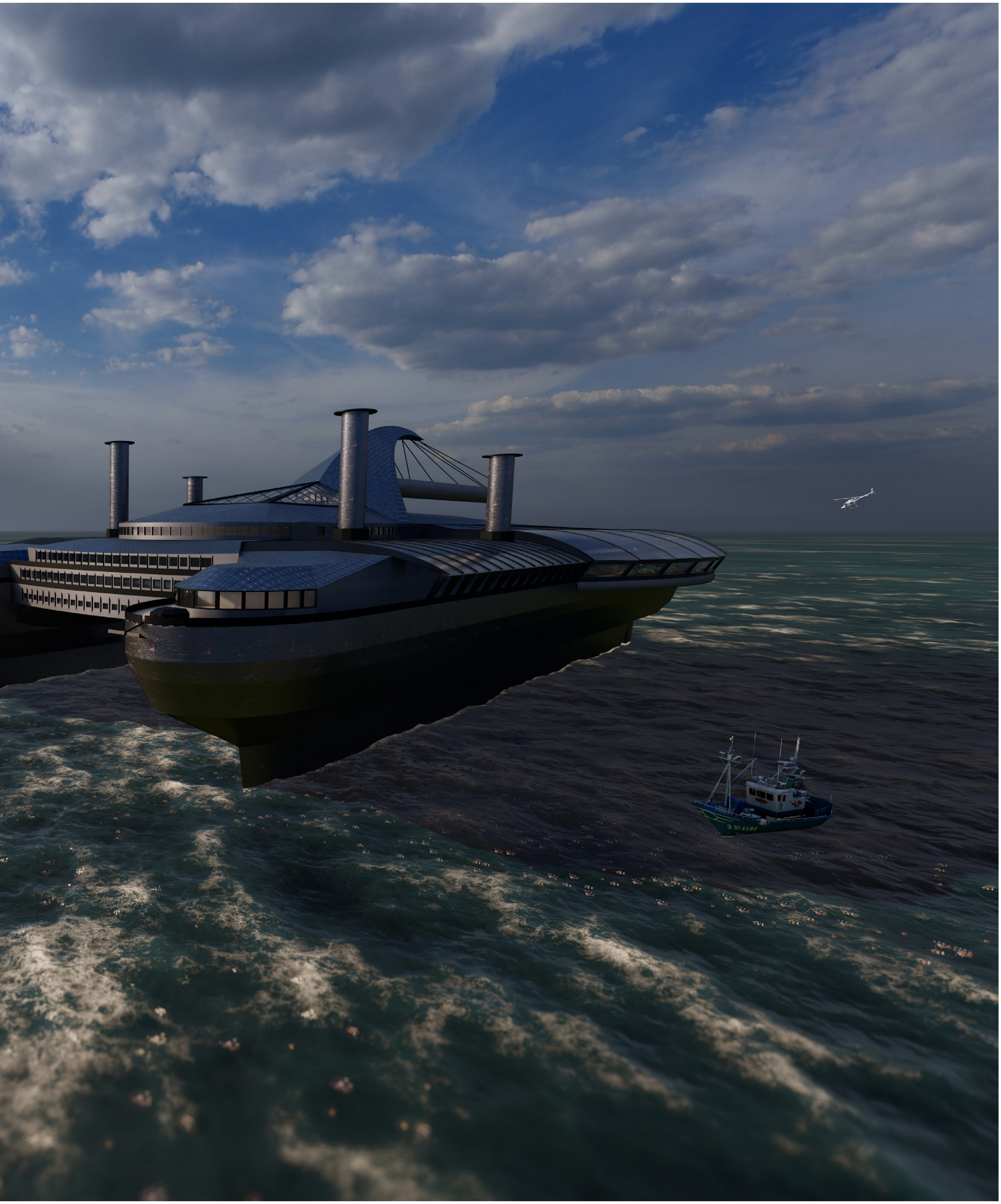


Fig. 6.4 Exterior Render 02

Fig. 6.5 Exterior Render 02



Comparable to the designation of land within cities, the Seascraper is organized by grouping related programming into connected zones. Since the vessel's capability to sprawl is a limiting factor, the programs are stacked on top of one another creating a compact three-dimensional micro-city. Figure 6.6 is a visual summary of the spacing of key locations. While there are similar spaces that are maintained throughout the vessel, there are also many areas where the compact design creates unique spaces. Figures 6.7-6.12 are a series of procedural cuts through the vessel to provide an example of the distribution of related programs. This program organization is often seen in urban mixed-use buildings as a way to blend the residential, commercial, or institutional zoning while keeping their functions separated. The lowest levels of the ship behave similarly to the manufacturing, industrial, and even agricultural zones. Equipped with the heavy machinery and navigation equipment that is essential to the daily operation of the vessel itself, this area is only accessed by a few maintenance crews. By contrast, the upper levels of the vessel would house the majority of the residents and behave like the residential, commercial, and recreational zones. The upper levels of the ship can house up to 200 residents at any given time and contain various amenities to accommodate, support, and provide a well-needed avenue for the residents to unwind.

The intent of this thesis is to create a unique structure that serves a meaningful purpose within its immediate community as well as to contribute to the global community. This thesis is not just a waterfront building that is situated within viewing distance of water, it is a structure that is fully engaged with the ocean. Its purpose of ocean stewardship through the removal and recycling of plastic is intended to provide immediate care and foster a community with an environmentally focused perspective striving to put an end to the neglect by previous generations. Since this structure is an investment in the future of ocean sustainability, an emphasis on low-impact designs to mitigate ocean ecosystem disruption or destruction has been an important factor to consider.

While this vessel is primarily focused on the improvement of ocean habitats, its function cannot eclipse the wants and needs of its occupants. Without a dedicated crew this vessel could not function. Therefore, there are various amenities aboard that will ease the transition between life on land and life on the water. These spaces are intended to replicate, albeit on a smaller scale, what one finds in many urban settings. These areas focus on the creation of meta-communities to form a meaningful bond between the residents outside of the work they are doing. This includes the making of spaces that will stimulate the mind, challenge the body, and provide areas for relaxation. These spaces punctuate the resident's daily life in the form of interactive green spaces and gathering spaces, fitness rooms and areas for sports, library and digital media areas, and even café and bar spaces. The addition of these spaces is intended to create an enjoyable experience for the resident's extended inhabitation.

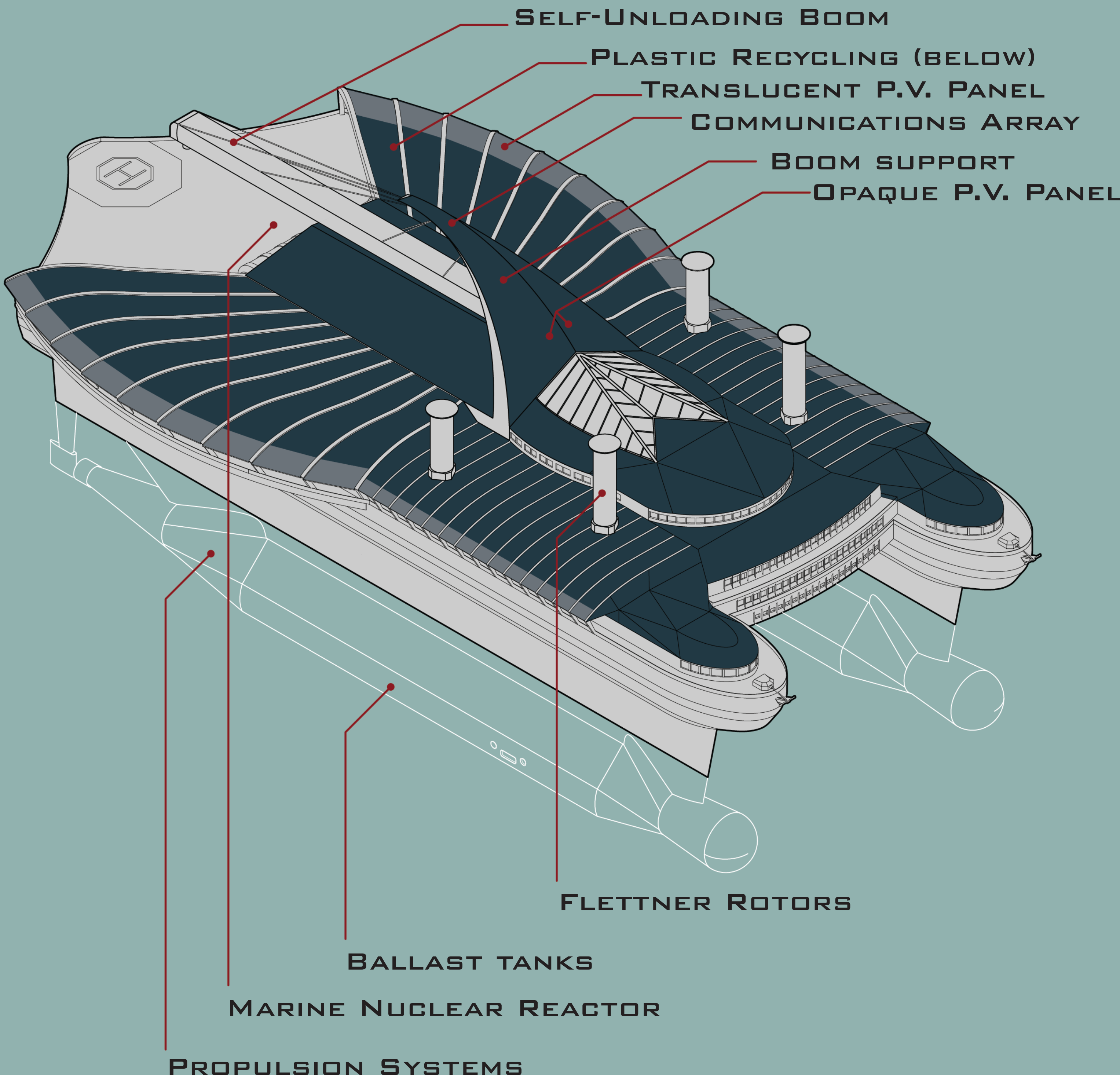
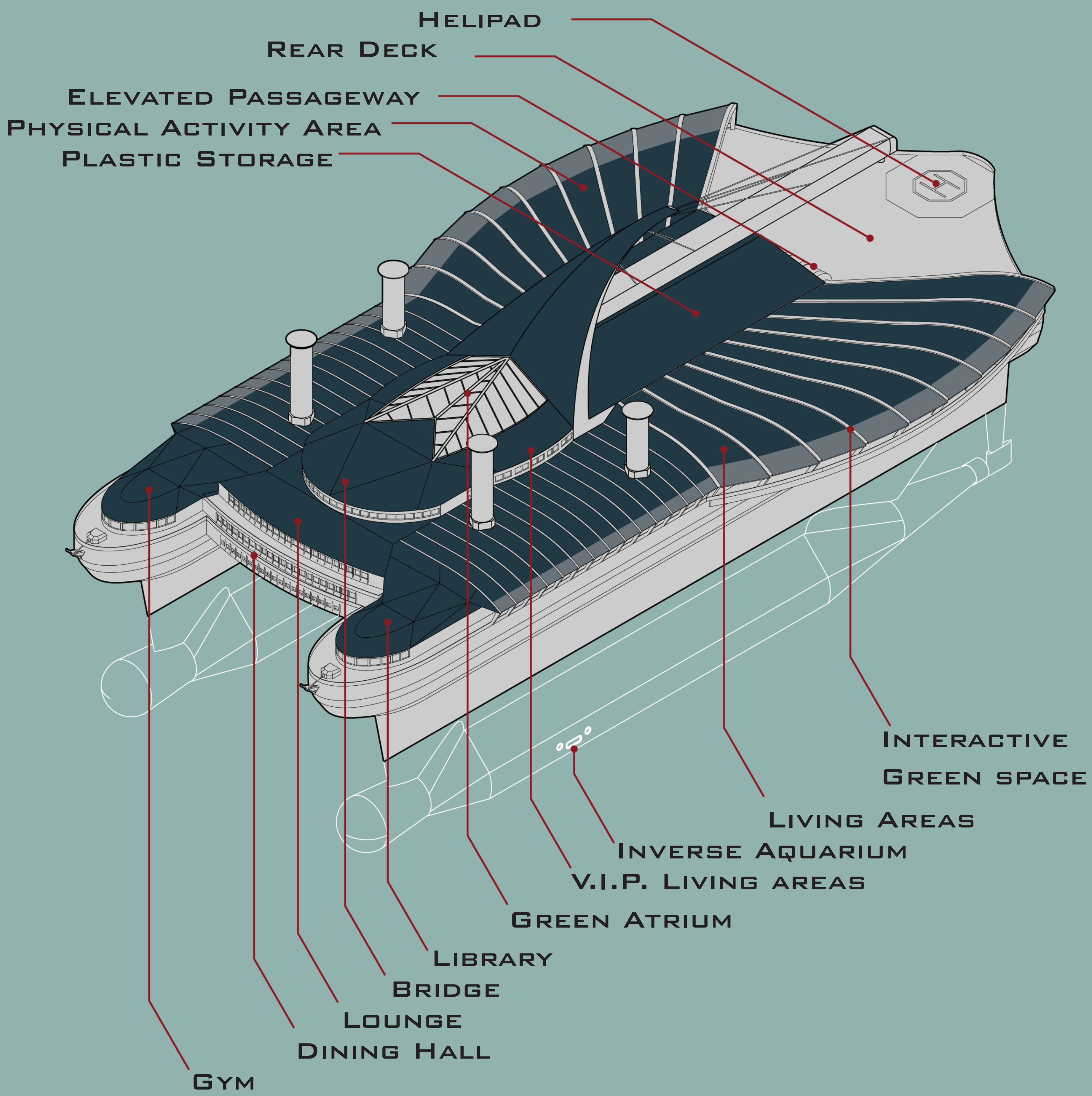


Fig. 6.6 Summary of Key Areas


Helipad
Rear Deck
Elevated Passageway
Physical Activity Area
Plastic Storage
Interactive
Green space
Living Areas
Inverse Aquarium
V.I.P. Living areas
Green Atrium
Library
Bridge
Lounge
Dining Hall
Gym

Longitudinal Elevation

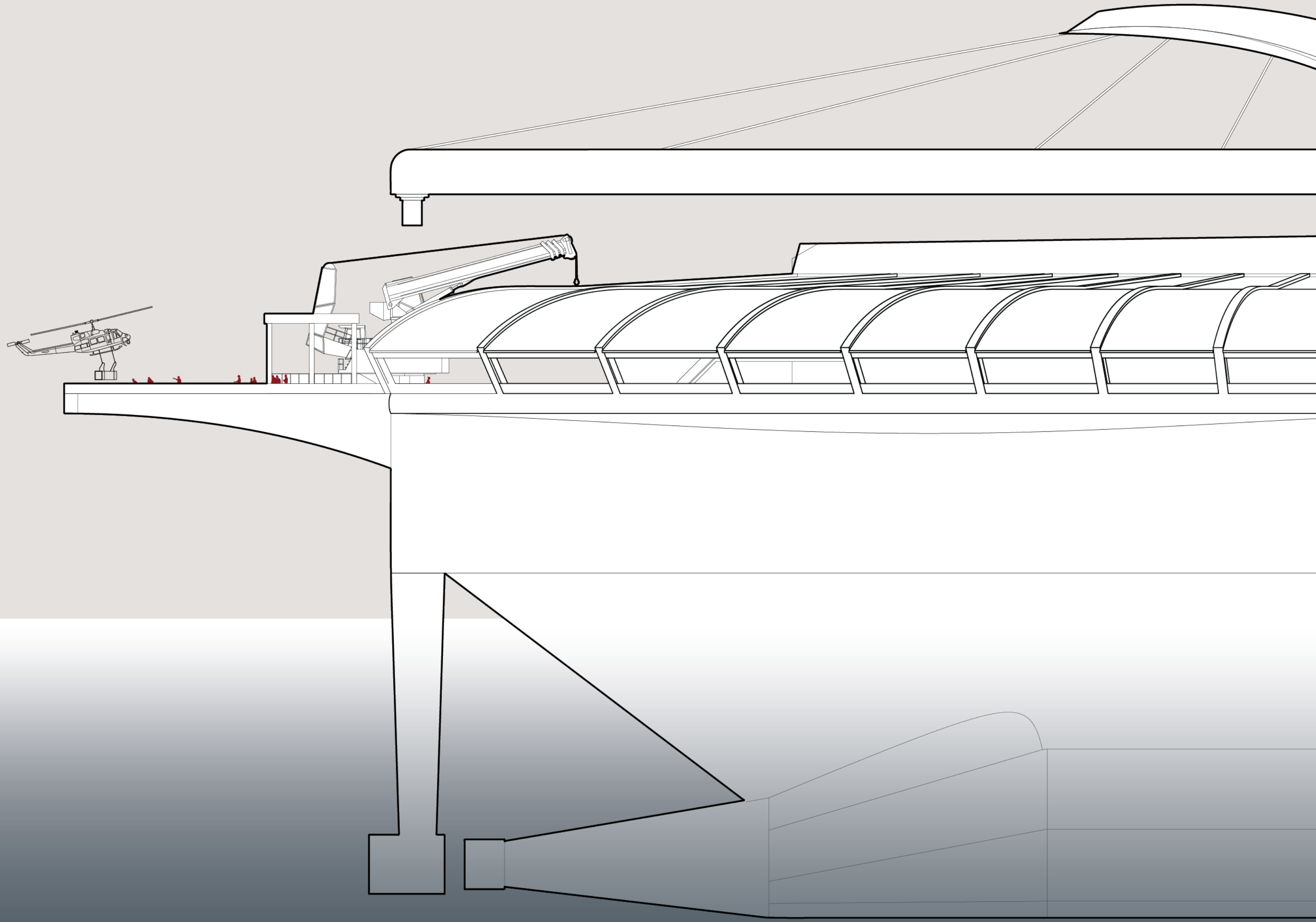
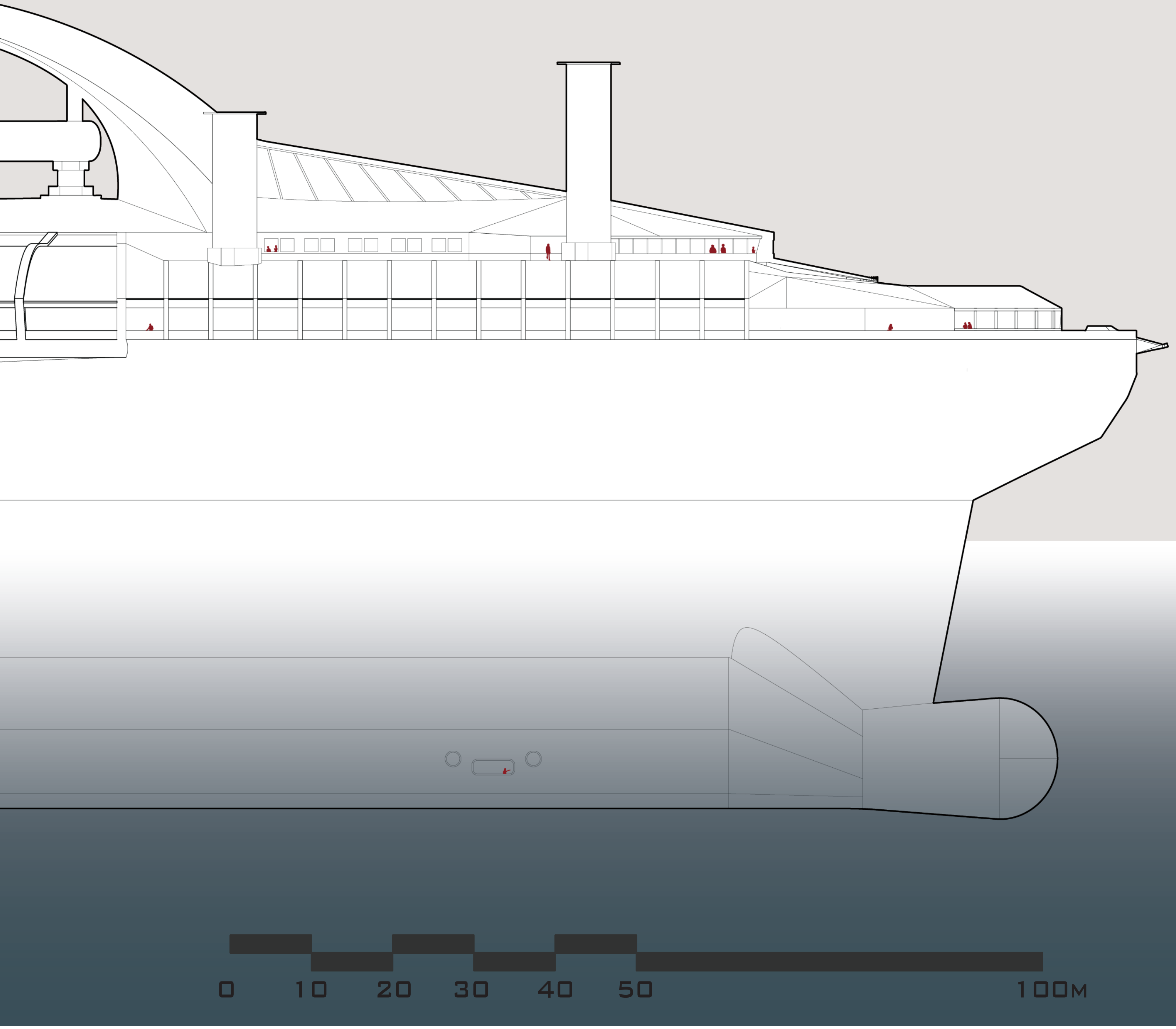


Fig. 6.7 Elevation of the broadside of the vessel.


0
10
20
30
40
50
100M

Longitudinal Section

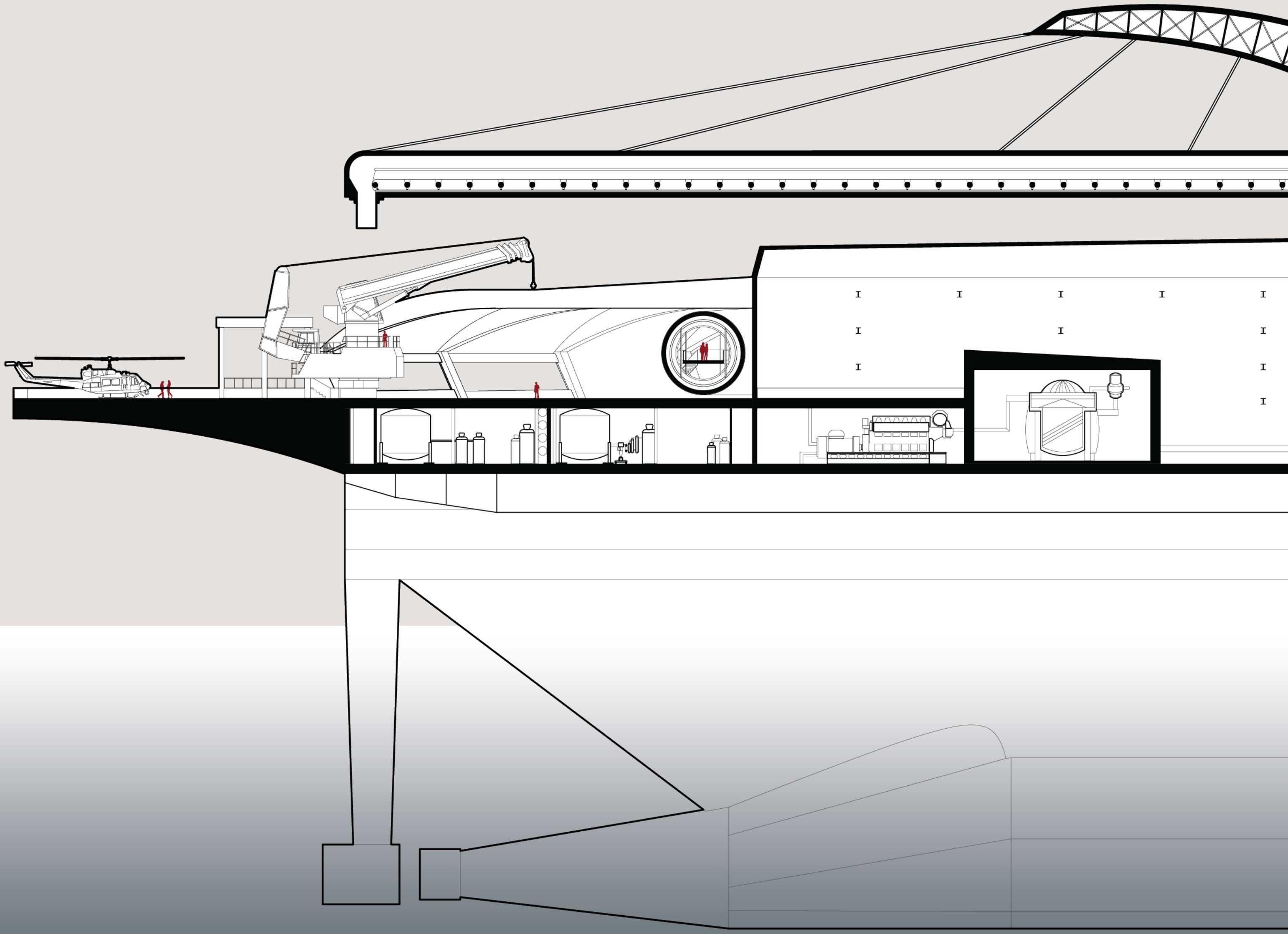
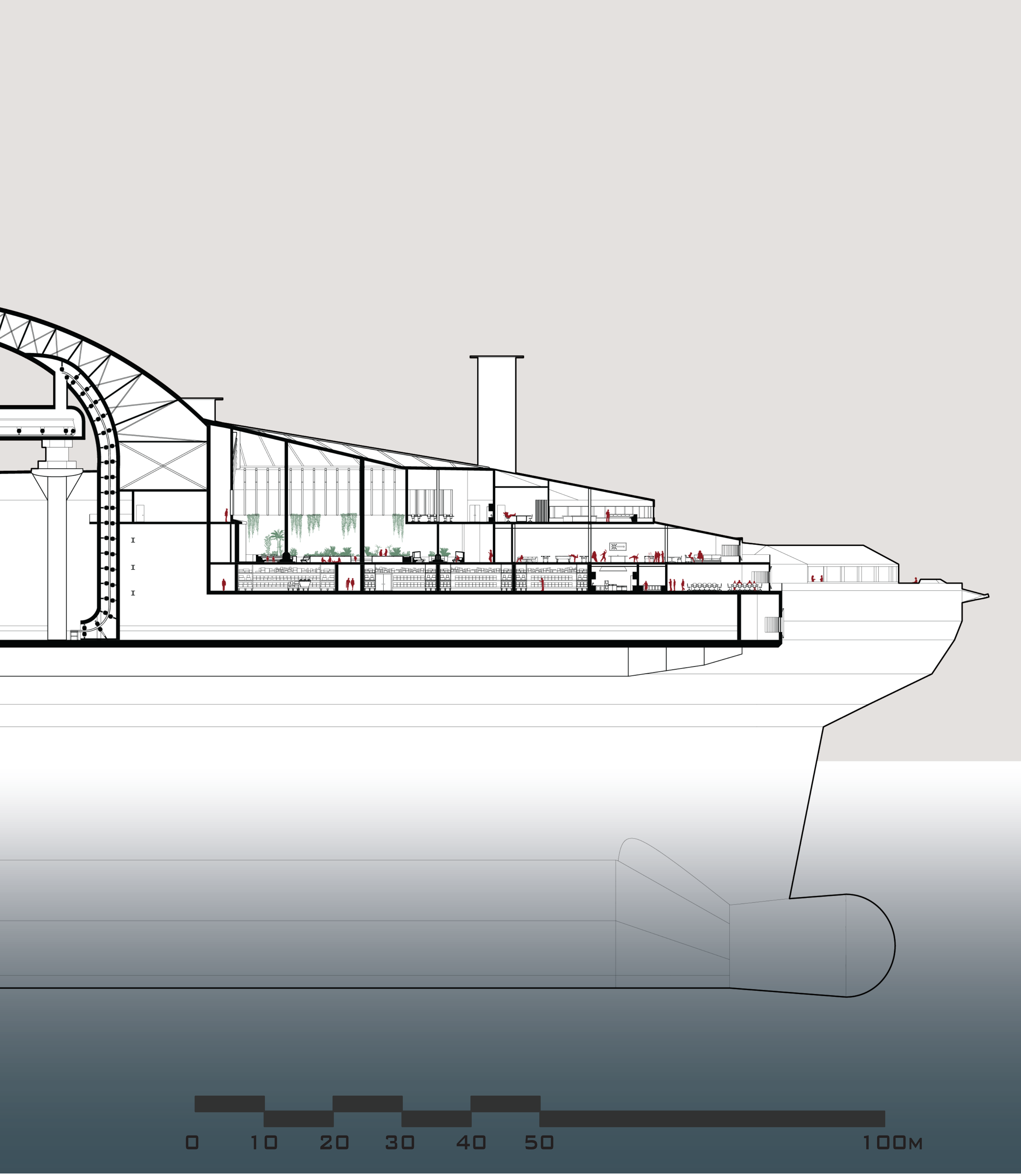


Fig. 6.8 Section through the middle of the vessel.


0
10
20
30
40
50
100M

Transverse Elevation

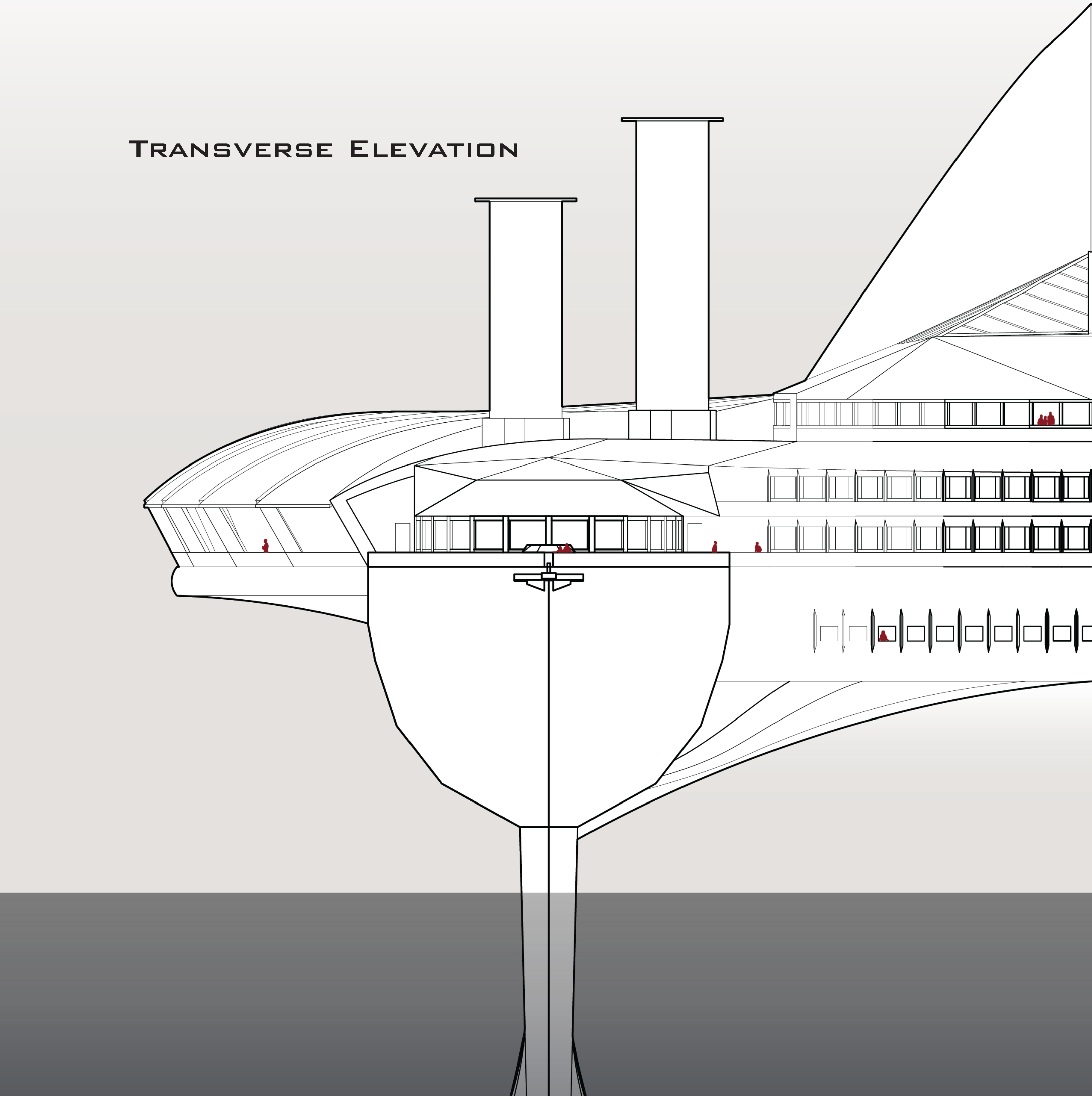
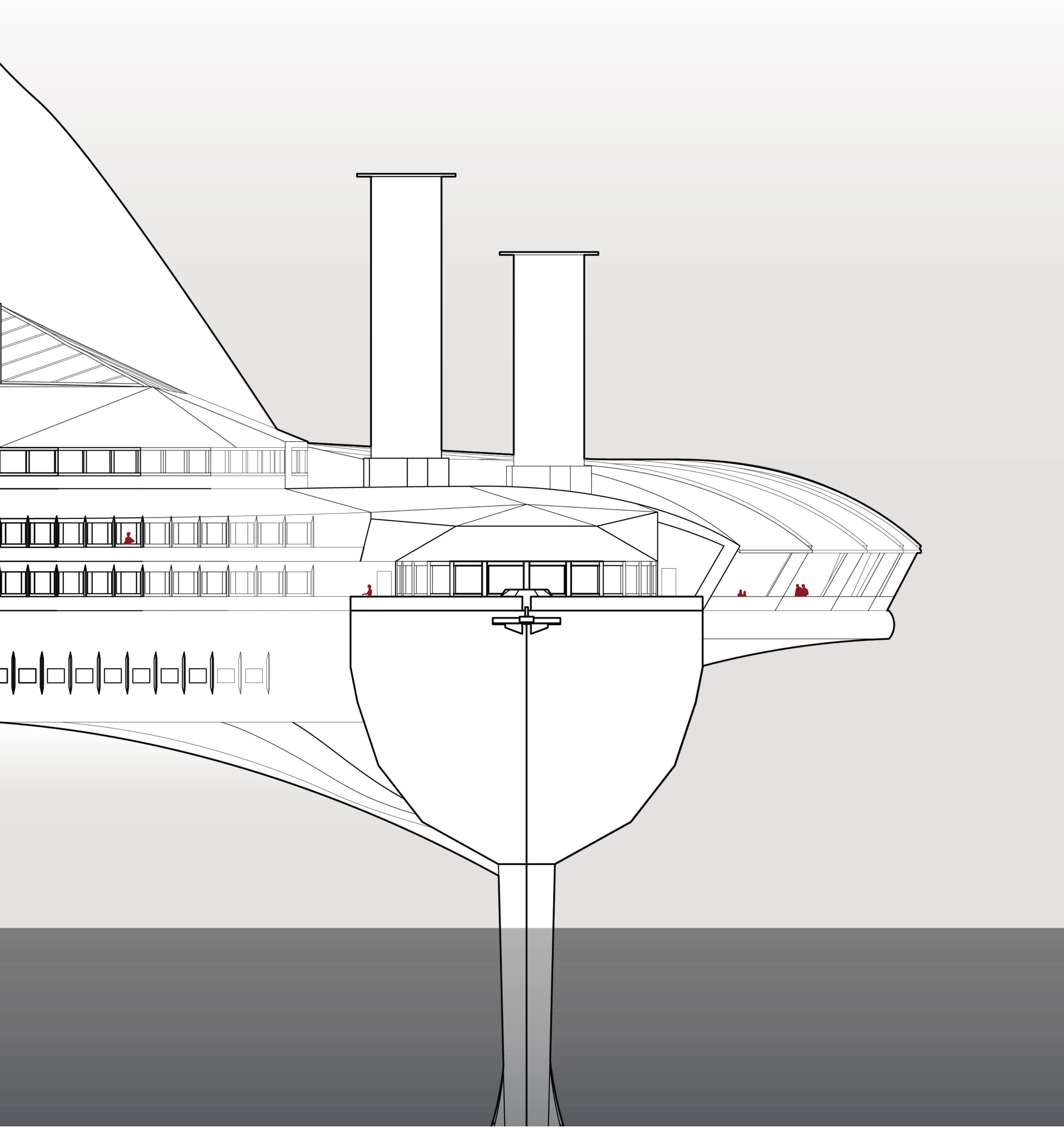


Fig. 6.9 Front elevation of the vessel.



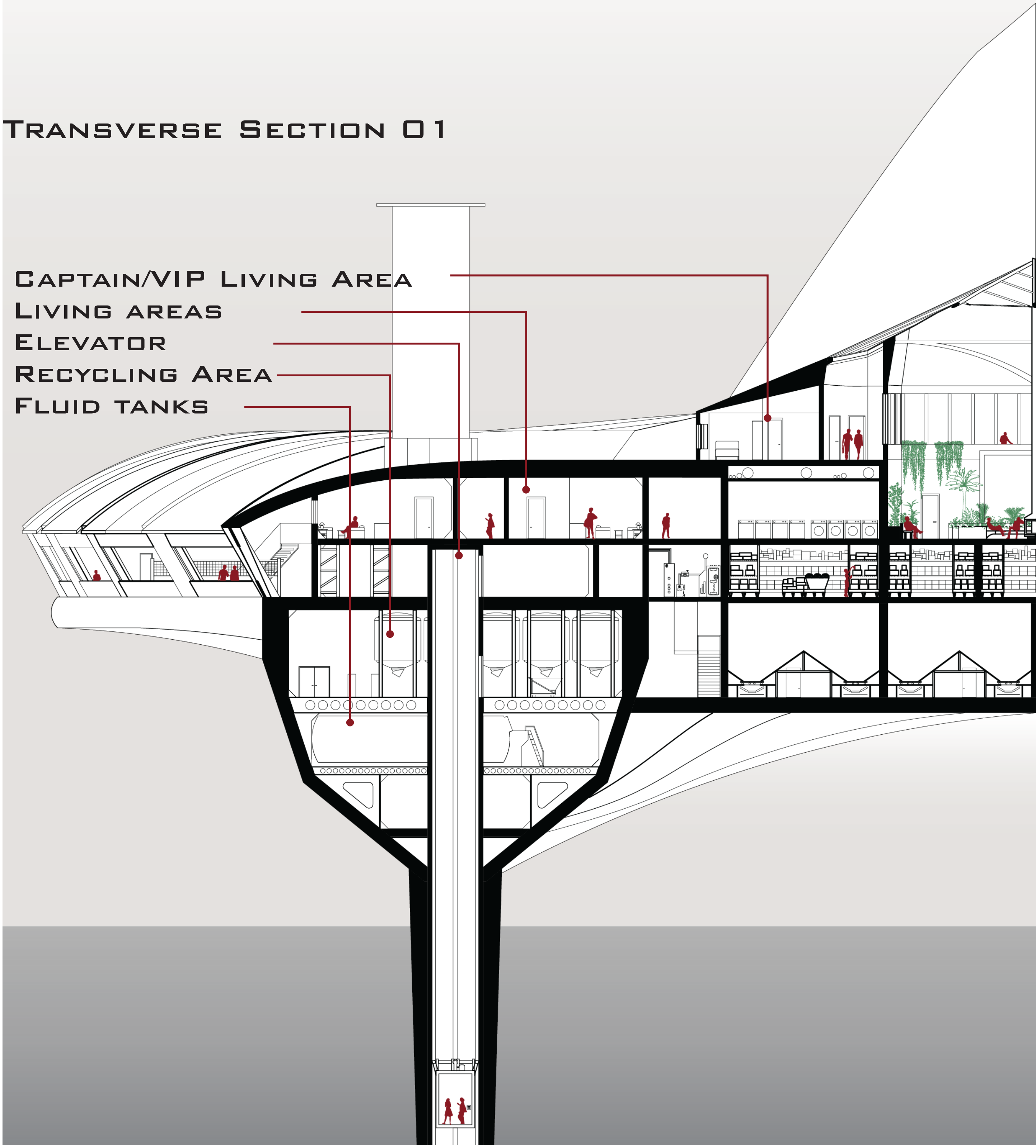
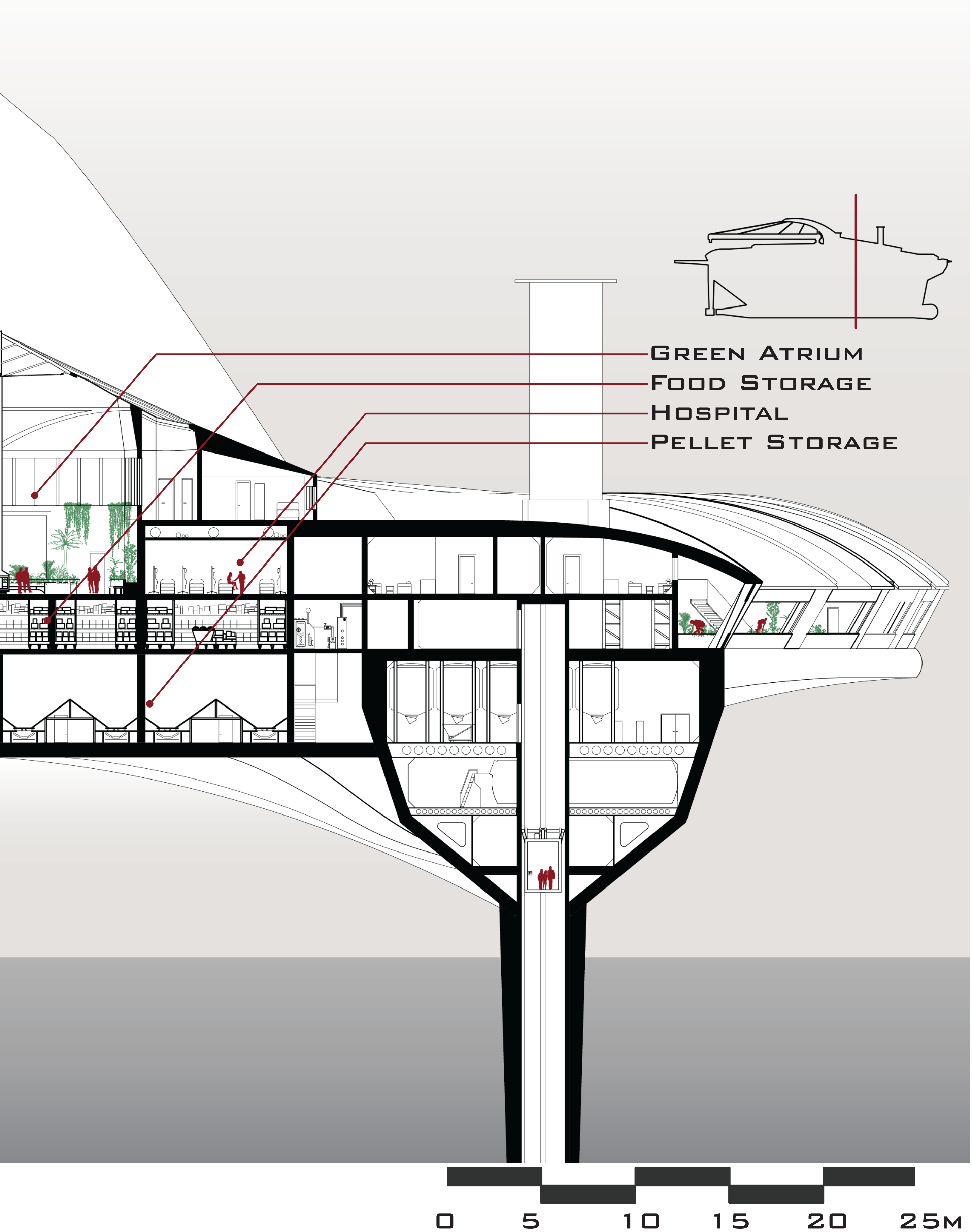


Fig. 6.10 Transverse Section 01


Green Atrium
Food Storage
Hospital
Pellet Storage
0
5
10
15
20
25m

Transverse Section 02

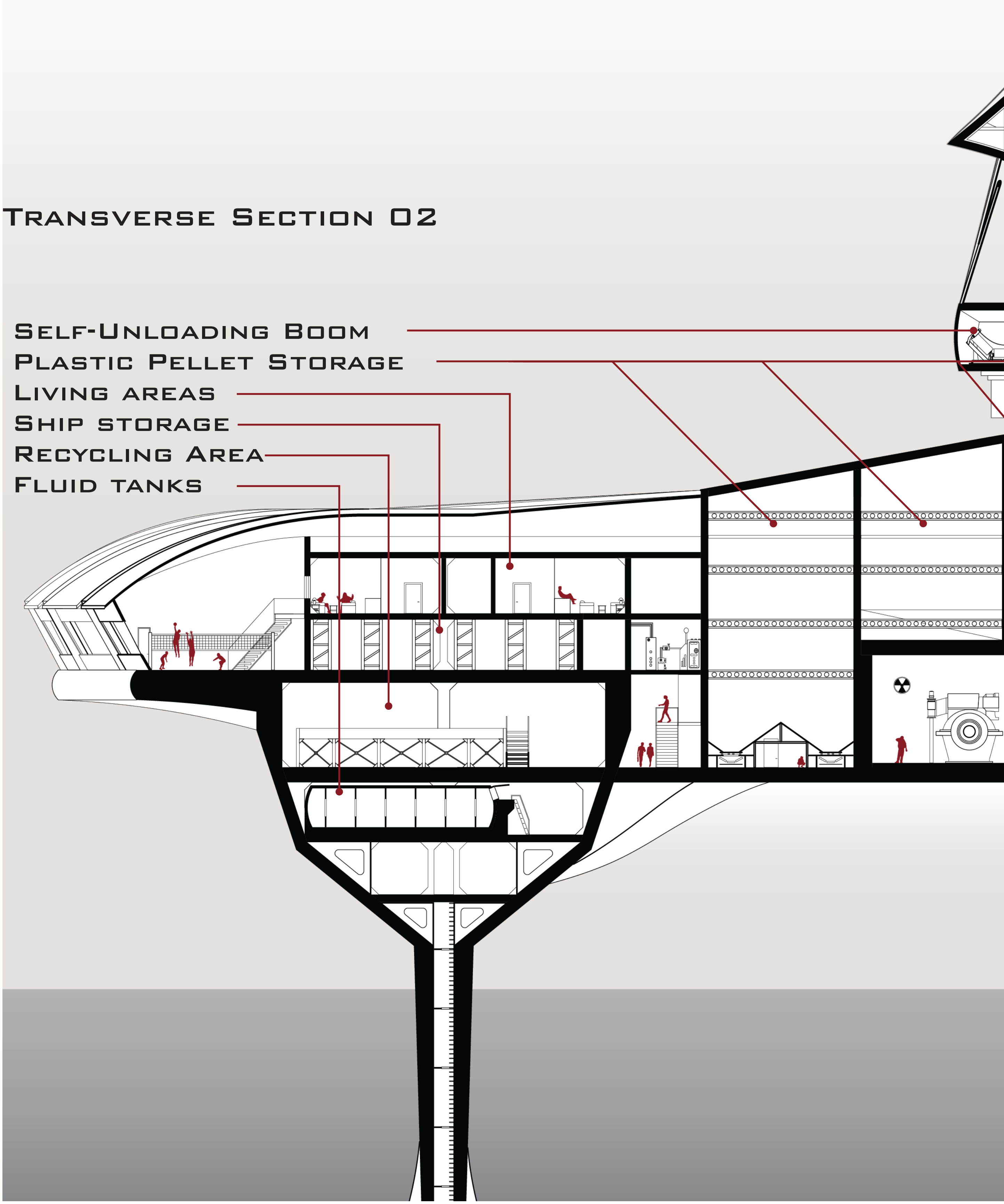
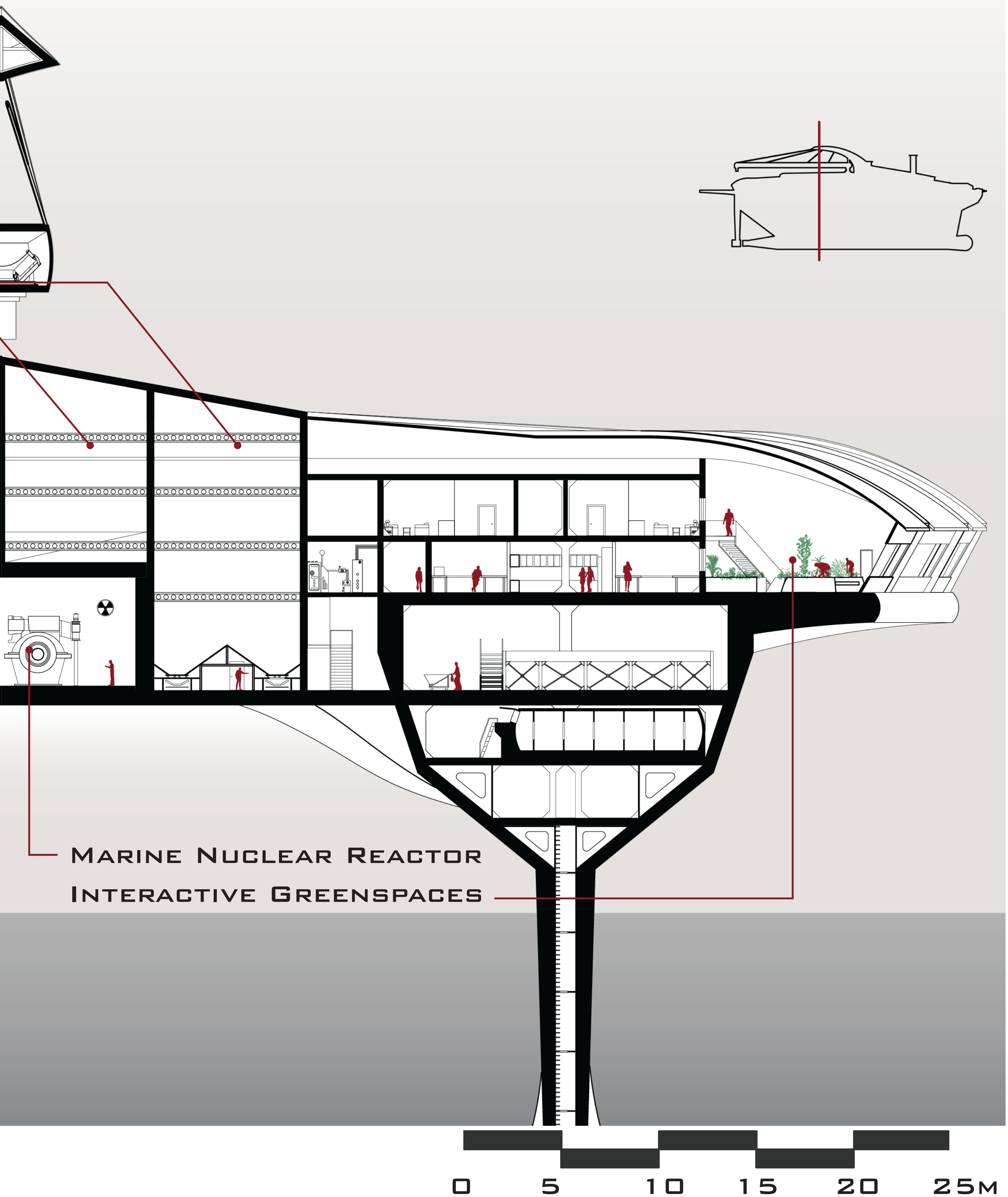


Fig. 6.11 Transverse Section 02



Marine Nuclear Reactor
Interactive Greenspaces
0
5
10
15
20
25m

Transverse Section 03

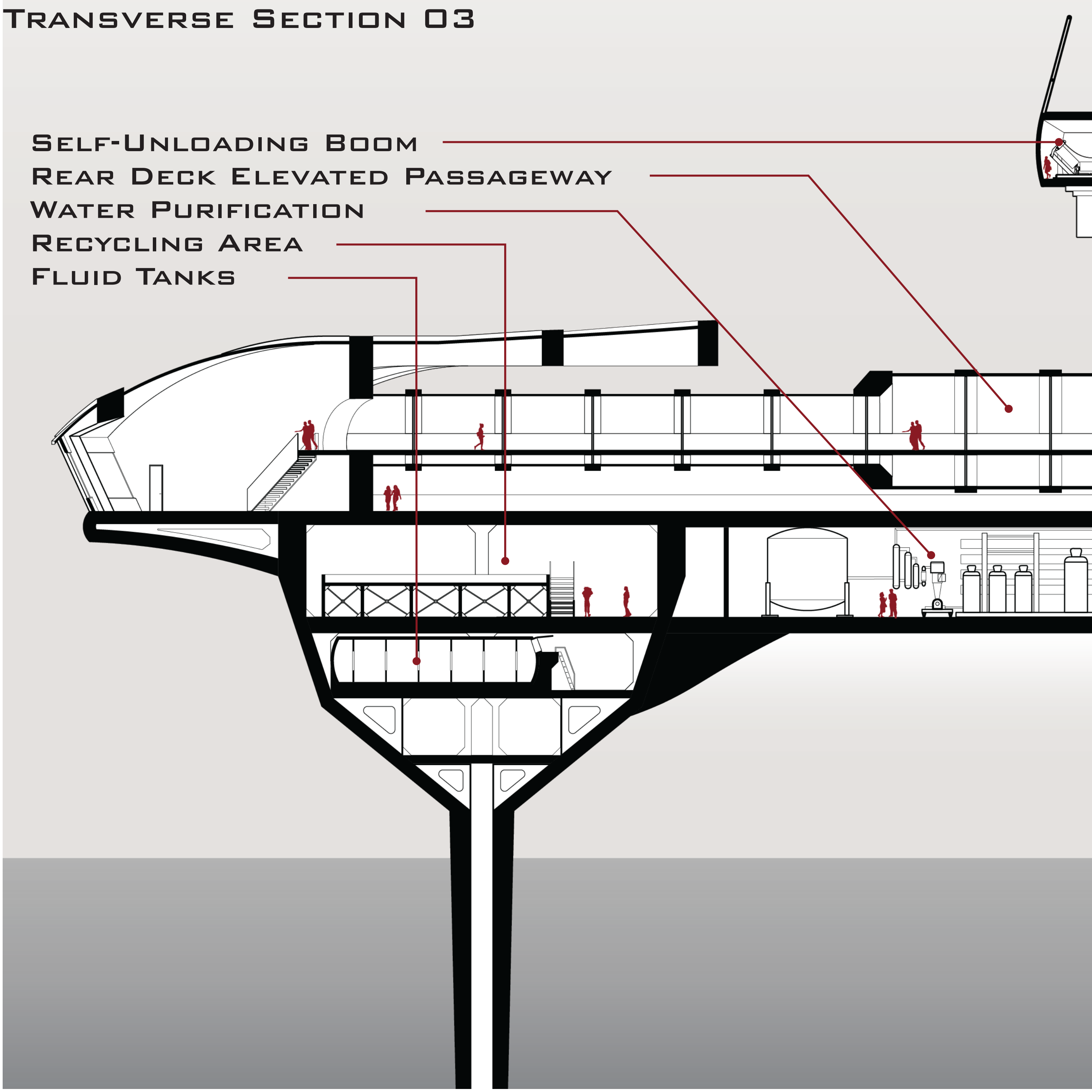
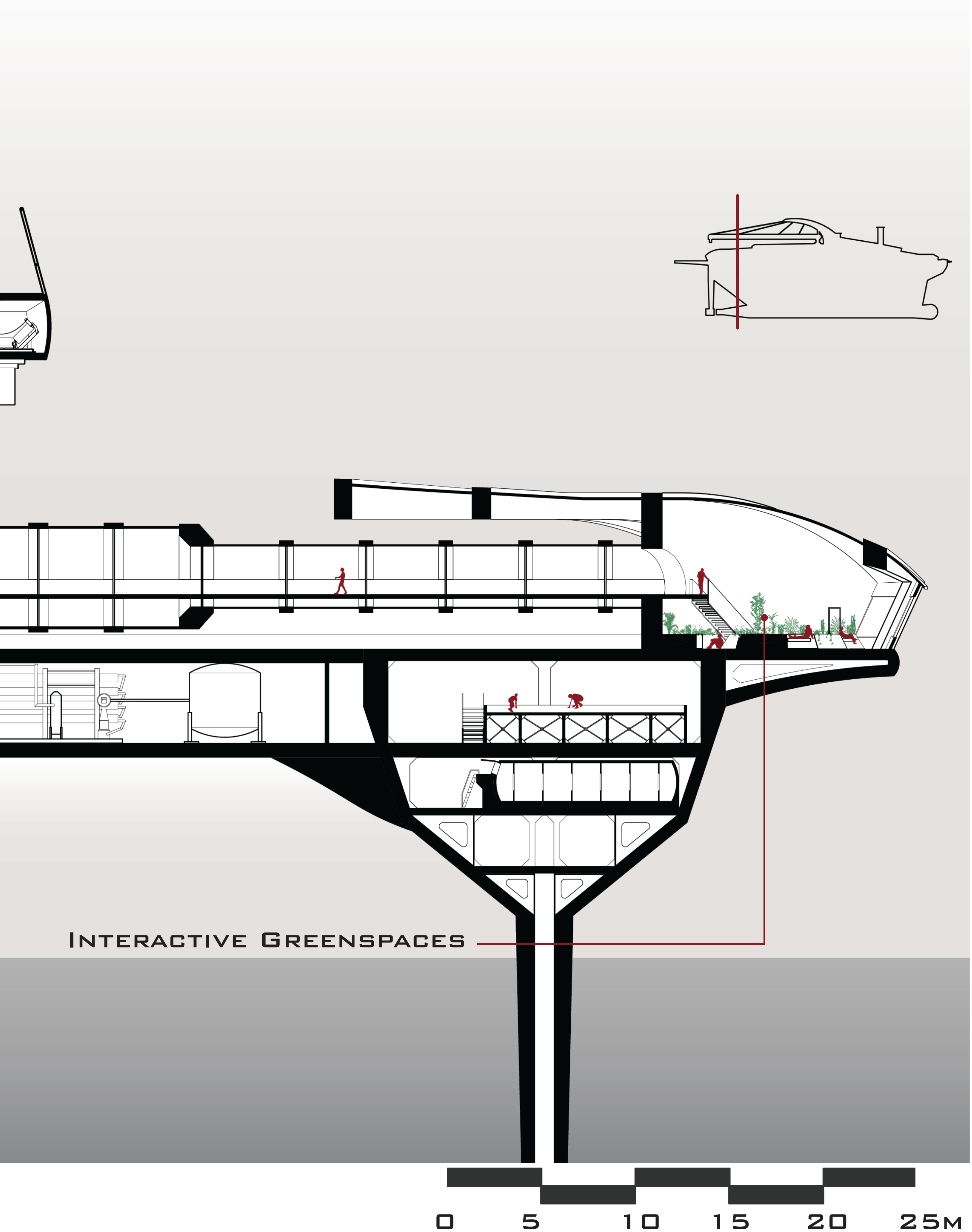


Fig. 6.12 Transverse Section 03


Interactive Greenspaces
0 5 10 15 20 25m

The Bridge

The large proportions of modern ships make it incredibly important for its crew to be able to manoeuvre and control with precision. The Bridge is where the overall command of the ship takes place. By consolidating all of the vessel's major controls and functions into one area, the small crew of specially authorized personnel is responsible for the safe navigation of the whole vessel. In addition to housing the steering equipment and engine controls, there is also an area for the nautical navigation charts and communication equipment that are essential to plotting a course in the open ocean.

The highest level of the ship is by no means restricted to containing only the Bridge; it is also the optimal location for the self-unloading boom, and the Flettner rotors. Since this is the highest level on the Seascraper, the rotors can efficiently capitalize on the wind energy with the least amount of interference from surrounding elements of the ship. The self-unloading boom must be able to swing up to 180 degrees to effectively offload onto surrounding vessels; therefore, it must be placed at one of the highest points so that it does not interfere with the rest of the ship's functions when not in use. Figure 6.13 illustrates the internal conveyor mechanism of the boom. The specific layouts of the bridge spaces can be seen in figures 6.14-6.15.

Boom Cross Section

1:100

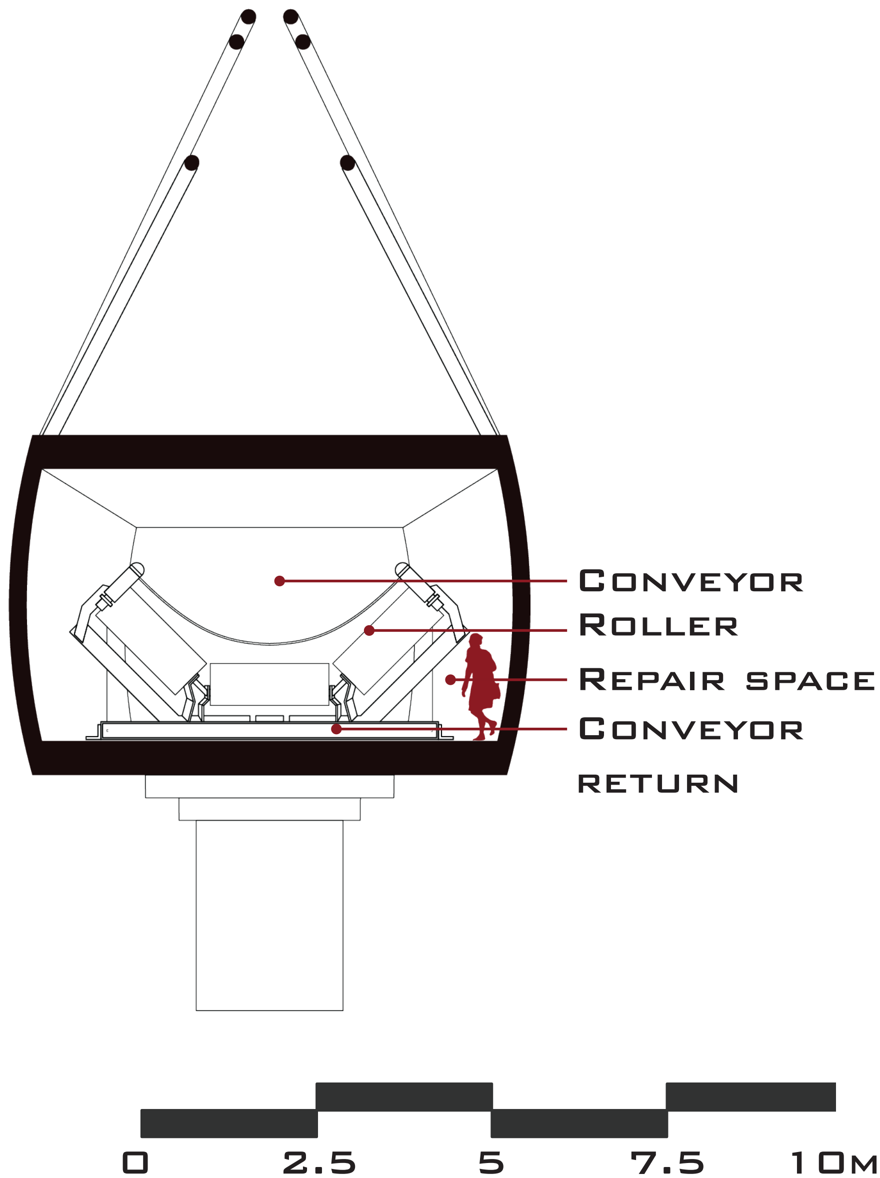
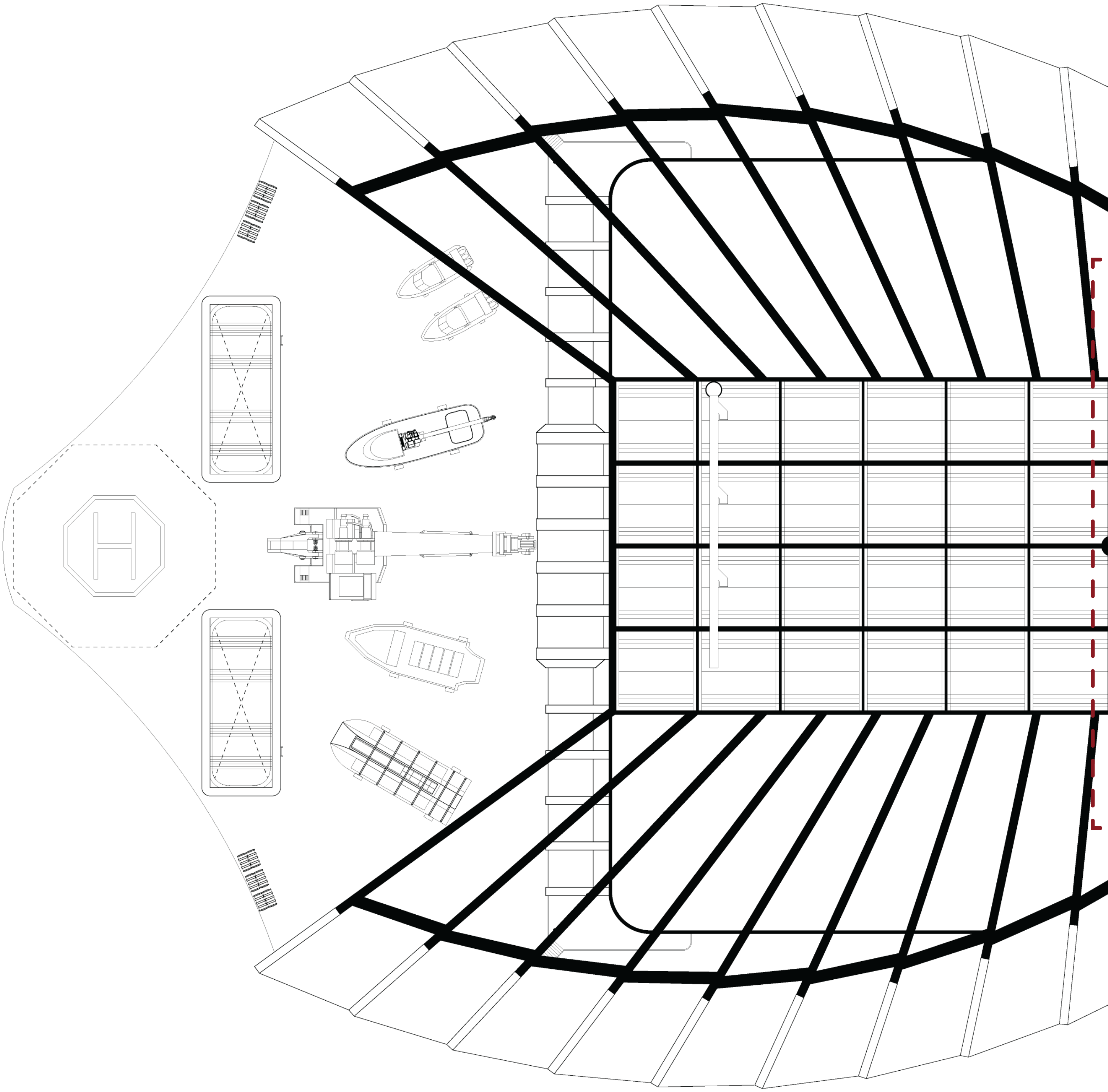
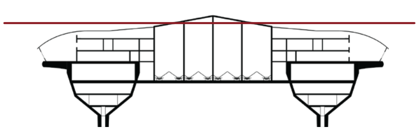


Fig. 6.13 Typical Boom Section

An essential component of self-unloading vessels, the boom can rotate up to 180 degrees to accommodate depositing resources while on the move.

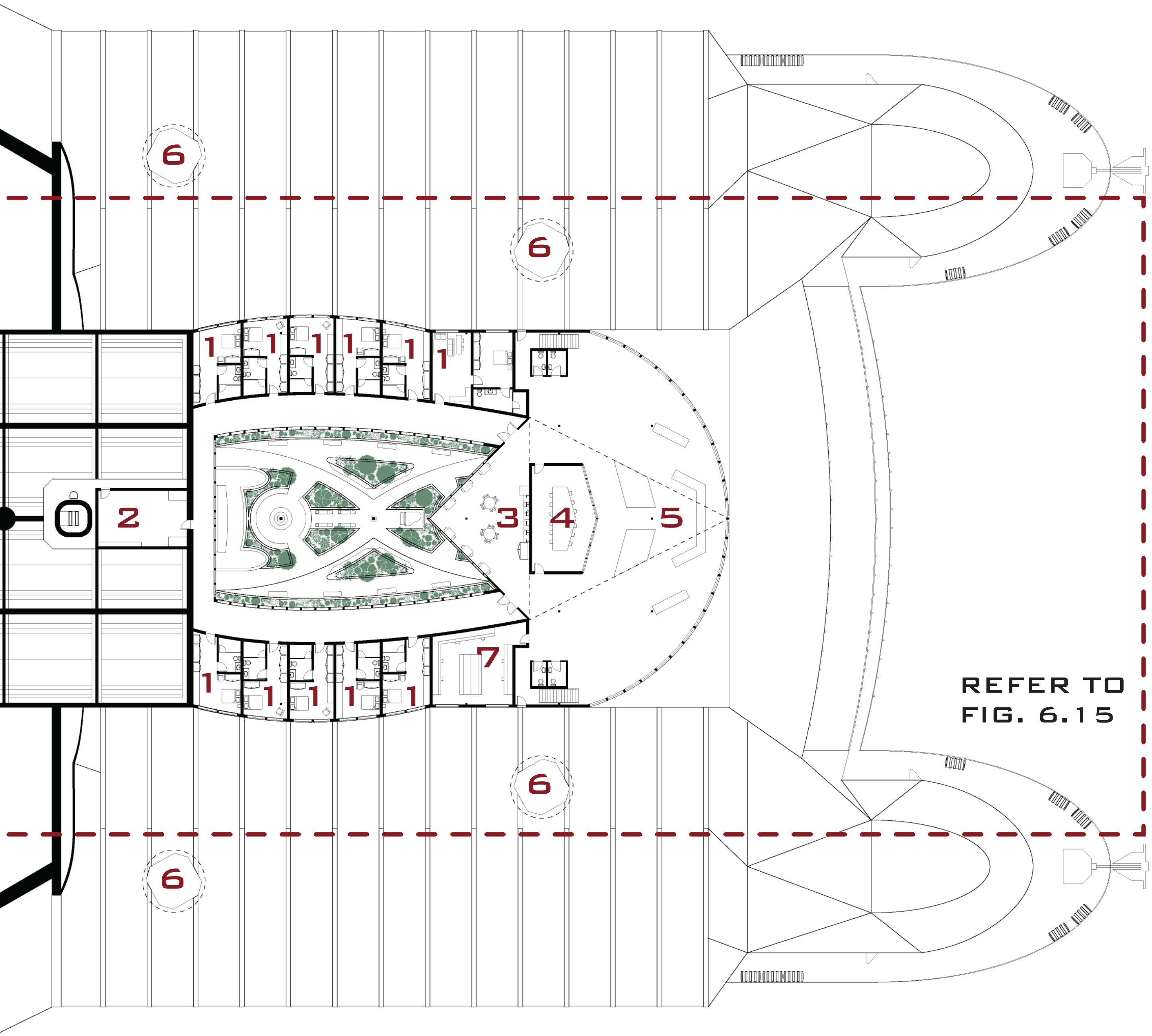




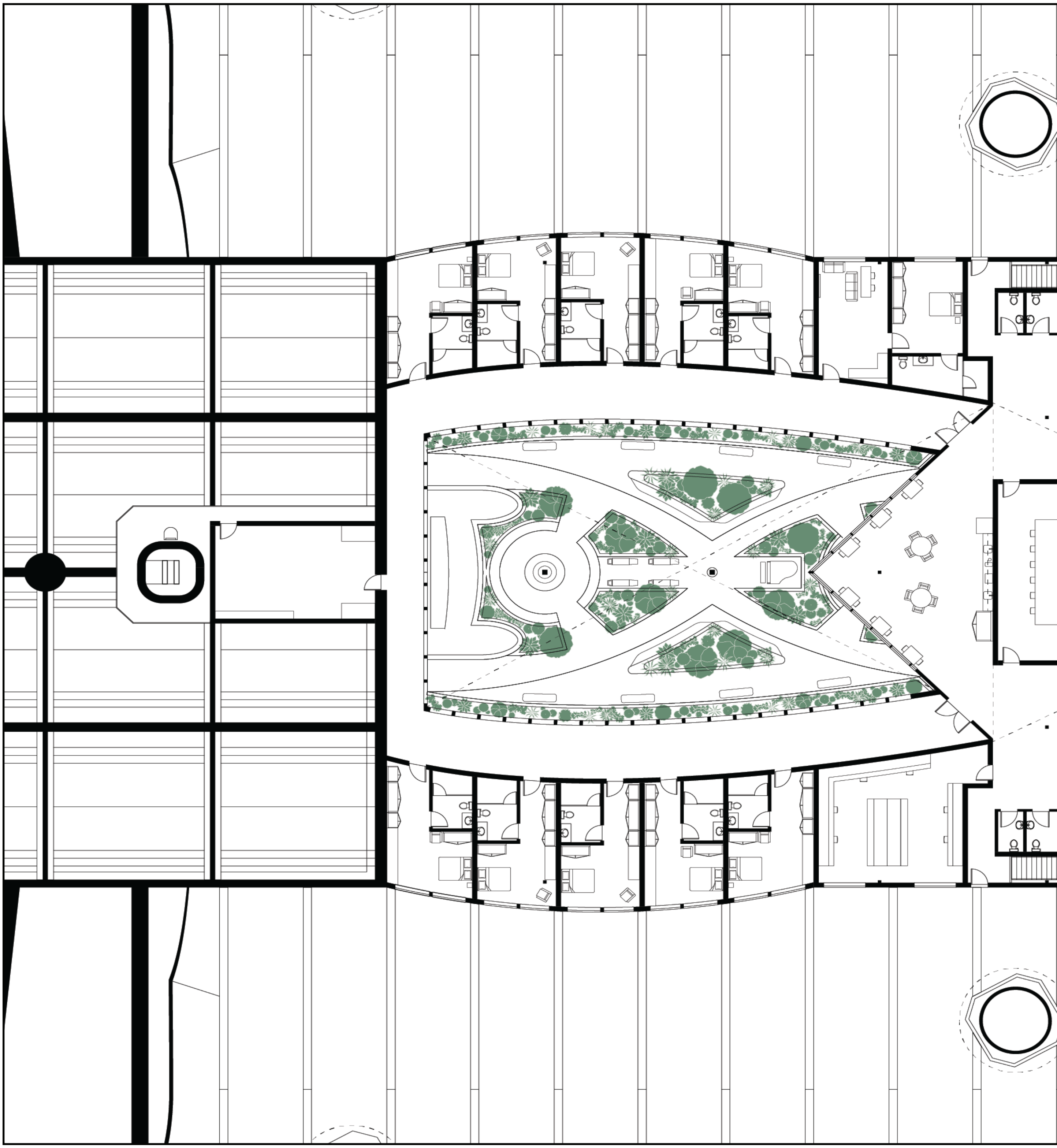

0
10
20
30
40
50
100m

Bridge Plan

Fig. 6.14 Labeled Bridge Plan

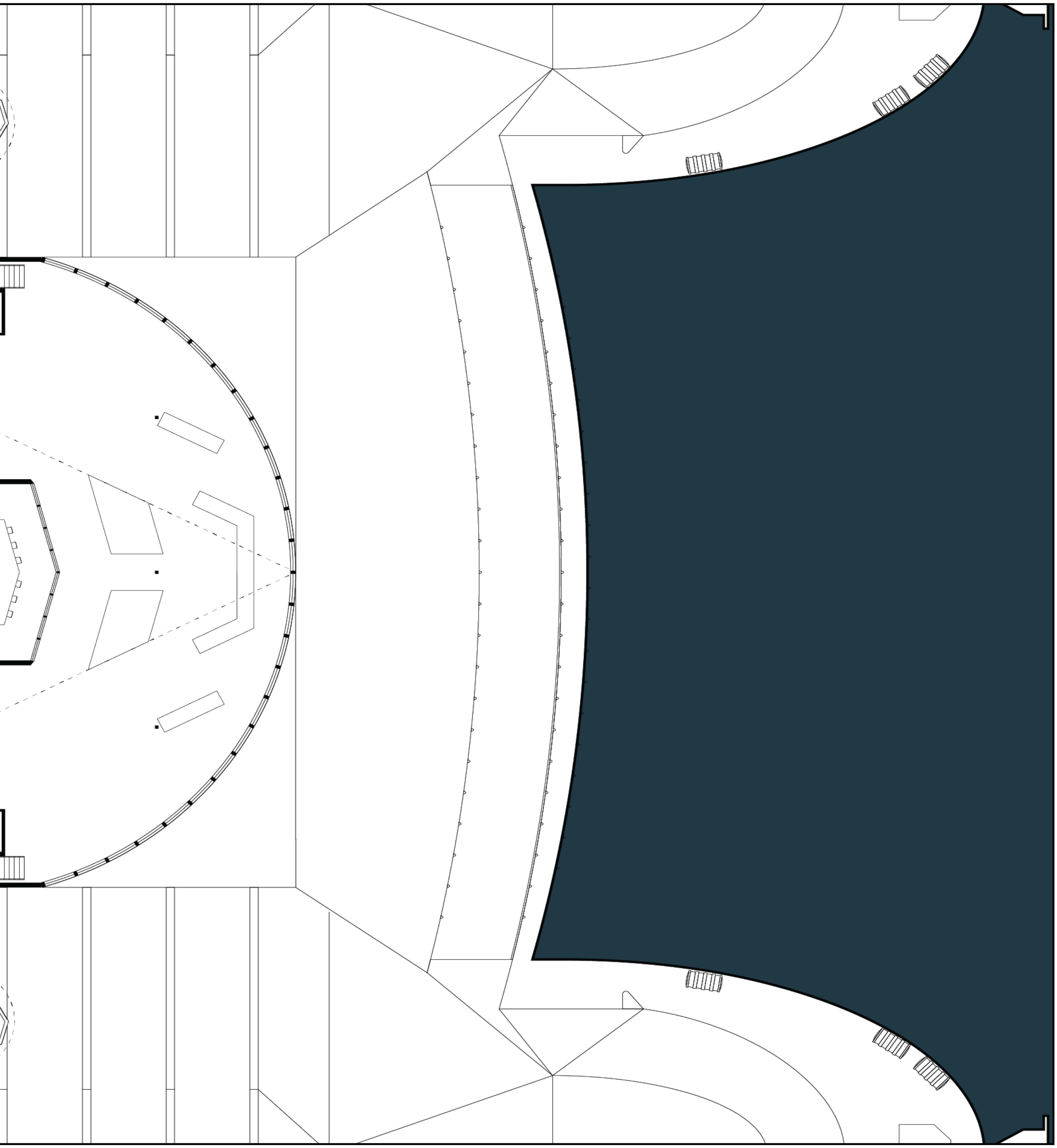


1 Captain & VIP Living Areas
2 Boom Control Station
3 Bridge Kitchen Area
4 Meeting Room with Radio
5 Bridge
6 flettner rotors
7 Nuclear Control Room



Detailed Bridge Plan

Fig. 6.15 Detailed Bridge Plan



Living Areas

Immediately below the Bridge level is the primary living areas for the residents onboard the Seascraper. These spaces can be equated to a neighbourhood, a housing-focused area that has a mixture of spaces reminiscent of key commercial and recreational functions. Allowing crew members to focus on something other than their work is an essential component to extended stays on the open ocean. Historically, the life of a sailor has been far from glamorous. They "had to accept cramped conditions, disease, poor food and pay, and bad weather."[110] This neighbourhood level is designed to ease the transition from life onshore to the time spent at sea. As shown in figure 6.16 this level includes a place for the residents to do their laundry, use a computer lab, and even a recover in a small medical bay in the event of on-site injuries. Additionally, figure 6.17 illustrates that this level is also equipped with a coffee-bar lounge, media rooms, and a games area where residents can relax from the day's work. Since the residents of this vessel will be on-board for extended periods of time it is important that these key interior spaces are not barren, purely functional voids. As seen in the following image (Fig 6.17), these non-industrial interior spaces would be finished similar to the interiors of modern sailing ships and include the following: extensive use of cedar planking for the ceilings, painted fibre glass for the walls, a durable floor, as well as stainless steel for workstations and fixtures. Cedar is a type of wood that will not only add a sense of warmth to the space but is also naturally resistant to water and rotting caused by exposure to the moist sea air.

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110 "Life at Sea in the Age of Sail." Royal Museums Greenwich. Accessed February 21, 2022. https://www.rmg.co.uk/stories/topics/life-sea-age-sail#:~:text=Sailors%20had%20to%20accept%20cramped,1805%2C%20shared%20many%20common%20experiences.

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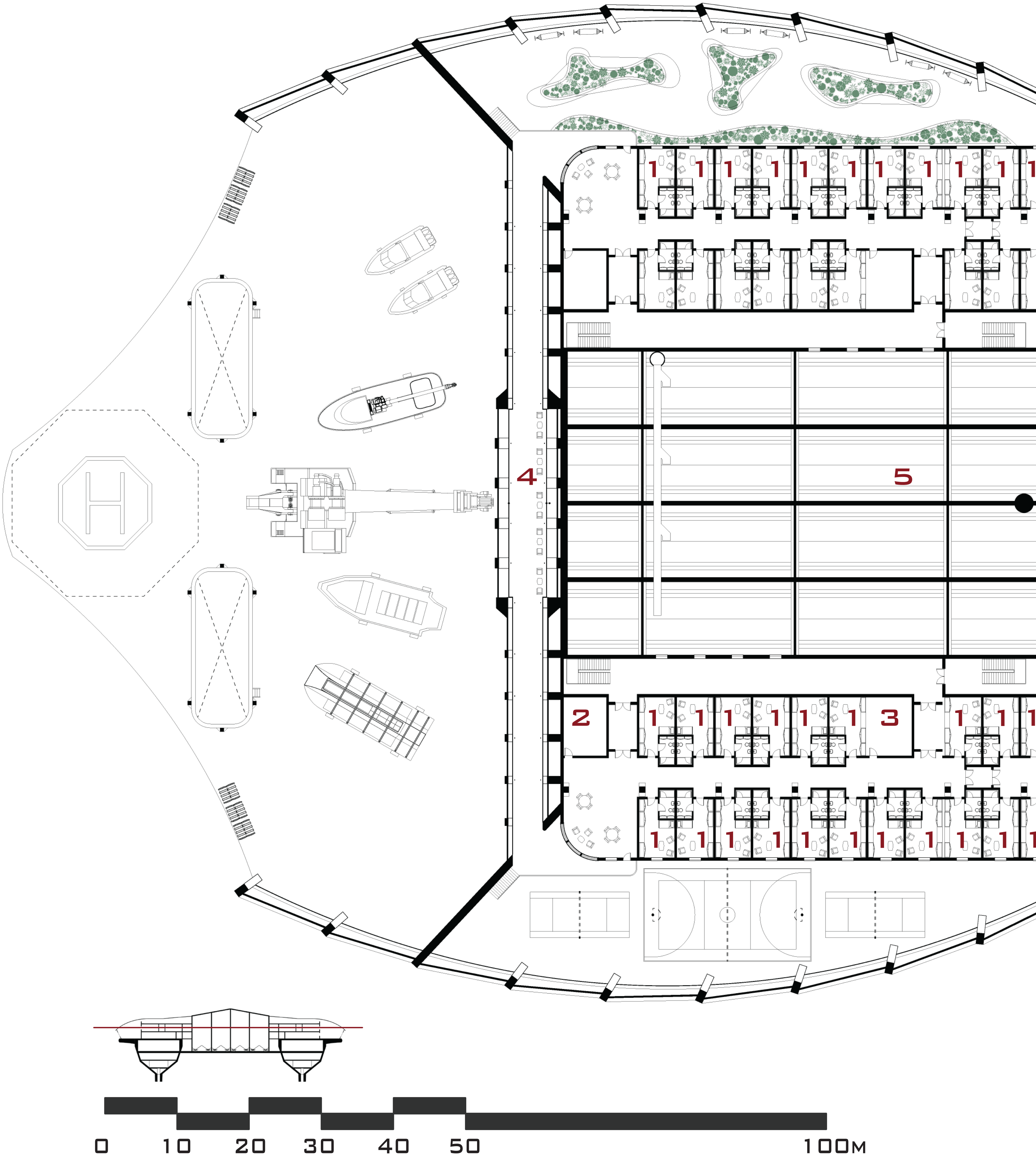
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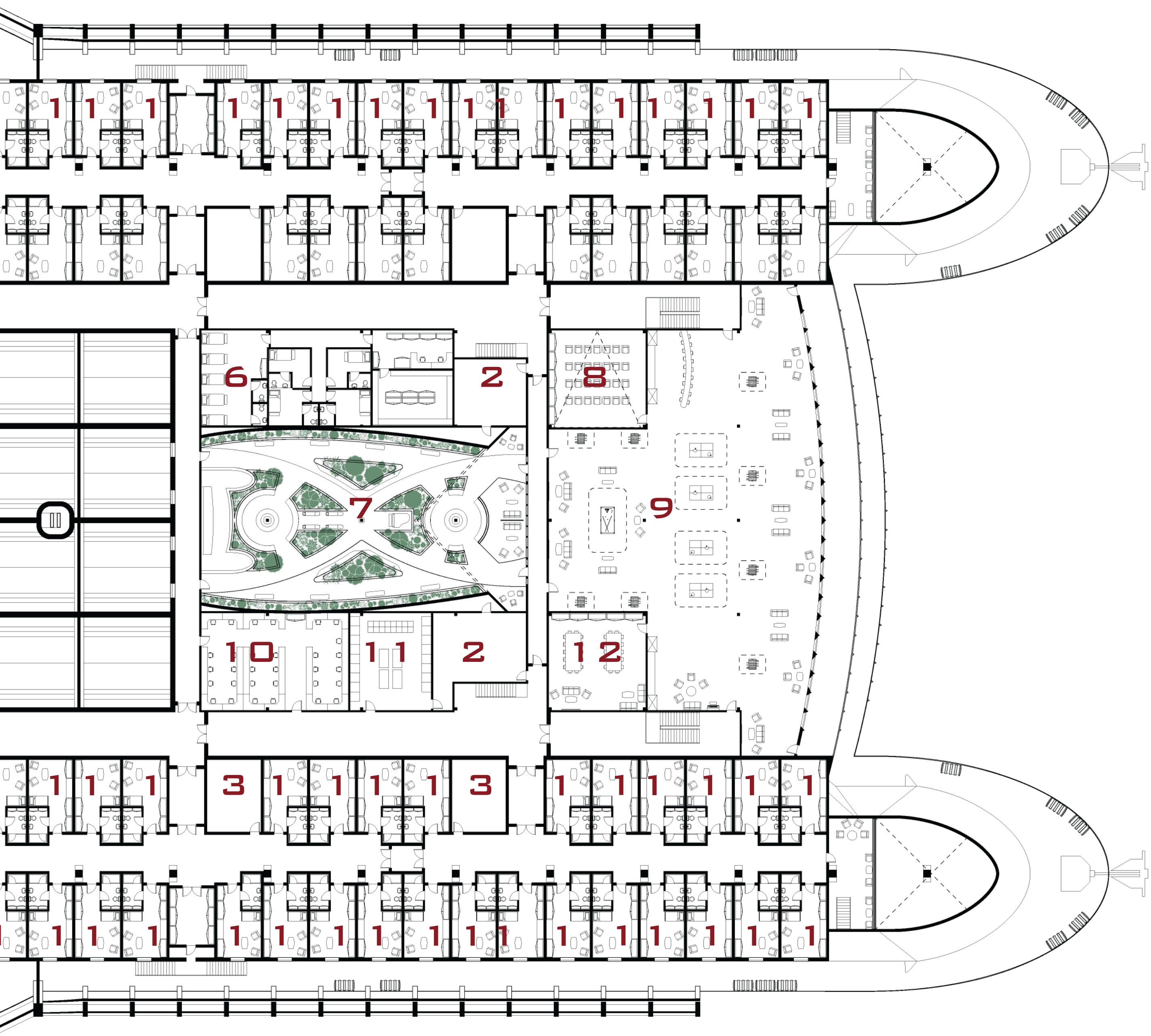
100M

Living Areas Plan

Fig. 6.16 Labeled Living Areas Plan



1 Living Areas
2 Mechanical Room
3 Storage for Residents
4 Rear Viewing Platform
5 Plastic Pellet Storage
6 Ship Hospital
7 Biophilic Atrium
8 Media Room
9 Entertainment Lounge
10 Information Commons
11 Laundry Room
12 Games Room

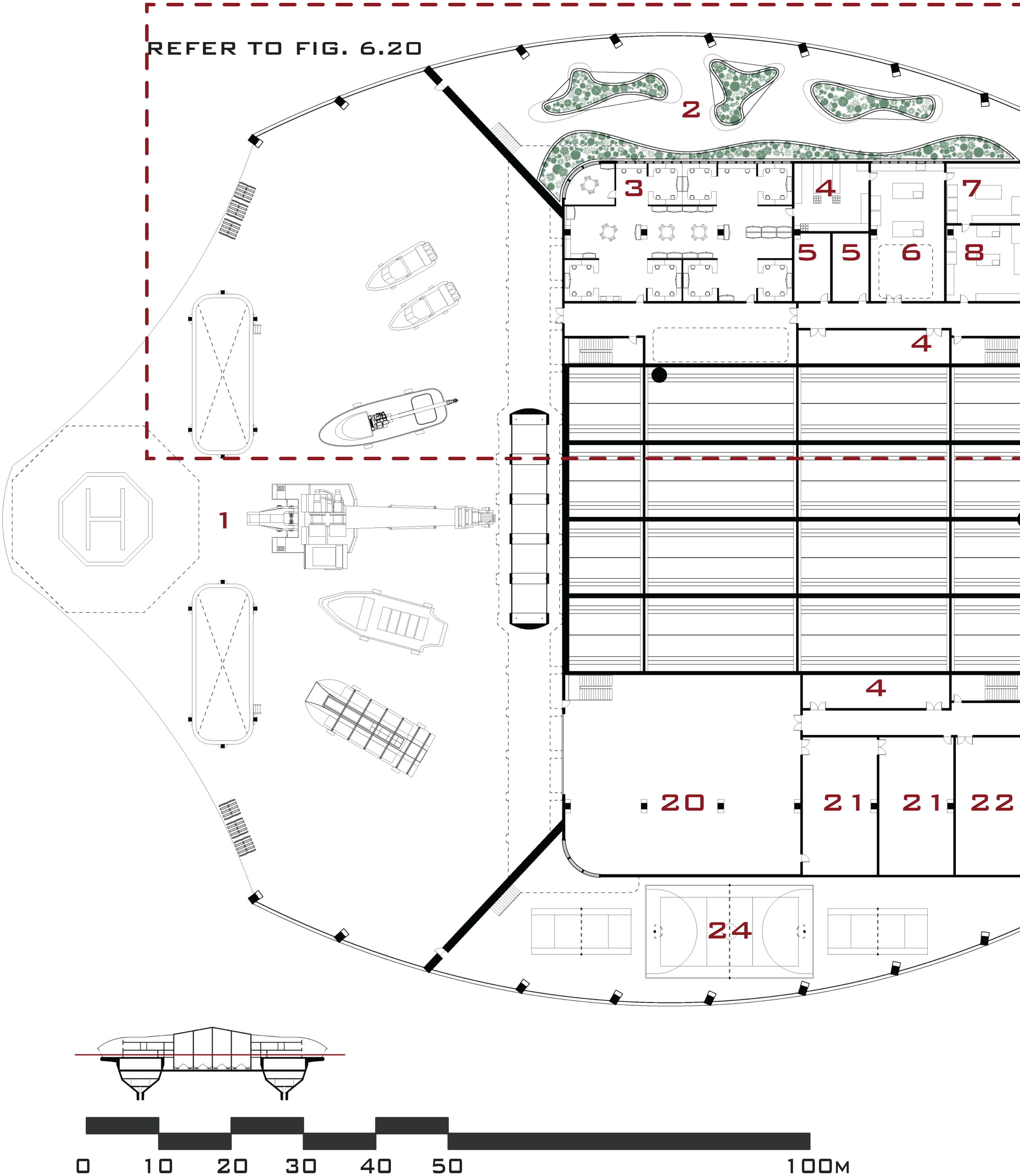
Fig. 6.17 Resident's Lounge Render

Main Deck

The main deck is composed of two bars of distinct programming anchored on either end by shared congregation spaces. The rear deck is a hub of activity where boats and scientific instruments are deployed, and where plastic is lifted from the water's surface to be deposited into the recycling systems. Visible in figure 6.18, the deck's surface is where the ship's boats are stored when travelling, under repair, or in inclement weather. In the event of the boats remaining in the water overnight, small RHIBs are deployed to ferry the crews back to the Seascraper. After being hoisted out of the water by the crane mounted on the deck, the boats are then mechanically affixed to the deck, thusly stored on the ship. Additionally, as seen in figure 6.18 there is optimal clearance for a helicopter to land, take off, and deposit materials. This area can be used for a variety of activities such as storing a scout helicopter to obtain an aerial view of the plastic patches, conduct VERTREP, or even load a patient for medevac.

Since the Seascraper vessel is predominantly isolated at sea it must be equipped with redundancies so that it can function if it is damaged by a particularly devastating storm. The vessel is outfitted with a mechanic shop to facilitate repairs in-situ to reduce any potential downtime that results from environmental damage, or simply daily wear and tear. Opening directly to the semi-enclosed portion of the rear deck, the mechanic shop is able to easily access the boats for routine maintenance and repairs. While these repairs are underway, the auxiliary systems can be activated to keep the ship operating, albeit, at a lesser capacity. The ability to conduct onsite repairs is not exclusively limited to the Seascraper vessel; parts required to repair the boats and trawls can also be stored onboard the main vessel. This means that the only time a trawl or boat must return to shore is in the event of a critical failure that completely disables it and requires a replacement of the unit. On the opposite side of the Seascraper are the various scientific laboratories and offices. These laboratories are essential to the crew's efficacy to test and record results in-situ. The alternative would be to collect raw data and specimens that would be subject to delayed inspection or experimental processes since their arrival to shore could take weeks or months. If any specimens are spoiled or if data becomes corrupted and lost on the trip back the scientists will be forced to return to sea at a later date. Therefore, the inclusion of a chemical lab, hydrographic lab, dry lab, and a staging area for deployable equipment is required. By separating the programs to distinct sections of the vessel there is little opportunity for interference in the limited space.

Whether it is a sprawling metropolitan city or the micro-polis of a ship, flexible spaces for future growth are an essential component to design. The needs of all human societies, no matter the size, will always ebb and flow. By programming and over-designing every available square metre of space, there is no opportunity to improve upon the current design. This often risks the sacrifice of an element previously thought of as too essential not to be included. With this in mind, various areas across the Seascraper are intentionally designated as areas for future growth to increase the vessel's overall ability to adapt to the needs of its occupants.


REFER TO FIG. 6.20
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21
22
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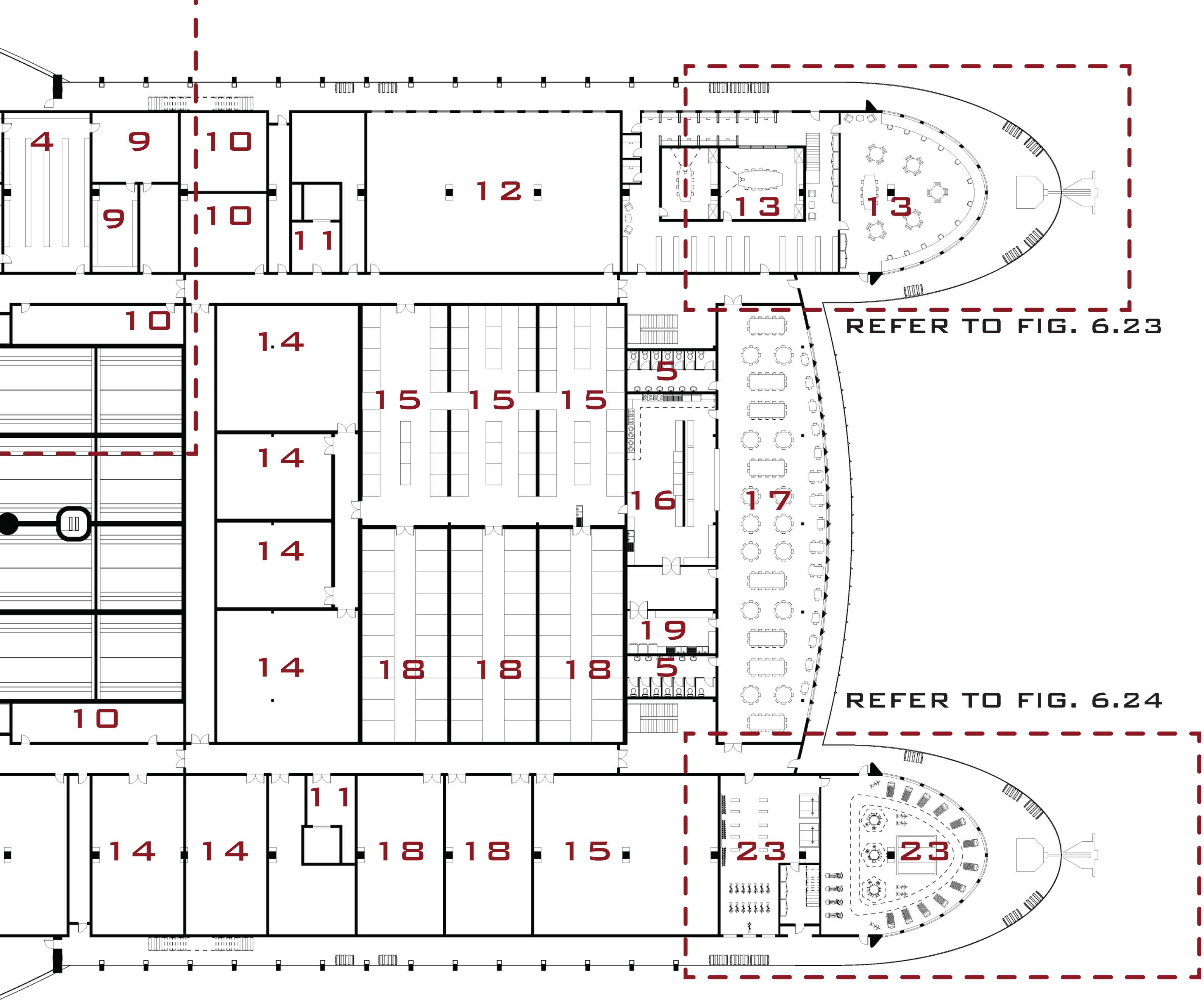
100M

Labeled Main Deck Plan

Fig. 6.18 Labeled Main Deck Plan



1 Exterior Deck & Helipad
2 Interactive Green Space
3 Research Offices
4 Storage
5 Washrooms
6 Main Laboratory
7 Prep Lab
8 Chemical Lab
9 Specialty Storage
10 Mechanical Room
11 Elevator Assembly
12 Flex Space
13 Library
14 Freezers
15 Pantry
16 Kitchen
17 Dining Hall
18 Cold Storage
19 Scullery
20 Workshop
21 Parts Storage
22 Ship Storage
23 Gym Areas
24 Physical Activity Area

Atrium

The complexities of a modern city-scape environment are a fairly recent phenomenon relative to the existence of human civilisations. Humans originate from nature and therefore have an instinctual connection to natural spaces. Within the planned zones of a city, it is essential to the positive development of the resident's mental health that there are areas of greenspaces that break up the monotony of concrete and glass buildings.[111] The incorporation of natural elements into an architectural space is referred to as biophilic design and its purpose is to foster a connection between the occupants of a space and the natural world. While the benefit of the atrium green space is similar to the green space on the rear wing, the atrium green space would be more aptly related to a public park space than a community garden. As seen in figures 6.19-6.22 this interior space is built around the practice of connecting the people that occupy it with natural elements through biophilic design. The large atrium space utilizes the benefits of stack effect, natural ventilation, and the air purifying processes of plants to create a space that feels fresh and inviting. Furthermore, the strategic use of acoustic panelling coupled with the existing plants and water feature will be able to muffle and reduce much of the exterior noise. The use of this tranquil area is not limited to daytime use as the electric fire pits and sky lights will be able to simulate a modest backyard bonfire under stars that are unobscured by the light pollution normally found near dense urban areas.

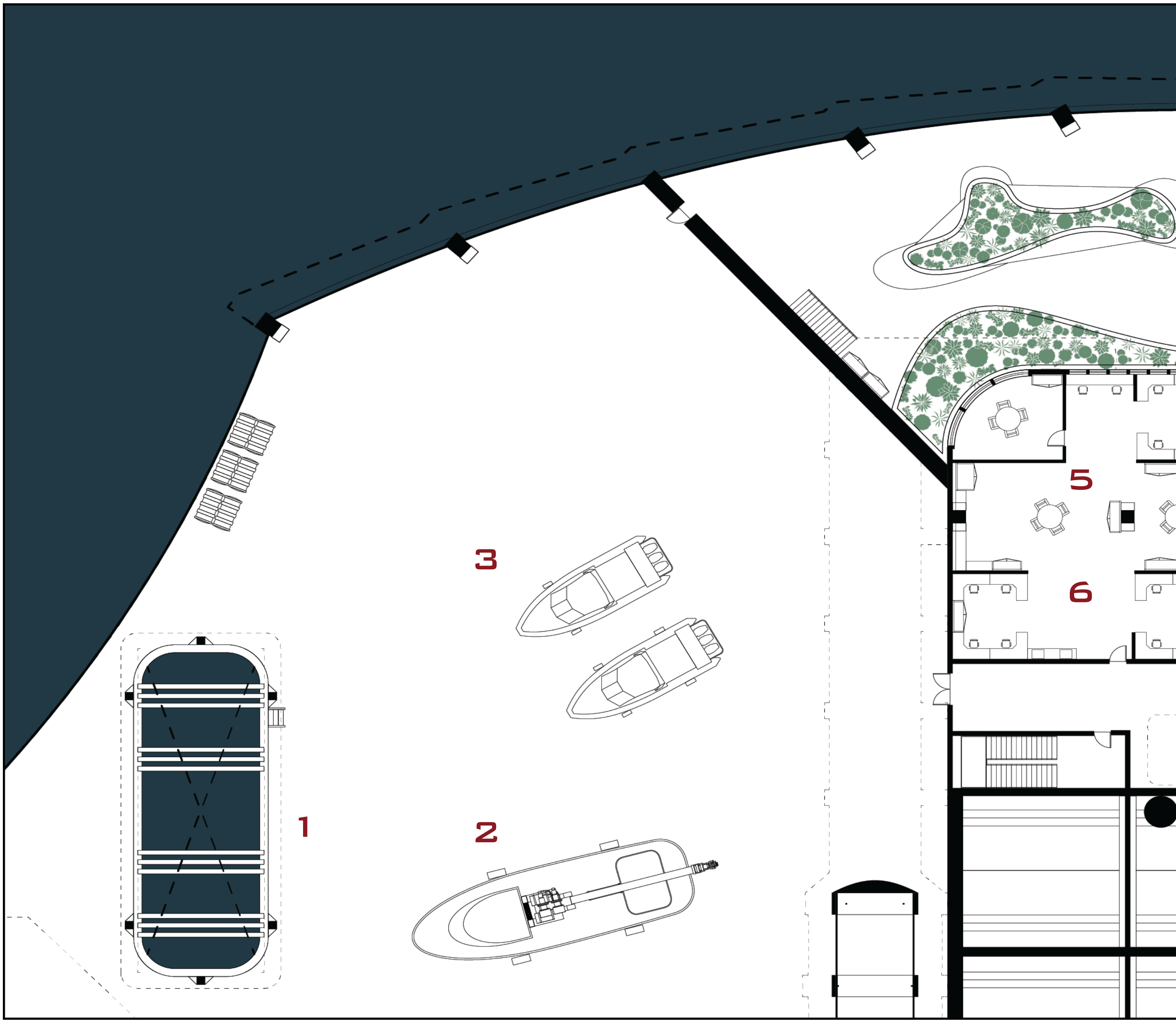
111 Banting. "Report on the Environmental Benefits and Costs of Green Roof Technology for the City of Toronto" (2005): 24.

Interactive Green Space

Within one of the rear wings of the vessel is an interactive garden where the residents can choose to interact with the vegetation planted here. In an effort to bridge the gap between life on land and life at sea, I believe that having a space similar to a community garden would be highly beneficial for the positive mental health of the occupants. This area provides the occupants with an area where they can relax, work on something physically, and break away from the routine of the work week. Being out at sea for extended periods of time may lead to some residents feeling out of touch with the nature that they are conditioned to enjoying. This stimulation void eventually manifests into a state of displeasure with their surroundings. However, a community garden provides the opportunity for the residents to put their unique touch on a public area of the vessel while being respectful to the other members. Furthermore, the natural processes of extensive vegetation improves the air quality of the vessel.

Towards the front of the ship the programming transitions from active working areas to areas of intellectual, physical, and sociocultural congregation. These areas are an informal platform for the residents to interact with each other outside of their professional settings. These areas include a library, a gym, and the dining hall.

Fig. 6.19 Central Atrium Space Render



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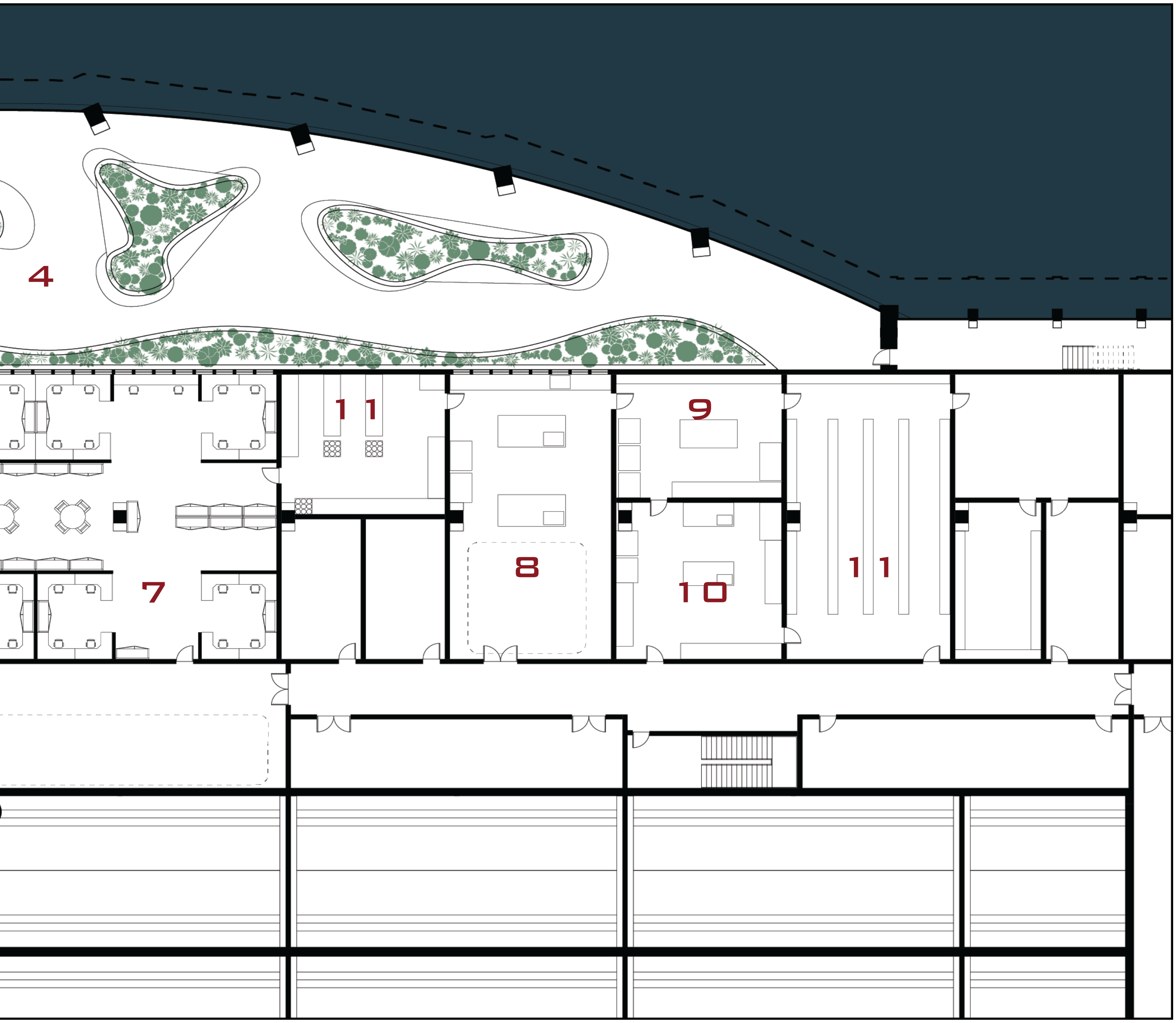
Researcher Offices

Fig. 6.20 Main Deck Plan: Researcher Offices



1 Vertical Boat Deployment
2 Collection Boat 1
3 RHIB 1 & 2
4 Interactive Green Space
5 Research Offices
6 Dry Lab
7 Hydro-graphic Lab
8 Main Laboratory
9 Prep Laboratory
10 Chemical Laboratory
11 Laboratory Storage

Fig. 6.21 Interactive Green Space Render 01

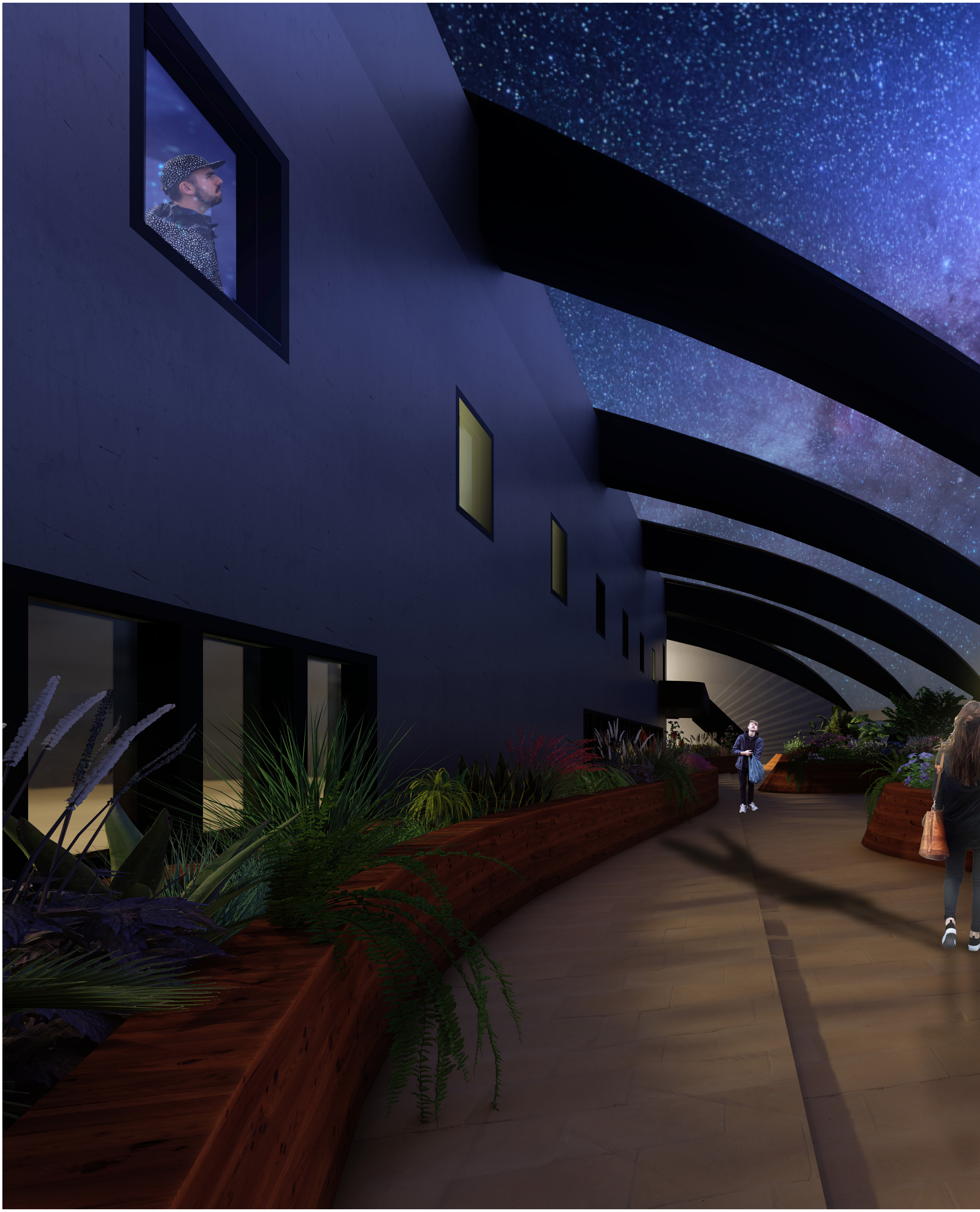
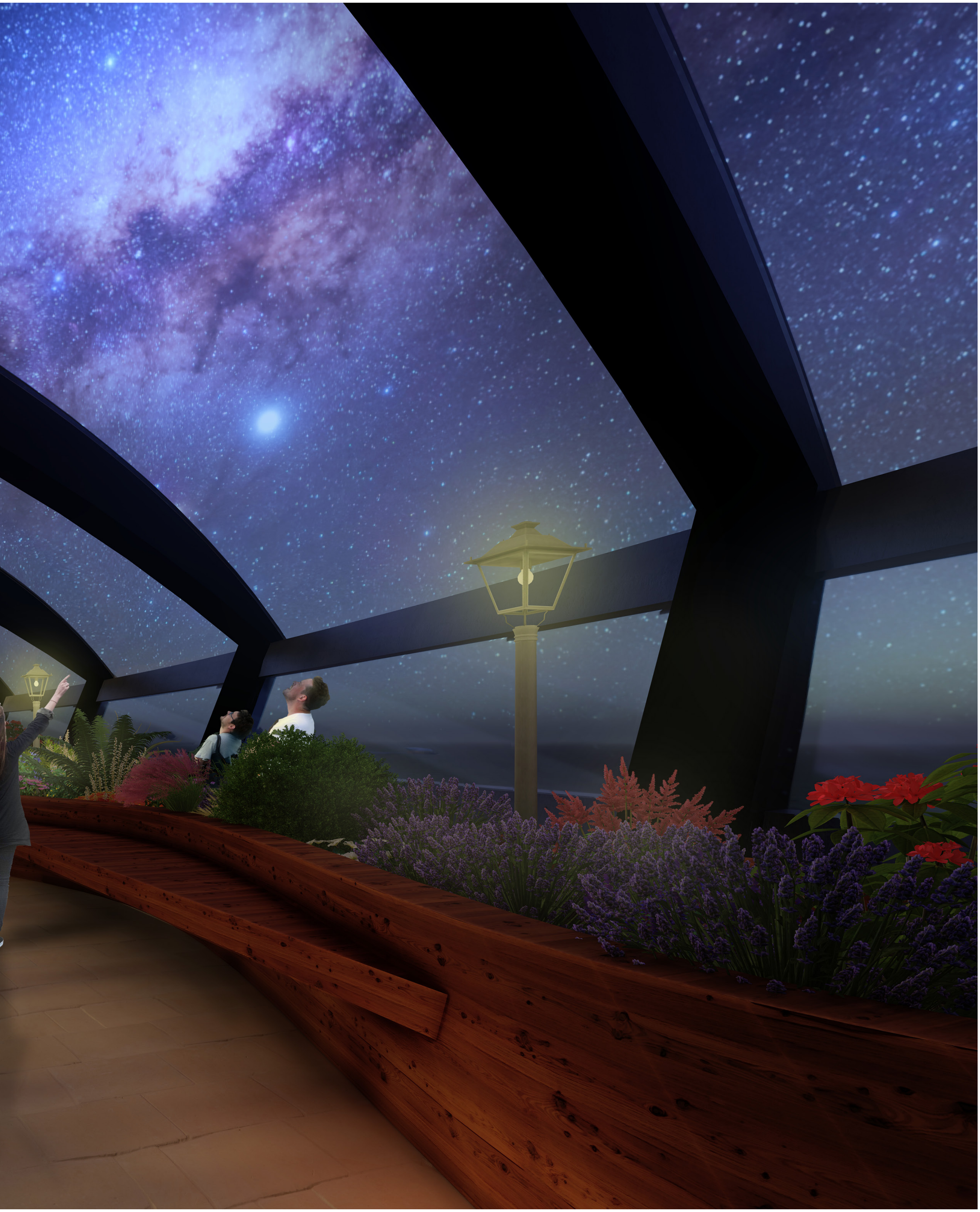


Fig. 6.22 Interactive Green Space Render 02



Library

Even in the digital era, one cannot forget the importance of books. While the internet resembles an endless ocean of information, it is an extremely impersonal and dispassionate information distribution hub. Even the renowned John Milton emphasizes the importance of books in the *Areopagitica* (1644), where he speaks out against the censorship and restriction of books. Milton states: “books are not absolutely dead things; they have a potency of life in them to be as active as that soul was whose progeny they are.”[112] Books are a reflection of their authors, often containing a fragment of their personality. This personality fragment interacts uniquely with its readers. Additionally, every fold and crease from the previous reader becomes a form of meta-narrative with which future readers engage, creating a bond between all readers. However, information collected through the internet is acquired in a completely isolated vacuum.

A physical library breaks away from the creeping sterility of the internet and is a place for people to come together to have discussions, obtain education and participate in quiet contemplation. As shown in the following images (Fig. 6.23 and 6.25) the desks and work surfaces can be used by the researchers and students aboard the vessel. Whether they want a desk as a quiet work area or for group collaboration the library can adapt to these needs. The library can act as a gateway for the students and researchers to access a curated collection of resources that relate to the ocean and its inhabitants.

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112 **Milton, John. Areopagitica. Jebb ed. Cambridge: Cambridge University Press, 1644.**

Gym

While onboard any ship for extended periods of time it becomes quickly apparent that there is only a small fraction of walkable space compared to living on the land. This lack of space potentially leads to an unhealthy, sedentary lifestyle. Therefore, the installation of a space that is dedicated to the upkeep of the occupant's physical health is extremely important. This space, visible in figure 6.24, will allow the residents to keep in shape, as well as discuss the techniques they employ to safely use the gym. Additionally, due to the lack of space, there is limited opportunity for the residents to channel any of their excess energy. The extensive equipment in the gym can become their outlet. Furthermore, the ribbing of the exterior wings is partially inspired by the engineered timber structural systems that are seen in sports facilities. These ribs allow for large open spaces below, which is ideal for the residents to compete against each other in various court-based sports that can be played indoors. Whether it is a place for venting frustrations or starting the day with a run, the gym is critical in maintaining the occupant's physical well-being.

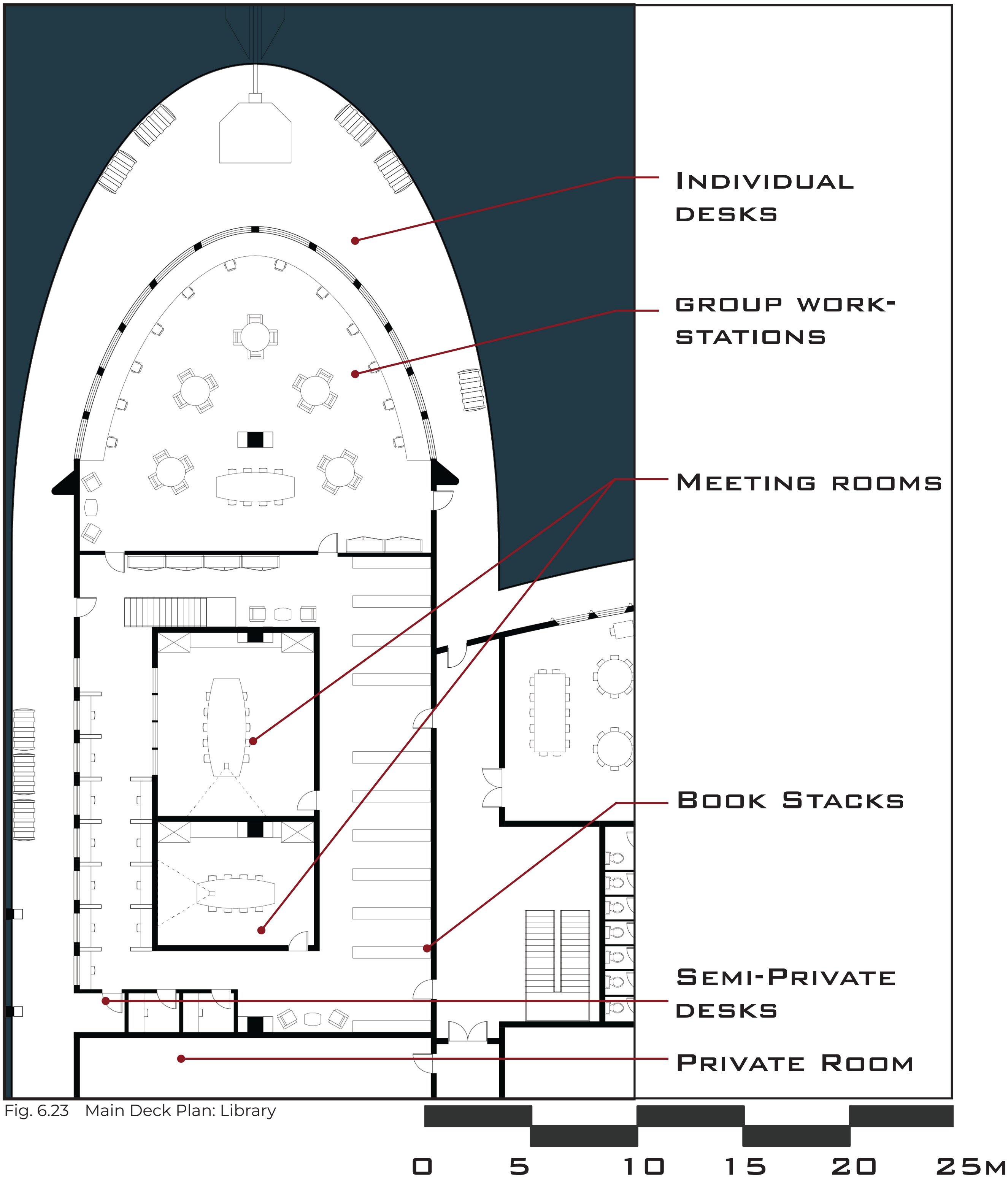


Fig. 6.23 Main Deck Plan: Library

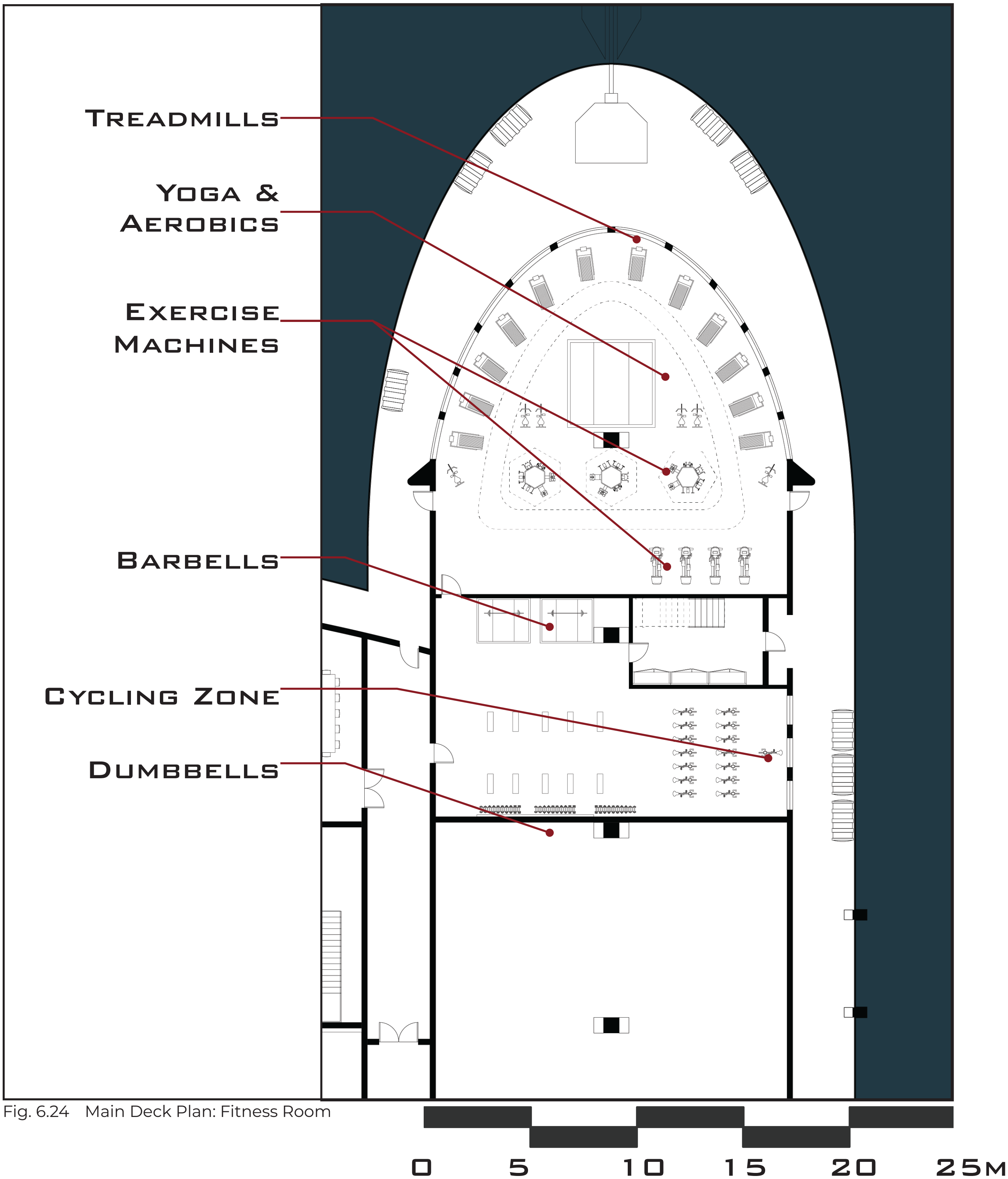


Fig. 6.24 Main Deck Plan: Fitness Room

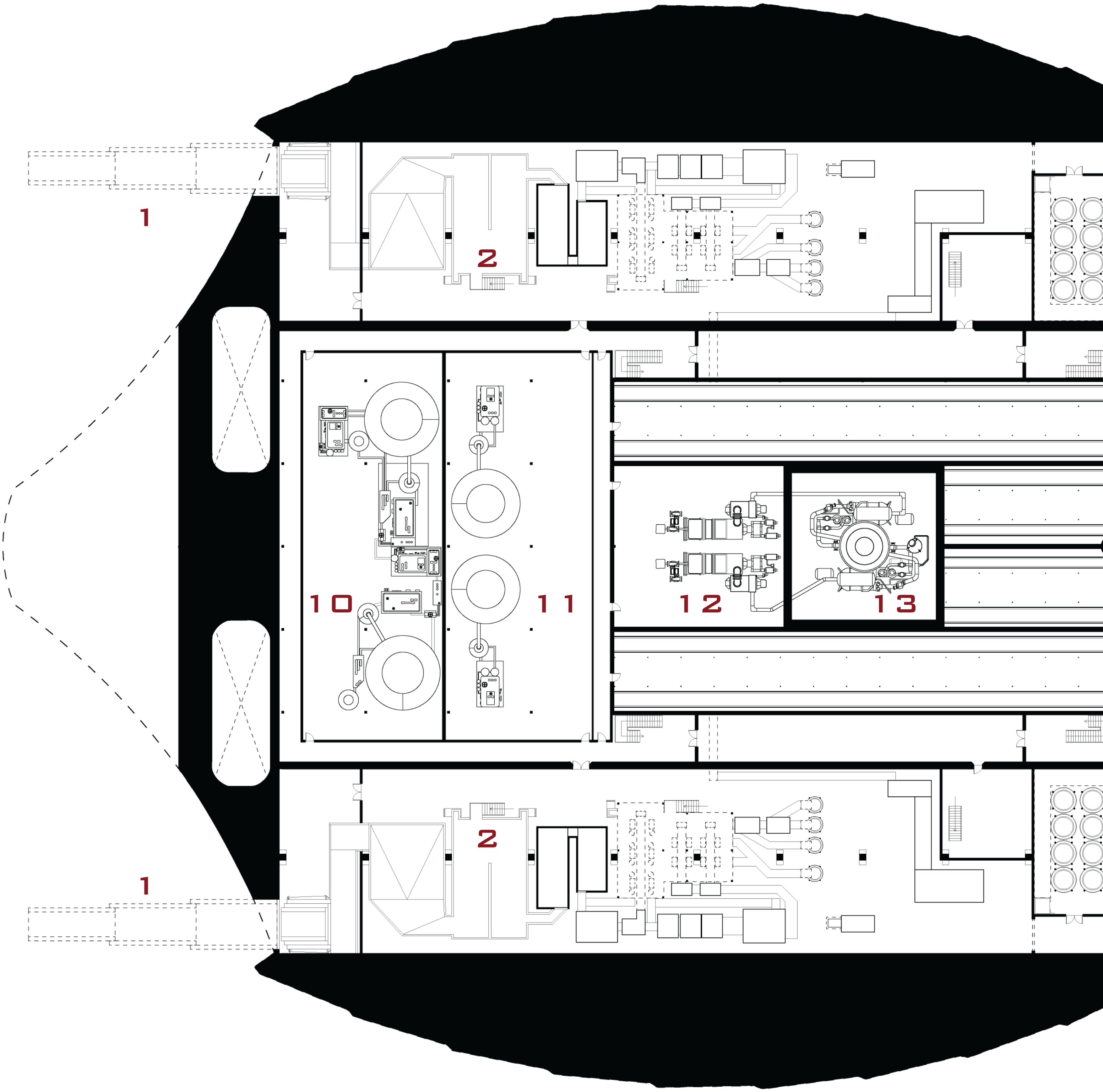
Fig. 6.25 Library Interior Render

Dining Hall

Since food is a necessity for human life it is also a significantly limiting factor on how long a vessel can stay out at sea. Therefore, a sizeable portion of this level is dedicated to the storage of frozen and pantry goods. With the main deck's central positioning and a majority of the food supplies located on this level, the inclusion of the ship's kitchen and dining hall is the clear choice. Since the vessel spends an extended period of time in isolated conditions there is a significant need for the ability to store large quantities of resources. However, as essential to life as food is, to reduce it to just a resource stored in a room is a great injustice. Since time immemorial food is a great unifier amongst people. Although the base ingredients may be similar, distinct cultures around the world have vastly different food identities due to their local climatological and geographical conditions. These culinary traditions are passed down through the generations and adapted over time as distinct cultures meet, evolve, and create culinary fusions. In some conditions of extended isolation, food is often an undervalued element, seen only as a medium to deliver one's daily nutritional and caloric requirements in lieu of positive social interactions. The dining hall presents the platform for one's native culinary identity to be put on display, accepted, and enjoyed by everyone on-board. Since the dining hall is an area where all crew members congregate, it is a warm and inviting area for them to get to know each other outside their professional setting.

Lower Decks

The lower decks of the vessel are akin to a city's manufacturing, industrial, and agricultural zonings. The first lower deck level, illustrated in the following image, figure 6.26, is comprised of the recycling facilities, hydroponic systems, water desalination and wastewater treatment equipment. The second lower deck, as seen in figure 6.28, is primarily comprised of storage tanks for freshwater, reclaimed and uncleaned wastewater, and biofuels. These levels function similarly to the heavy industrial areas of a city, an essential component, yet often placed further away from the core. Industrial operations are often disruptive and have more specialized requirements than that of a typical city block. These factors still exist while on the Seascraper, however, the collection and recycling of ocean plastics is the driving factor behind the development of this vessel. To accommodate the larger size of this machinery, this level is a double-height space. Additionally, this extra allotment of space will enable the use of interior platforms and overhead conveyor systems to aid the industrial nature of the programming, as well as increase the density of usable space. Figure 6.27 is a detailed breakdown of the recycling equipment aboard the vessel. Due to their large size and central placement, the back-up generators and space for future battery storage will also be located on this level. The inclusion of desalination, wastewater treatment and hydroponic systems, while not an inherent requirement of maritime travel, are necessary and crucial elements for improving the vessel's overall autonomy. Without these systems the Seascraper would be entirely dependent on constant resource infusions from the shore.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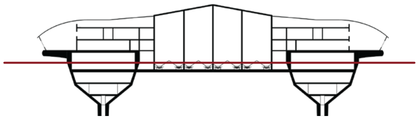


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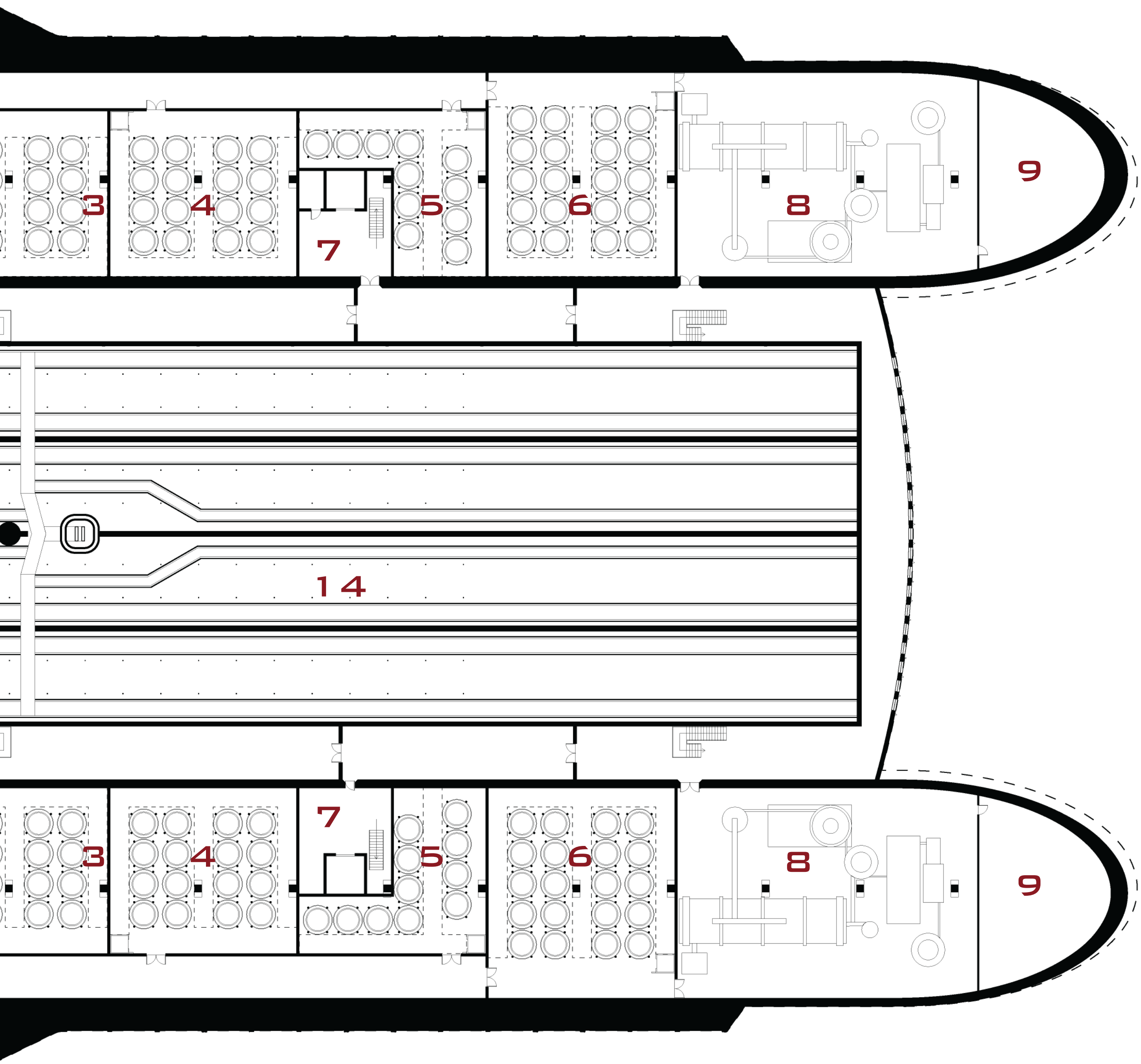
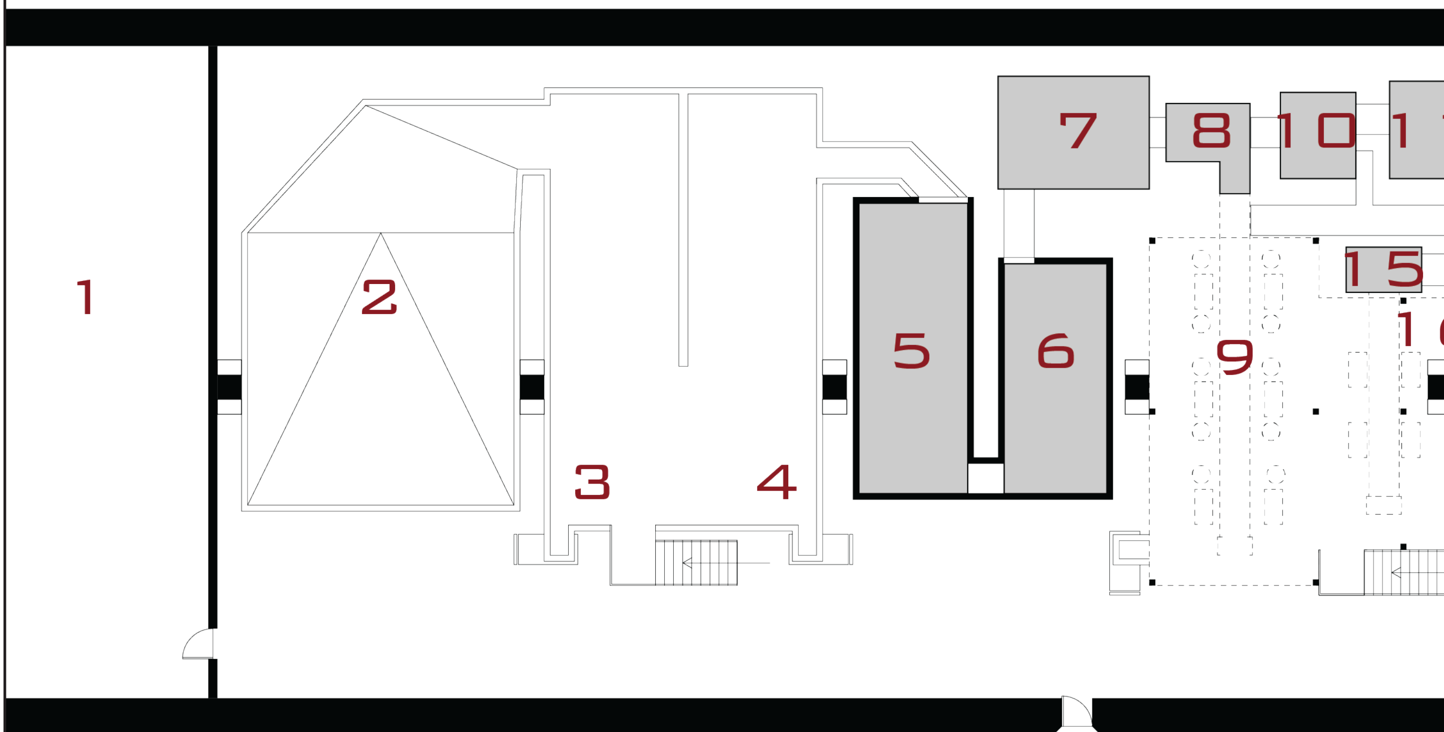
Lower Deck Plan

Fig. 6.26 Labeled Lower Deck Plan

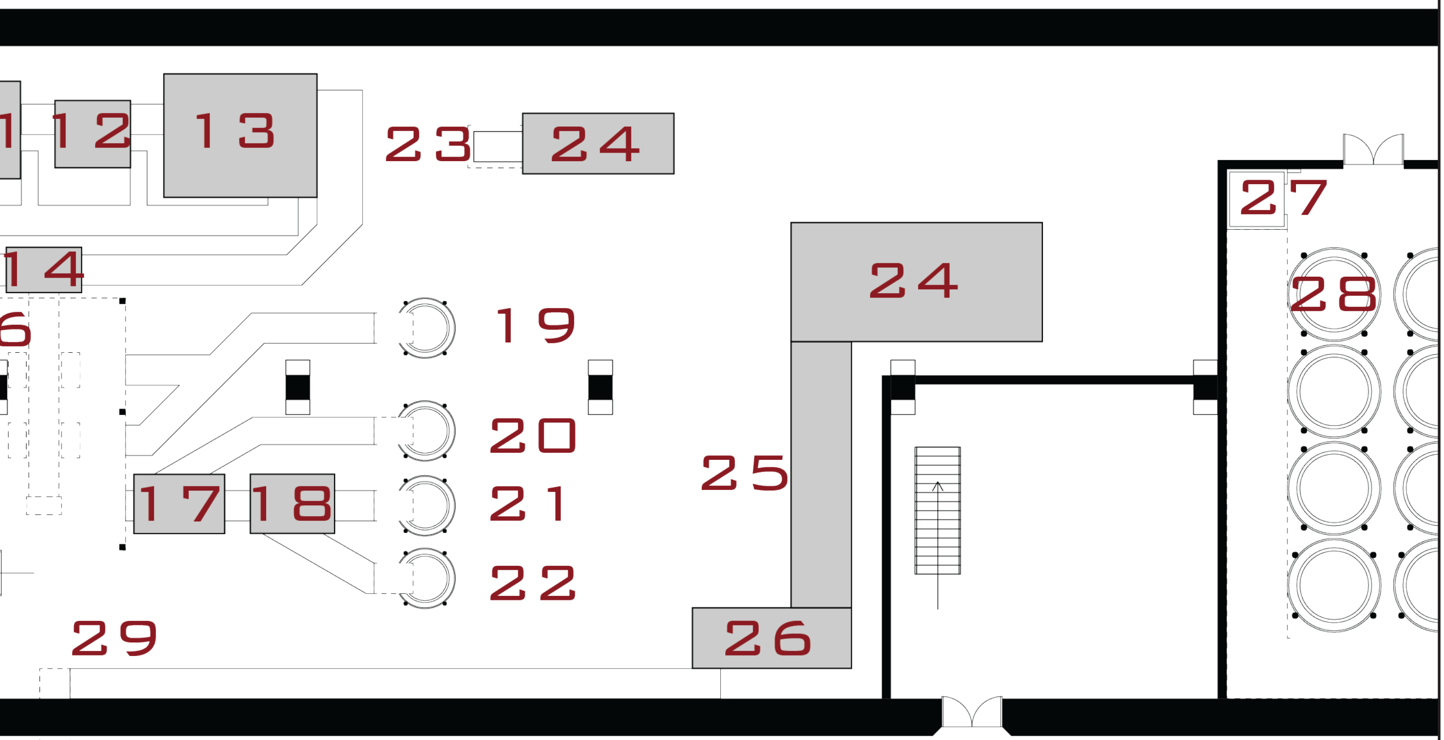


1 Surface plastic conveyor
2 Recycling Area
3 HDPE Storage
4 LDPE Storage
5 Foam Storage
6 Fibre Storage
7 Elevator Storage
8 Pyrolysis Equipment
9 Anchor Machinery
10 Waste Water Treatment
11 Water Purification
12 Turbine Room
13 Marine Nuclear Reactor
14 Plastic Pellet Storage

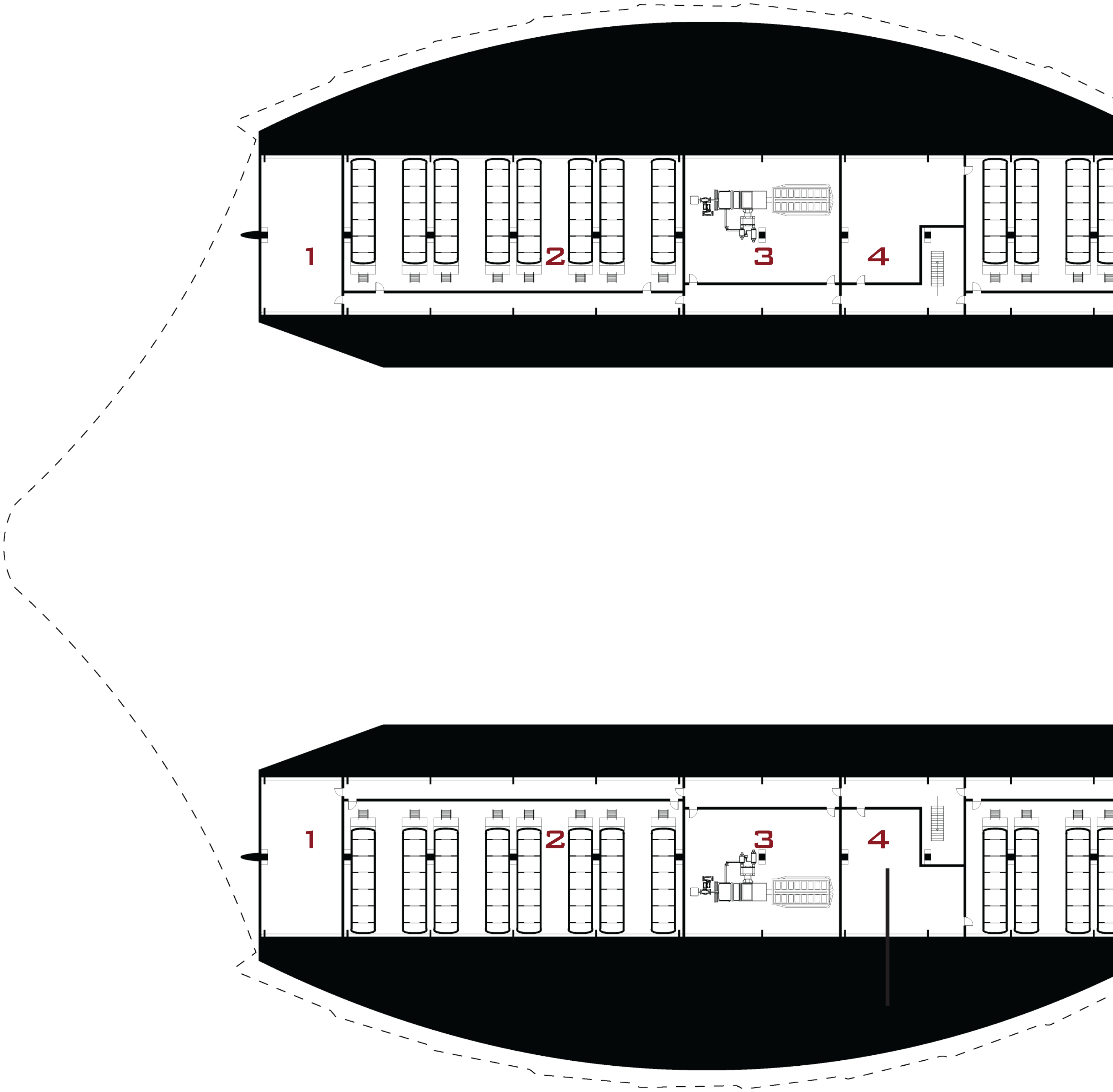


1	METAL STORAGE	11	FROTH FLOTATION
2	PRE-SCREEN PLATFORM	12	FOURIER TRANSFORMED INFRARED
3	ORGANICS DISPOSAL	13	BALLISTIC SEPARATOR
4	NON-RECYCLABLE WASTE	14	DUAL DECK SCREENING FINE
5	WASHING MACHINE	15	DUAL DECK SCREENING MICRO
6	DRYING MACHINE	16	SECONDARY SORTING PLATFORM
7	SHREDDER	17	EDDY CURRENT SEPARATOR
8	FERROUS MAGNET	18	OPTICAL SORTER
9	SORTING PLATFORM	19	TEMPORARY STORAGE - FOAM
10	TRIBO-ELECTRIC SEPARATION	20	TEMPORARY STORAGE - FIBRE

Fig. 6.27 Detailed Recycling System Plan



21 TEMPORARY STORAGE - LDPE
22 TEMPORARY STORAGE - HDPE
23 CHUTE TO PYROLYSIS/INCINERATOR
24 MIXING CHAMBER
25 EXTRUDER
26 PELLETISER
27 ELEVATOR/LIFT
28 PLASTIC FEEDSTOCK STORAGE
29 TO PLASTIC PELLET STORAGE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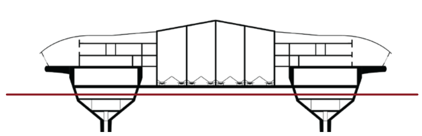
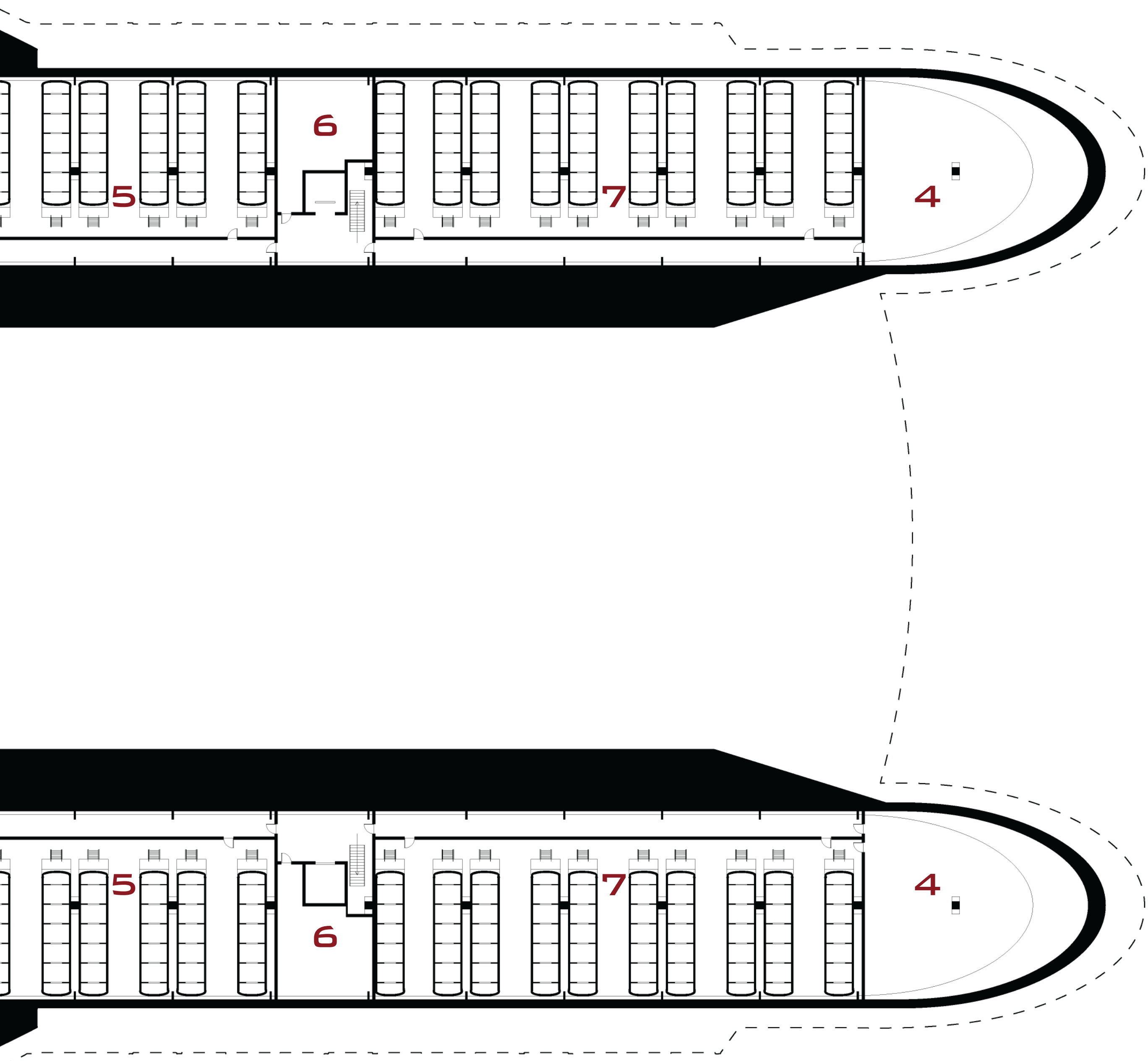


Labeled Lower Deck Plan

Fig. 6.28 Labeled Lower Deck Plan with Details



1 Char Storage
2 Waste Water storage
3 Backup Generator
4 Pump Room
5 Purified Water Storage
6 Elevator Assembly
7 Pyrolysis Liquid Product

Pontoon Levels

Beyond the lower decks are the sub-surface pontoon levels. Figures 6.29-6.33 illustrate that the pontoon levels are comprised of the propulsion equipment and associated machinery, the nuclear reactors, and the ballast tank systems. An elevator connects a small section of the pontoons to the lower deck levels to facilitate the transfer of material and people between these levels. These areas are extensions of the industrial areas and are typically not accessed by the average crewmember. However, a pontoon-level area accessible by all is the inverse aquarium. The inverse aquarium is an area with a series of windows that allow the residents to safely peer into the depths of the ocean. As shown in figure 6.35, these sub-surface views are vibrant and bustling with life in direct contrast to what can typically be see above the surface.

Since the condition of ocean plastics has no single person or entity to fault for its creation, I believe that this is a global issue that can be remediated through a multinational effort. The International Union for Conservation of Nature (ICUN) is a part of the United Nations Environmental Programme (UNEP) and is the global authority on the natural world. This organization will spearhead the task of implementing the vessel as well as accompanying policies that will reduce the overall production of new plastics. With the ocean environment inching ever closer to a total collapse, the Seascraper can remove massive quantities of plastic. While this vessel is not designed to reap the economic benefits of transforming plastic debris into a recycled product it can be seen as a mode of preventative maintenance; a method to ensure that the rich bounty of resources that originate from the ocean are present for the foreseeable future. Furthermore, the process of constructing a large ship is inherently an international endeavour. For example, the Seascraper is a vessel designed by a Canadian, however it may be built in the large shipyards found in Korea, with an American captain overseeing a diverse and multinational crew. Ocean plastics have reached the conditions of a super wicked problem, and this means that no single nation is equipped to deal with a problem of this magnitude, nor are they inclined to put a significant amount of resources into a singular focus. With the support of the UNEP, this load can be evenly distributed and shared as a global community.

Pontoon Section Key

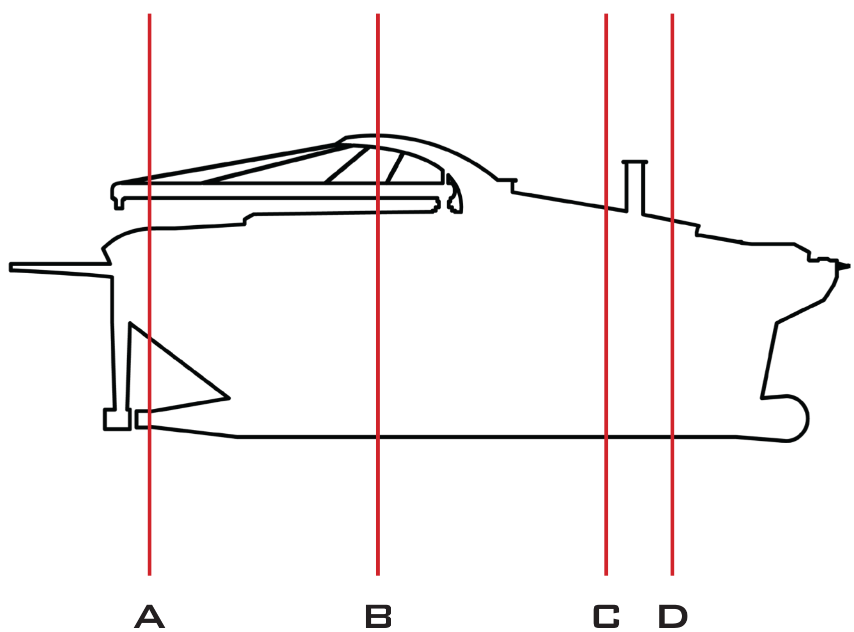


Fig. 6.29 Pontoon Key Section

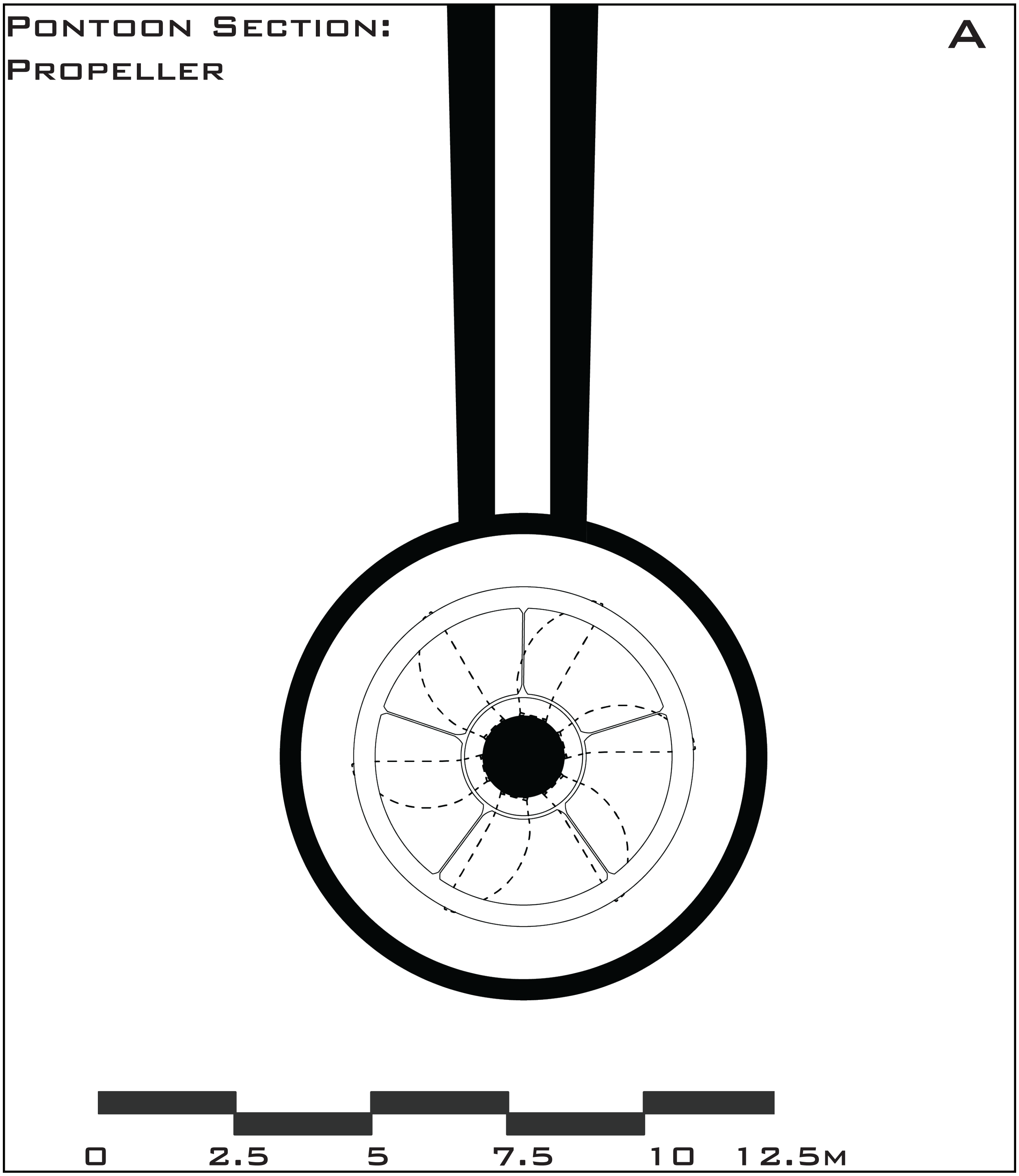


Fig. 6.30 Pontoon Section: Propeller

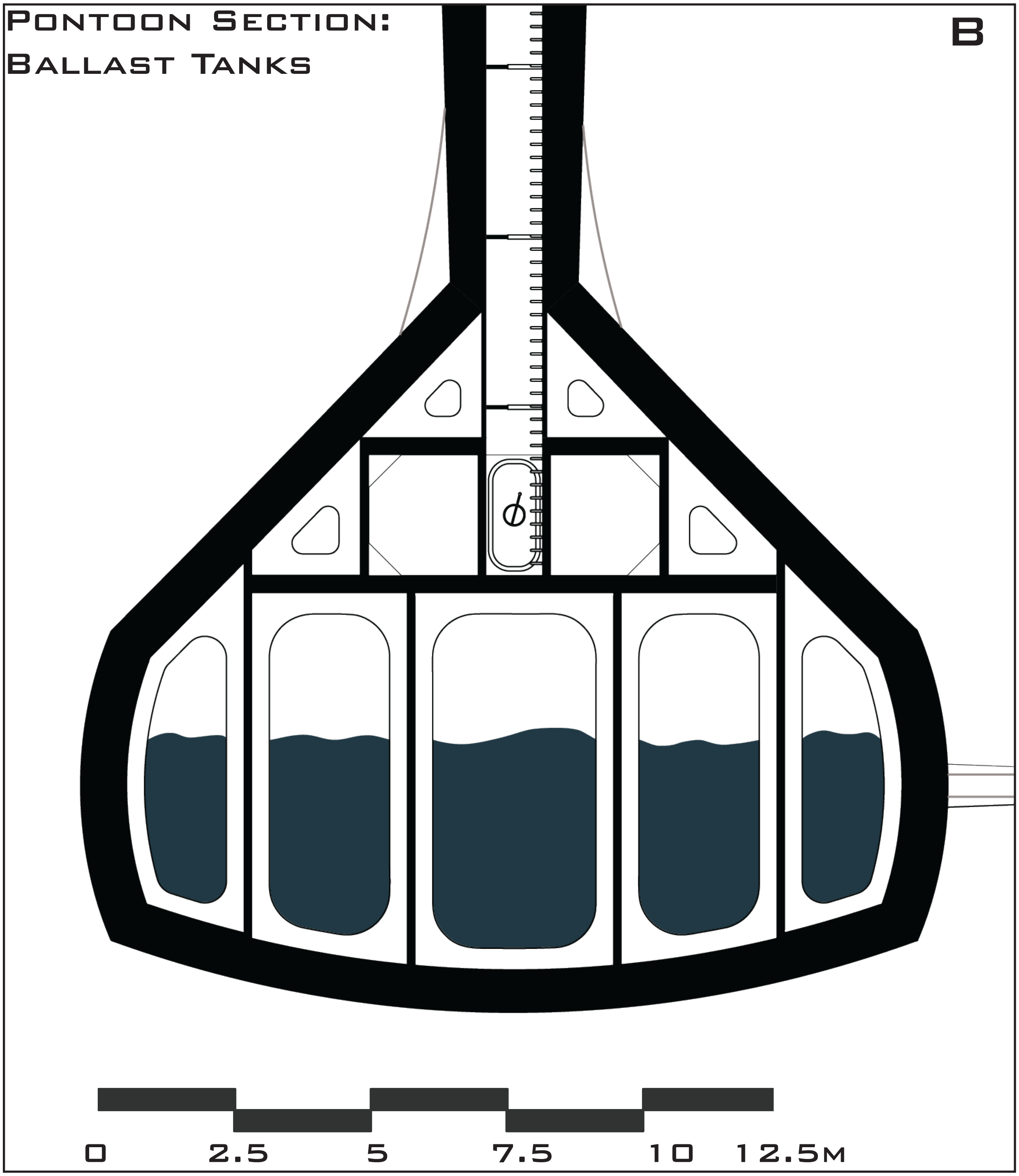


Fig. 6.31 Pontoon Section: Nuclear

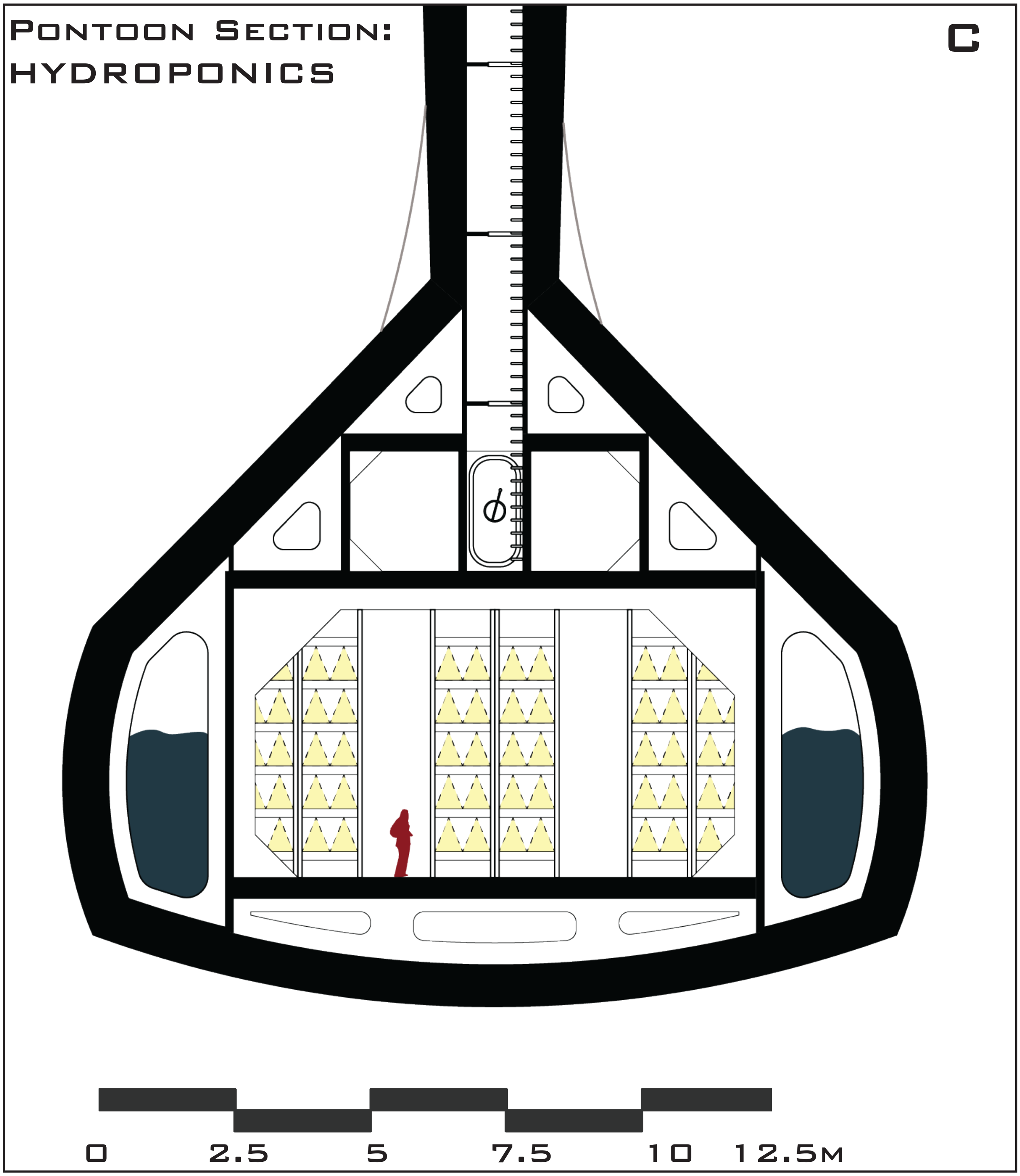


Fig. 6.32 Pontoon Section: Ballast Tanks

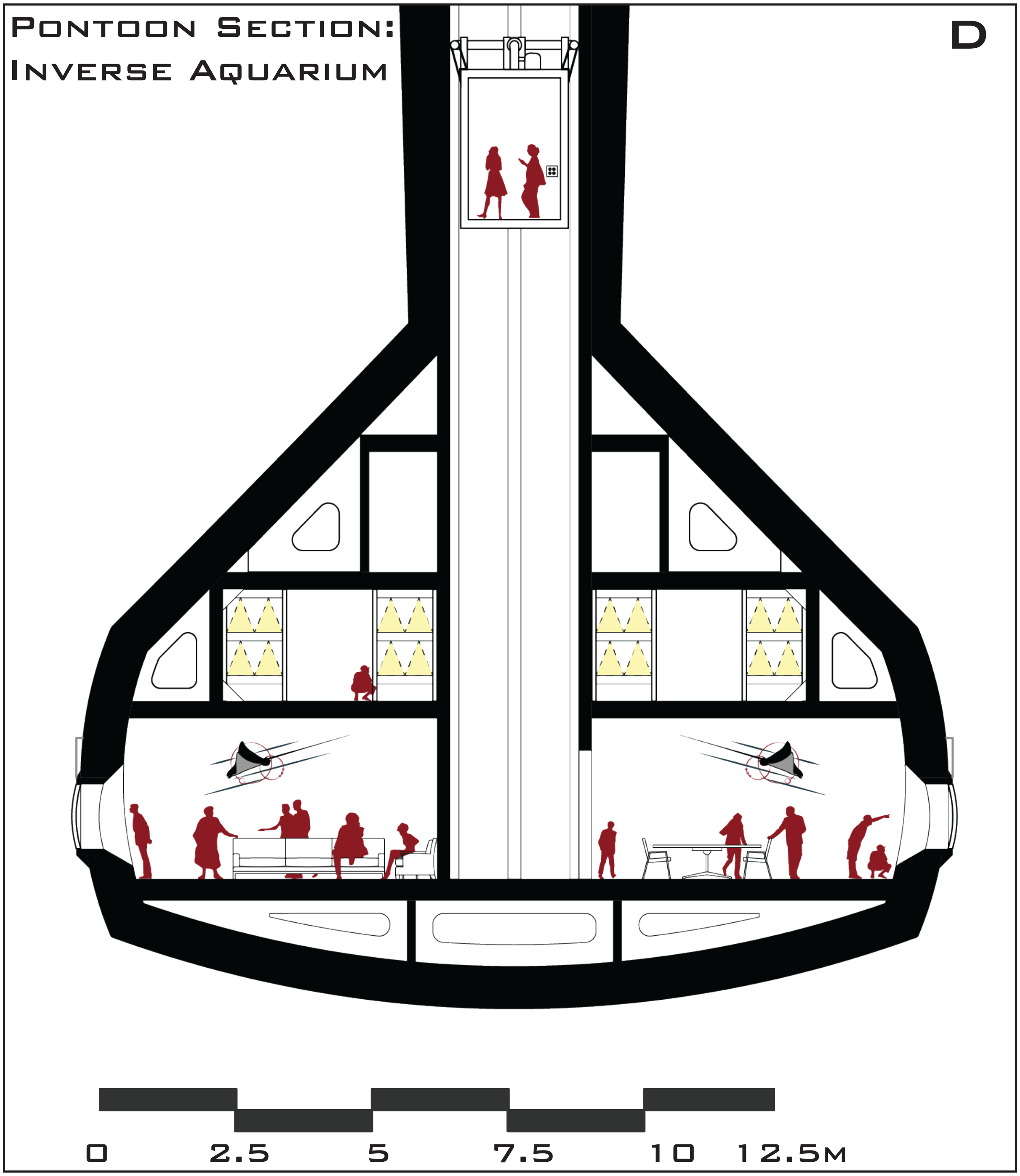
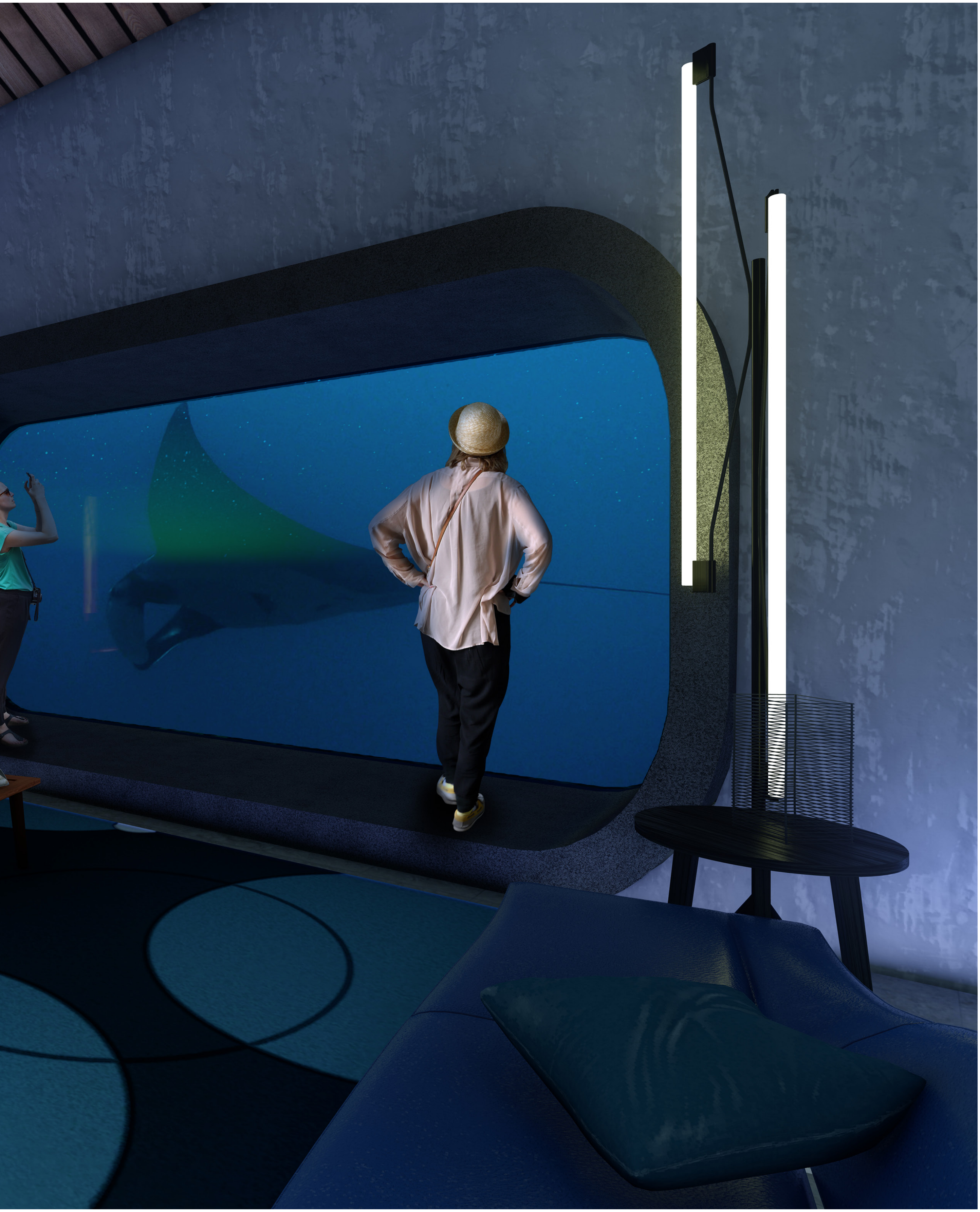


Fig. 6.33 Pontoon Section: Inverse Aquarium

Fig. 6.34 Inverse Aquarium Render



06

Chapter 6
Conclusions

Conclusions

This thesis proposes a unique design for an ocean-based mobile recycling facility to remove the millions of tons of plastic debris that accumulate in the ocean each year. Moreover, it is an investment in the future development of a stable ocean architecture that contributes to the increased inhabitation of such a harsh environment, with the ultimate goal of wide-spread ocean settlement.

Architecture is a centuries old profession that is regularly evolving alongside humanity and is constantly redeveloping itself to meet newly proposed challenges. Yet, the challenge of architecture working with water rather than against it is often overlooked. Water is undeniable. Regardless of the plans of architects or engineers, water inevitably will flow where it wishes. Rather than viewing water as a nuisance and attempting to control it with force, perhaps it can be viewed as an asset and be integrated into an effective design. The Seascraper is a prototype that is working towards designs that sever the earthly tether while maintaining considerations for its passengers and its environment.

The Seascraper has the capacity to comfortably support human life for long periods of time, potentially years. However, it is unlikely that most of the over 200 inhabitants will remain on the vessel indefinitely. A majority would only stay for several months at a time, eventually returning to their lives on the shore. Some key researchers and sailors may decide to stay aboard for a year or two at a time. Yet, even these resolute residents may leave for a brief period to visit family, report their findings in conferences, or just simply wish to participate with the rest of the world however they see fit.

Ecological Responsibilities

The Seascraper is an ocean-faring vessel that is designed to heal ocean ecologies through the removal of waste plastic. All processes onboard the ship, such as collecting, recycling, and disposing plastic are supplemented by the extensive systems that harness solar energy. The propulsion needs are also supplemented through the energy from the pull of the ocean's currents and the wind whenever possible. The plastic that is removed from the environment is either recycled into pellets that can be remade into new products or permanently removed from the environment by turning it into an alternative source of fuel. These actions are intended to reduce the total quantity of new plastics entering production, and later, improperly discarded. However, I believe that the consistent power generated through marine nuclear reactors is the ideal course of action since green energy is not as reliable.

Jane Jacobs' book *The Death and Life of Great American Cities* speaks extensively on the importance of streets within a city. Streets and sidewalks are an important gauge of the city's overall safety. Jacobs explains that having eyes on the streets, in the form of residents casually monitoring the neighbourhood, whether it is from working on their front yard, sitting outside on their porch, or just simply being outside and speaking with their neighbours regularly, dramatically reduces crime rates and creates safer feeling neighbourhoods.[113] By contrast, deliberately continuing to act in ways that perpetuate danger actively erode our learned psychological barriers and open up the possibilities

113 Jacobs, Jane. The Death and Life of Great American Cities. New York: Random House, 1961.

of uncivilised actions occurring at a higher frequency.[114] As this frequency of delinquency increases, opportunistic entities transition from a state of entropy into an uneasy form of tribalism. She alludes to this tribalism as the institution of "Turf," a patchwork of claimed parts of a city or neighbourhood, belonging to various gangs.[115] The owners of this turf would often violently assault members of rival gangs trying to encroach upon this territory. I believe that this exact scenario is unfolding at a global scale with a "plastic gang." The plastic's encroachment upon the ocean is met with the death or assimilation of all other elements (such as the "biotic gang" and the "abiotic gang") that are opposed. The Seascraper is the first step towards adapting this "eyes on the streets" approach to the ocean.

Global responsibilities

As the level of global environmental consciousness increases there will be an increased demand to mass produce bio-degradable plastics or a dramatic surge in the return of plastic alternatives. However, the ocean still remains the final dumping ground. Whether this waste occurs from negligent fishing practices or overflow from an incapable city waste management system, all plastic waste comes from human use. While there is a progression towards sustainable plastics, the existing waste plastics must be removed. Removal efforts at the source would dramatically reduce new plastics from entering into the ocean, however there is still the matter of plastic currently in the ocean. In order for the designs proposed in this thesis to become a reality, support from The

114 Jacobs, The Death and Life of Great American Cities, 42.

115 Jacobs, The Death and Life of Great American Cities, 47.

international Union for Conservation of Nature is needed. Collecting plastic from the ocean must become a societal commitment of extreme necessity. We as humans must work to improve our waste management systems, reduce our dependency on plastic, and increase our personal levels of care with the environment.

Future Considerations

The short-term goal of the Seascraper is the complete purging of waste plastic from the ocean. The long-term goal is to begin developing autonomous or semi-autonomous ocean structures that can effectively sustain extended periods of human occupation. These new structures, whether vessel, platform, or combination of the two need to be able to withstand the relentlessness of the ocean while providing the opportunity for its citizens to thrive. The design of an ocean-based recycling facility functions effectively in most global ocean conditions, however there is enough flexibility in its design for the vessel to be adapted to the specific constraints of its operating area.

Expansion beyond the scope of plastic collection in the Pacific Ocean takes the form of ocean cities. These mobile hubs of human activity focus on understanding, utilizing, and caring for what has previously been alien environment. Interdisciplinary communication and consultation are essential for the evolution of traditional architectural boundaries. A variation of micro-poli currently exists with cruise ships; however, unlike most cities they do not generate, improve upon, or create anything. These vessels only consume resources and belch waste. For the passengers they are an ideal vacation, a small period of self-indulgence, travel, and relaxation.

However, the validity of cruise ships falls short when faced with the reality of rising water levels which will inevitably flood most coastal cities, and consequently, displace millions of people globally. The disruption does not stop with the housing arrangements of its citizens. Many coastal communities are dependent on the infrastructure designed to acquire resources from the ocean. In this era of rising coastal waters, the ship micro-polis designs start to become increasingly necessary. However, these next steps must have the ocean micro-polis shift away from the vacation ideals of a cruise ship and instead focus on autonomy, self-sufficiency, and the well-being of its occupants.

The design of the vessel proposed in this thesis is not pigeonholed into functioning exclusively as a plastic recycling facility that specializes in the North Pacific Ocean. The applied principles and functions can be utilised in all ocean conditions, with local adaptations to improve the application. This resilient architectural presence is not intended to stagnate as a single unique structure. The intention is to utilize this design as a stepping-stone that is consistently redeveloped to respond to emerging challenges.

A useful future modification to the design of the ship would be to target the other forms of plastic. With the Seascraper focusing on the plastic that is currently on the surface of the water, there is still unknown quantities of plastics below. The scientist aboard the first iteration of the vessel must take this opportunity to cultivate knowledge on these sub-surface interactions of the plastic. Significant discussions with marine biologists, ecologists, engineers, and designers are needed to design an optimal method of plastic removal from both the ocean floor, and the spaces between the ocean's floor and surface.

Another potential future adaptation of these vessels would be to focus on the adaptation of creating a mobile fish farm. Rather than erecting a tank that the fish will live in, simulating their natural environment on land, utilizing their actual natural ocean habitat and its bounty of resources would be a low-impact way to practice ocean aquaculture. Since these vessels are designed for actively and passively traversing the ocean, they can move along the ocean currents and follow the nutrients as they flow through the water.

Additionally, international management bodies, such as the International Union for Conservation of Nature, (IUCN) can use these vessels as a mobile base of operations. These vessels would be able to act as a presence for the current and continued stewardship of the ocean environment.

Closing Remarks

Humanity has developed into the single most successful species on our planet. Driven by our ambitions to grow and fuelled by the rapid development of technologies, humans colonised nearly all of the ideal habitable zones. It is humanity's desire to maximise our reach so that it is equal to our grasp. In this pursuit there is often little concern for how we arrive at the results, just that these results are achieved. In the pre-industrial age, the negative effects of human settlement have been isolated to the local area and had the potential to recover naturally. However, the advent of heavy industry has introduced extremely toxic chemical concoctions into the environments, with the concentrations of these chemicals increasing at an exponential rate annually. Humanity has existed for thousands of years, yet in the last century, we have caused more damage to the environment than previously imaginable. This means that if we continue this behaviour our resources are severely limited. There has been no consideration for future generations.

Our lives are the longest thing we as humans can ever experience, however, in the grand scheme of time a single human life is a readily forgotten blip on the timeline. Human lifespans are short compared to the duration of the Anthropocene, which in turn, is short compared to the existence of the planet. We put too much focus on the here and now, trying to accumulate as much personal gain as possible, however, this outlook is incredibly short-sighted and is self-sabotaging. In order to extend the age of the Anthropocene indefinitely, we must shift to a generation perspective rather than a personal one.

This thesis presents a method to unite many disciplines against the environmental challenges that impact humanity at a global level. We are approaching the tipping point of an entire environmental collapse, but I am hopeful that the consciousness of newer generations will be able to make effective changes; changes that will correct the decades of human tampering with the fragile ocean ecosystem and allow it to remain a vital, sustainable resource for all future generations.

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Appendix

Skalgubbar

The people populating the renders in this thesis were obtained from Skalgubbar. Skalgubbar is a "steadily growing and carefully curated collection of cut out people by Teodor Javanaud Emdén and all the fantastic people he knows. Made to bring visualizations of unbuilt architecture to life. It's a personal project that follows his everyday life. Yes, he knows all of the people and call them friends."

If you liked any of the people from the renders and would like to use them in your own educational renders they can be found at www.skalgubbar.se. Just be sure to reference Skalgubbar as the source according to their licensing agreement!

WO Waterstudio.NL - Koen O[redacted]
To: Jordan D[redacted]

Tue 3/29/2022 11:45 AM

Yes sure, no problem

Dr. Koen O[redacted]

Green is good, Blue is better!

On 29 Mar 2022, at 17:43, Jordan D[redacted] wrote:

Hello!

May I have your permission to use some of the photos and information for the "Arkup, Avant-Garde life on water" that are on your website? I wish to use a few of these photos and a brief description of the project in my thesis document that I am producing in fulfillment of a Master of Architecture (Water) degree at the University of Waterloo School of Architecture. The use of these images and text will be for educational use only and I will credit Waterstudio and Arkup.

Thanks in advance for your time and consideration,
Jordan

Jordan D[redacted]
BAS Hon. M.Arch Candidate
University of Waterloo - School of Architecture

Reply | Forward

JD Jordan D[redacted]

To: [redacted]

Tue 3/29/2022 12:35 PM

Hello!

May I have your permission to use some of the information from the document: "A Century of Replenishment at Sea by Commander John A. L[redacted] that I located at https://www.history.navy.mil/get-involved/essay-contest/2017-winners/additional-essay-contest-submissions/a-century-of-replenishment-at-the-sea.html? I wish to use a brief description of the process of replenishment at sea in my thesis document that I am producing in fulfillment of a Master of Architecture (Water) degree at the University of Waterloo School of Architecture. The use of this text will be for educational use only and I will credit the US Naval Institue and Commander John A. L[redacted]

Thanks in advance for your time and consideration,
Jordan

Jordan D[redacted]
BAS Hon. M.Arch Candidate
University of Waterloo - School of Architecture

CS C[redacted], Scot [redacted]

To: Jordan DAscenzo

Tue 3/29/2022 12:42 PM

Hi Jordan,

You may use it but be sure to cite the source.

Best,

Scot C

...