Islands as refuges for surviving

global catastrophes

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**Abstract**

**Purpose** Islands have long been discussed as refuges from global catastrophes; this paper will evaluate them systematically, discussing both the positives and negatives of islands as refuges. There are examples of isolated human communities surviving for thousands of years on places like Easter Island. Islands could provide protection against many low-level risks, notably including bio-risks. However, they are vulnerable to tsunamis, bird-transmitted diseases, and other risks. This article explores how to use the advantages of islands for survival during global catastrophes.

**Methodology**: Preliminary horizon scanning based on the application of the research principles established in the previous global catastrophic literature to the existing geographic data.

**Findings** The large number of islands on Earth, and their diverse conditions, increase the chance that one of them will provide protection from a catastrophe. Additionally, this protection could be increased if an island were used as a base for a nuclear submarine refuge combined with underground bunkers, and/or extremely long-term data storage. The requirements for survival on islands, their vulnerabilities, and ways to mitigate and adapt to risks are explored. Several existing islands, suitable for the survival of different types of risk, timing, and budgets, are examined. Islands suitable for different types of refuges and other island-like options that could also provide protection are also discussed.

**Originality/value** The possible use of islands as refuges from social collapse and existential risks has not been previously examined systematically. This article contributes to the expanding research on survival scenarios.

**Keywords**: Existential risks, islands, survival, global catastrophe, social collapse, refuges

# 1. Introduction

In recent decades, researchers have identified many global risks which could result in the collapse of civilization and/or human extinction. These risks may be divided in three classes: natural, like asteroid risks (Gritzner *et al.*, 2006), low-tech, connected with currently existing technologies, like the risk of nuclear war (Barrett, Baum and Hostetler, 2013), and futuristic high-tech, connected with new expected supertechnologies, like nanotechnology (Freitas, 2000) and AI (Bostrom, 2014). Supertechnological risks are the most dangerous, as they are expected to be the most powerful and least controllable (Bostrom, 2002).

The best way to fight all the types of risks is to prevent (Bostrom, 2013) or mitigate them, but another option, or plan B, is to adapt in order to survive them. There are several ideas for how such risks could be survived, including a Mars colony (Musk, 2017), a Moon colony (Shapiro, 2009; Turchin and Denkenberger, 2018), underground bunkers (Jebari, 2014), space bunkers (Torres, 2016), and retrofitted nuclear submarines (which are one of the most cost-effective solutions (Turchin and Green, 2017)). Planning for surviving these risks, whether by mitigation or adaptation, should be a paramount ethical duty of humankind (Jonas, 1984; Green, 2014, 2016).

Several authors (Jebari, 2014; Beckstead, 2015) have analyzed the problem of global risk survival and concluded that most catastrophes are either too small or too large for bunkers or other refuges to be a useful option. But even a one percent increase in the chance of survival is worth considering, especially because there are not yet useful working ideas of the magnitude of some larger risks, such as unsafe AI (Bostrom, 2014). Additionally, at the Workshop on Existential Risk to Humanity (Gothenburg Chair Programme for Advanced Studies, 2017) Karim Jebari mentioned that such refuges will also be important for cultural transfer and as consolidation points, even if there might be many survivors in other places.

Baum has suggested that the gold standard for global risks refuges should be “surface independence” (Baum, Denkenberger and Haqq-Misra, 2015). Islands only partly satisfy this criterion: they are not connected to the mainland, thus making them discontinuous with the land surface of the Earth, but they are still accessible by air and sea. However, if they were very remote and equipped with underground and/or underwater shelters, they could provide a higher level of protection than surface-independent bunkers on the mainland for certain types of catastrophes.

By definition, global risks affect much or all the surface of the Earth, or at least all populated areas. This creates a chance for survival, as there is a probability that some parts of the Earth will be affected to a lesser extent. For example, a gamma ray burst (Ćirković and Vukotić, 2016) that happened away from the equatorial plane would have less of an effect on one of the polar regions. Likewise, extreme global warming (Hanna and Tait, 2015) would be more survivable on mountains at high latitudes, while atmospheric pollution (Mount, 1970) by some toxin or contamination could be less of an issue in the Southern hemisphere because of geography and atmospheric circulation patterns. Yet most catastrophes which could be survived on temporary space refuges on the Moon or Mars could also be survived on Earth, if there were adequate shelters or refuges, with some notable exceptions. Such exceptions include very large asteroid impacts, a severe and long-term case of multiple pandemics (with many lethal diseases active in the environment), or massive and irreversible global warming. For some preliminary calculations of the usefulness of shelters from global catastrophes see (Turchin and Green, 2017).

Islands have proven to be survival refuges for some species which are extinct in other places, like mammoths, which survived on Wrangel island up to 2000 BC (Vartanyan *et al.*, 1995). Islands have proven to be effective refuges for humans as well. For example, the islands of New Caledonia and American Samoa did not have a single death from the 1918 Spanish flu because of their effective quarantine measures (Bell *et al.*, 2006).

While islands have been extensively discussed as refuges for animals and plants, the topic of using islands as a means for humans to survive global catastrophic risks has not yet been formally explored. This article seeks to remedy this deficiency. Section 2 looks at the requirements for survival on islands; Section 3 looks at the possible role of islands as consolidation centers after a social collapse; Section 4 reviews several islands as possible refuges; Section 5 puts island refuges in the context of other possible types of refuges; Section 6 discusses how to maximize protection by combining islands refuge with subterranean and/or submarine refuges; and Section 7 discusses other places on Earth, similar to islands, where survival might be possible.

# 2. Island requirements for survival of catastrophes

## 2.1. Islands as protection against various types of catastrophes

Islands offer excellent protection against natural and/or low-tech catastrophes which are neither too large nor too small. Remoteness, isolation, and the diverse conditions found on different islands could be helpful features to aid survival in the face of different types of catastrophe.

Islands could provide protection against a human-to-human transmitted biological pandemic; as mentioned in the Introduction, some islands were able to escape the 1918 flu pandemic by implementing effective quarantine measures.

Islands may help to survive a long-term collapse in food production caused by nuclear winter, agricultural pests, and other catastrophes. Islands often have non-traditional food sources, such as birds and sea flora and fauna, which may provide independent subsistence for an indefinitely long period.

On remote islands, the extent of radioactive and chemical contamination from catastrophes would likely be smaller. This is especially true of islands located in the Southern hemisphere close to the Antarctic, as winds around the pole maintain some isolation from the rest of the atmosphere. Constant rains and winds may accelerate the decontamination of some islands (like Kerguelen). In addition, sea animals may be relatively less-contaminated food sources.

Islands away from the equator could provide protection against some of the direct effects of a gamma ray burst (muons) (Ćirković and Vukotić, 2016) if they were in the constant shadow of the Earth, below the horizon of the gamma ray source.

In the case of global war or technological collapse, many islands could become unreachable. This would protect them against human-borne diseases, pirates, looters, and certain autonomous weapon systems such as land-based or short-range drones. Additionally, remote and sparsely populated islands may be not interesting military targets. In case of war, it may be more expensive to reach them than to ignore them, though this depends on the nature of the war. For example, the Germans used remote unpopulated islands in the Arctic (Grossman, 2016) and in the Southern Ocean (Rogge and Frank, 1956) as secret bases during World War II, and the Allies later sent cruisers to Kerguelen to check if Germans were hiding there.

It might be too expensive for a hostile AI to seek out and kill small groups of people in remote places, if they do not pose an immediate risk to the AI’s interests. However, over time the AI’s risk calculation might change.

## 2.2. Island desirable properties

Based on the types of expected catastrophes where islands could help discussed in Section 2.1, the desired properties of an ideal island-refuge can be listed:

**Remote**. The island should be several thousand kilometers from large human settlements, lay beyond the major lines of maritime transport, and preferably not be accessible by airplane.

**Sparsely populated.** It is preferable that the island have a small constant population, neither too big nor too small. Having a larger population may create or bring other risks, like difficulty of governance or quarantine violations, while a completely uninhabited island would probably lack the necessary infrastructure for human survival, and therefore have poor long-term prospects. A native population could also help to build the refuge, thereby lowering its price. It looks like the best size for an island population is between 100–1000 people, with ecological studies indicating that short-term and long-term minima are in the 50–500 range, respectively (Frankham, C. and B.W, 2014). Too few people will also lead to genetic problems.

**Fertile.** The island should be able to provide humans with all they need for long-term survival, especially food. It should also include other resources needed for long-term human survival, including fresh water, wood, various ores, domesticated plants and animals, and the ability to support levels of technology above primitive hunter-gathering.

**Energy.** The island should have adequate sunlight, wind, hydroelectric, geothermal, biomass, fossil fuel, or other forms of available energy such that the refuge is able to sustainably meet its own heating, fuel, and electrical needs. Luckily, islands tend to be awash in energy sources, particularly wind; in addition, tropical islands have intense sunlight and volcanic islands have geothermal potential.

**High ground**. The island should have a sufficiently high and accessible mountain to allow construction of a tsunami shelter. Many catastrophic scenarios like asteroid impacts may create extremely high tsunamis, and even a remote island could be affected. At least a 1 km mountain, not covered by a glacier, is desirable.

**Geologically stable.** The island should be non-volcanic or no longer actively volcanic, and not susceptible to the massive landslides that sometimes occur in eroding coastal areas, particularly islands (Masson *et al.*, 2006). Such geologic instability creates an obvious risk for the inhabitants in the form of eruptions, earth movements, and tsunamis. Islands which are of non-volcanic origin, or extinct volcanos, may tend to have lower risk.

**Accessible by ship.** The island should be accessible by large ships and submarines and have a protected harbor. Islands lacking harbors or sufficiently protected landing areas would be difficult to develop into refuges, as well as being difficult for future transportation.

**Legally suitable for development.** Many remote islands are nature reserves, where only scientific research is allowed. Islands with good harbors may already be used by militaries to the exclusion of others. Almost all islands are owned by different countries with different laws, and many islands are subjects of territorial dispute. Finding the right legal conditions may not be easy.

**Defensible.** The island may need air and maritime defenses to protect it against unwelcome guests, such as looters or autonomous weapons. Tragically, depending on the type of catastrophe, the refuge might even need to protect itself against refugees, as they could bring infectious diseases with them. However, if an island becomes a significant military base, it could become a legitimate military target in the event of a catastrophic war.

**Resilient to climate change**: There are two large ice masses which could be affected by climate change relatively tear-term: Greenland and West Antarctica. Each could raise sea level by more than 7 meters (and if all the ice on Earth melted, it raise sea level by 66 meters (National Geographic, 2013), but this would require a very long time and even higher warming, as most of this ice in the Antarctic). Such sea rise is already a problem for low-lying tropical atolls, which are affected not only by the sea rise itself but also by higher storm surges. For example, the Maldives has median elevation of 1-1.5 meters (Maniku, 1990), and thus is not suitable as an island-refuge. Also, global warming would increase the temperature of the oceans which would make tropical cyclones more severe (Emanuel *et al.*, 1995; Webster *et al.*, 2005), and allow cyclones to appear closer to the polar regions. In the reverse case, one of extreme global cooling, low-lying islands will be more effected by moving ice masses, which can create ice surges upon shores, which can reach a height of 10 meters (Lendon, 2013). Combining the expected sea-level rise and the possibility of higher than usual storm surges (as wells as possible tsunamis and other events) we can see that refuges should be built on heights above at least 20 meters; for escaping possible asteroid impact, volcanic, and landslide tsunamis, the risks of which will be discussed in the next section, the height should be even higher, probably above 100 meters. Thus a suitable island refuge should have hills for housing.

There are around a million islands on Earth, but given these criteria, only a few may be suitable as refuges for surviving global catastrophic risks: an overview of a few of the most suitable islands can be found in Section 3.

## 2.3. Vulnerabilities of islands

Islands are vulnerable for several reasons, and planning should take these possible vulnerabilities into account and seek ways to mitigate and adapt to them:

**Tsunamis**. Oceans are good at transmitting energy over long distances via waves, and some tsunamis can be extremely large. For example, bolide impactors have been implicated in several tsunamis: the east coast of Australia has remnants of a large possible tsunami as high as 80 meters in last 1000 years (Bryant and Nott, 2001), connected with hypothetical asteroid impact or volcanic explosion near New Zealand. The Eltanin impact 2.5 millions years ago may have generated a wave of up to 200 meters, which affected southern South America (Ward and Asphaug, 2002). Other sources of tsunamis include volcanos, earthquakes, and landslides (McMurtry *et al.*, 2004). Many islands are located near other islands which are volcanic and could produce very high tsunamis. Asteroid impacts and undersea nuclear bombs like Russian Status-6 (Porter, 2018) could also create very high waves, but their height diminishes quickly (in reverse proportion to the distance): so, kilometer size tsunamis can’t travel far.

**Birds and their infections**. Migratory birds often land on islands, and most remote islands have large bird populations. Unfortunately, birds might carry bird flu, a serious pandemic risk, as well as some parasitic insects, which could carry other diseases. However, not all islands are like this; for example, Guam has few birds because their eggs are eaten by invasive snakes (Amand, 2000).

**Aggressors, both intentional and unintentional.** Islanders may be attacked by human or robotic aggressors (intentional attackers) or may encounter ships with dangerous infected people on them (unintentional aggressors). At any particular time, there are thousands of ships on the world’s oceans, and many may move around the sea for months after a global catastrophe, possibly carrying infected people. Pirates are also a possible risk in the post-catastrophic world.

**Hurricanes**. Many tropical islands are vulnerable to extreme weather events, like the Great Hurricane of 1780, which killed about 22 000 people in the Lesser Antilles. More recently, hurricanes such as Irma and Maria have devastated islands in the Caribbean.

**Cold** **and ice**. Most poleward islands may be covered with permanent glaciation if the global temperature falls even a few degrees. However, such islands might be useful in a situation of short-term but intense global warming.

**Volcanos**. There are risks of volcanic events on many volcanic islands or on nearby islands. For example, a pyroclastic flow on Martinique in 1902 killed 30 000 people with only 2 survivors (Zebrowski, 2002).

**Geologic instability.** Many islands have had massive landslides in the past, and several have active landslide dangers today. For example, on the Big Island of Hawaii, the Hilina slump threatens to send up to 10 000–12 000 km3 of land, roughly 10% of the entire island, into the ocean (Smith, Malahoff and Shor, 1999).

**Air access risks.** It might seem that having an air strip would be an advantage for an island refuge, as it would allow for the quick arrival of evacuees, but in fact air travel is a major vector for the spread of infectious disease.

## 2.4. Different survival scenarios on islands

Different types of possible catastrophes suggest different scenarios for how survival could happen on an island. What is important is that the island should have properties which protect against the specific dangers of particular global catastrophic risks. Specifically, different islands will provide protection against different risks, and their natural diversity will contribute to a higher total level of protection.

**Quarantined island survives pandemic**. An island could impose effective quarantine if it is sufficiently remote and simultaneously able to protect itself, possibly using military ships and air defense.

**Far northern aboriginal peoples survive an ice age**. Many far northern peoples have adapted to survive in extremely cold and dangerous environments, and under the right circumstances could potentially survive the return of an ice age. However, their cultures are endangered by globalization. If these peoples become dependent on the products of modern civilization like rifles, motor boats, etc., and lose their native survival skills, then their likelihood of surviving the collapse of the outside world decreases. Therefore, preservation of their survival skills may be important as a defense against the risks connected with extreme cooling.

**Remote polar island with high mountains survives brief global warming of median surface temperatures, up to 50 °C**. There is a theory that the climates of planets similar to the Earth could have several semi-stable temperature levels (Popp, Schmidt and Marotzke, 2016). If so, due to climate change, the Earth could transition to a second semi-stable state with a median global temperature of around 330 K, about 60 °C, or about 45 °C above current global mean temperatures. But even in this climate, some regions of Earth could still be survivable for humans, such as the Himalayan plateau at elevations above 4000 meters, but below 6000 (where oxygen deficiency becomes a problem), or on polar islands with mountains (however, global warming affects polar regions more than equatorial regions, and northern island will experience more effects of climate change, including thawing permafrost and possible landslides because of wetter weather). In the tropics, the combination of increased humidity and temperature may increase the wet bulb temperature above 36C, especially on islands, where sea moisture is readily available. In such conditions proper human perspiration becomes impossible (Sherwood and Huber, 2010), and there will likely be increased mortality and morbidity due to tropical diseases. If temperatures later returned to normal—either naturally or through climate engineering—the rest of the Earth could be repopulated.

**“Swiss Family Robinsons” survive on a tropical island, unnoticed by a military robot “mutiny.**” Most AI researchers ignore medium-term AI risks, which are neither near-term risks, like unemployment, nor remote risks, like AI superintelligence. But a large drone army—if one were produced—could receive a wrong command or be infected by a computer virus, leading it to attack people indiscriminately. Remote islands without robots could provide protection in this case, allowing survival until such a drone army ran out of batteries, fuel, ammunition, or other supplies.

**Primitive tribe survives civilizational collapse.** The inhabitants of North Sentinel Island, near the Andaman Islands in the Indian Ocean, are hostile and uncontacted. The Sentinelese survived the 2004 Indian Ocean tsunami apparently unaffected (Voanews, 2009), and were the rest of humanity to disappear, they might well continue their existence without change.

**Tropical island survives extreme global nuclear winter and glaciation event**. Were a nuclear, bolide impactor, or volcanic “winter” scenario to unfold, these islands would remain surrounded by warm ocean, and local volcanism or other energy sources might provide heat, energy, and food. Such island refuges may have helped life on Earth survive during the “Snowball Earth” event in Earth’s distant past (Hoffman *et al.*, 1998).

**Remote island base for project “Yellow submarine.”** Some catastrophic riskslike a gamma-ray burst, a global nuclear war with high radiological contamination, or multiple pandemics might be best survived underwater in nuclear submarines (Turchin and Green, 2017). However, after a catastrophe the submarine with survivors would eventually need a place to dock, and an island with some prepared amenities would be a reasonable starting point for rebuilding civilization.

**Bunker on remote island.** For risks which include multiple or complex catastrophes such as a bolide impact, extreme volcanism, tsunamis, multiple pandemics, nuclear war with radiological contamination, etc., island refuges could be strengthened with bunkers. Richard Branson survived hurricane Irma on his own island in 2017 by seeking refuge in his concrete wine cellar (Clifford, 2017). Bunkers on islands would have higher survivability compared to those close to population centers, as they will be neither a military target nor as accessible to looters or unintentionally dangerous (e.g. infected) refugees. These bunkers could potentially be connected to water sources by underwater pipes, and passages could provide cooling, access, and even oxygen and food sources.

## 2.5. Survival times and population

As analyzed in our article on nuclear submarines, the minimal viable human population is roughly 100–1000 people, and an ideal island should be able to support this population (preferably on the larger end of the range) for a long time, perhaps even thousands of years (Turchin and Green, 2017). In the event of a smaller catastrophe, a shorter period of isolation is needed for survival, putting fewer requirements on an island.

The required survival time on an island will depend on how long it takes before it becomes possible to repopulate the mainland, and that depends on the nature of the catastrophe. Polynesian people were able to survive on islands for millennia, as well as preserve their ability to settle other islands, using only canoes and relatively low-tech navigation technologies (Anderson and McGovern-Wilson, 1990). People from our contemporary culture may need to develop the infrastructure to support more advanced technologies, like motor boats, which will either limit the time of isolated survival, or require a larger population capable of supporting advanced education and the manufacture of more complex technologies.

The isolated survival time may range from several years to millennia, and this uncertainty puts different requirements on islands. Long-term survival of a small group only seems possible if they keep or obtain survival technologies similar to those of indigenous peoples like the Inuit or Polynesians. Unfortunately, many of these skills have been lost to colonization and globalization.

## 2.6. The problem of resettling the Earth from a small island

Some islands may support primitive human life for a relatively long time, even thousands of years, but resettlement of larger land masses would be needed to rebuild a global civilization. However, this could be difficult if the island lacks large trees, since access to shipbuilding materials would be not easy. Knowledge of shipbuilding should be preserved, as well as the resources necessary to build new ships. For example, Kerguelen Islands does not have large trees, as it is mostly tundra, and barring sufficient resources, humans could be trapped on it forever. Thus, trees, tree seeds, and other necessary supplies (perhaps greenhouses and/or windbreaks to protect seedlings, fertilizer, etc.) should be included while planning a refuge there.

## 2.7. Funding the creation of island refuges

The large number of diverse already-populated islands and other remote places creates some form of natural protection against catastrophe. Building more sophisticated island-refuges from scratch may be extremely expensive. However, if materials which could increase survivability, such as seeds, books, and data storage, are stored on the best islands for global survival, they may cost-effectively increase the chances that the island will facilitate human survival.

Many risk adaptation projects, such as shelters and refuges, carry an opportunity cost because their realization could prevent the implementation of other useful projects. Therefore, ways to reduce the price of each project, including the use of existing facilities or unique ways of attracting funding for a specific type of project, like selling places in the refuge, advertising, tickets, tourism, etc., should be examined. (Though this should be done with care, as some of these activities could compromise the refuge’s efficacy in certain ways.) Island-refuges could be expensive, but many cost-reduction options exist. Ideally, the cost of catastrophic risk protection projects could be negative, if they earn money through the means described above, or even attract entrepreneurs.

Some billionaires have reportedly invested in constructing personal refuges, and they may desire to do so on remote islands. In that case, refuge-builders could utilize the personal desires of these individuals to promote the survival of larger numbers of people by building more complex survival shelters in these places. Such personal shelters reportedly are already being created on the South Island of New Zealand (Osnos, 2017), but these are probably not sufficient to protect adequately against many risks. For example, the safest place should be constantly inhabited by a prepared crew which lives in isolation; however, the arrival of the owner of the refuge with his family by airplane could increase risk in case of a biological catastrophe.

Selling the rights to live on a remote island as a part of the “backup crew” for humanity may be one way to fund such a project. Tourism and art residencies might also contribute. Remote military installations (yet not significant enough to target) could also be of interest, as well as remote scientific stations, like on Kerguelen, or the Martian base simulation on Devon Island (FMARS, 2018).

# 3. An island as a center of cultural and technological preservation after a weak catastrophe or a civilizational collapse

As Jebari noted (Jebari, 2014), refuges are important not only to preserve the last members of the human species, but also for the preservation of important cultural heritage in form of a living tradition (e.g., our value system), and as centers of coordination for reconstruction in the case of global social collapse.

Cultural preservation will be especially important if the appearance of complex technology is not a typical outcome within the evolution of human societies, but rather the result of one or more rare events. If this is true, then humanity could have been stuck indefinitely at the tribal or imperial levels, and perhaps even gone extinct were some dangerous global challenge to appear.

Even if many people survived on land after a societal collapse, their social organization might be centered around looting the remains of the previous high-tech civilization, as happened in the first few centuries after Rome’s demise. As a result, they would not only lose the skills needed to create useful technologies, but also acquire a set of negative skills, based on scavenging, piracy, and violence. This would prevent their development towards recovery, until, at last, all technological remains were looted and all knowledge lost. It should be noted that after the fall of Rome this downward spiral was avoided by copying and preserving ancient knowledge with religious fervor. In other words, technological remains can paradoxically prevent the appearance of a new complex society, because it is always cheaper to scavenge and loot. This happened to some extent after the collapse of the Soviet Union, when selling factories and their contents for scrap was cheaper than re-starting manufacturing.

In this case, even small societies which preserved effective social organization and an uninterrupted educational process could become seeds for the re-creation of technological civilization. Large islands, inaccessible to gangs of looters, could be such centers of reconstruction. They should have universities, high levels of human capital, adequate military defense, and abundant natural resources. Possible examples include New Zealand, Hawaii, Taiwan, Japan, and Iceland.

If such islands could retain high levels of technology, over time they would gain an advantage over the gangs of looters on the continents. Their higher education would promote better healthcare, and better medicine could allow higher rates of population growth. In that case, the restoration of global technological civilization might take less than one millennium, and the new civilization might not be divided into conflicting countries. The island would be the main center of power, leading to a much more stable society with smaller risks of a new global catastrophe resulting from global war—though there also may be other surviving islands that are uncooperative.

However, if there were no such place to support this hopeful outcome, gangs of looters could instead develop cruel empires in a state of constant war, and further catastrophes would occur. The cycle of collapse–development–destruction could repeat, each time with a smaller chance of full and stable recovery, as resource depletion and climate change made each future recovery harder, until the point of total extinction.

# 4. Overview of a few islands as possible refuges

Despite the fact that there may be as many as one million islands in the world, most of them will provide little or no protection. Only a few islands have the necessary conditions described in Section 2.2. Here, a few potential island refuges are described and then compared in Table 1.

## 4.1. The Kerguelen Islands as one of the most suitable archipelagos for long term survival

One of the most attractive islands for long-term survival of global risks is the French archipelago of Kerguelen in the southern Indian Ocean. Kerguelen’s main Grand Terre island has the following attractive features for long-term survival:

It is very remote from any other constant human settlements; for example, is it 3000 km from the island of Reunion. The Kerguelen Islands lie outside the main trade lines, so the probability of a random ship arriving there is low. The islands are inside the circumpolar Antarctic current, and they are surrounded by strong winds (the “Roaring Forties” and “Furious Fifties”), which will not accidentally bring any ships from further north.

A return trip from Reunion to Kerguelen by ship takes 28 days. The islands do not have an airport, so they cannot be reached by air, and they are too remote for helicopter travel. While Easter Island is even more remote from other human settlements, it is more populated and more often accessed by ships and planes.

The intense and isolating wind circulation around the South Pole could increase the time required for ash or radioactive clouds from the northern hemisphere to reach the South polar region. But the Kerguelen Islands are also not too close to the South Pole: they are at the equivalent latitude as southern Germany; thus, they get quite a bit of sunlight.

The Kerguelen Islands have a stable but cold climate, with temperatures above freezing most of the time. The main island has edible vegetation and many edible animals, including 3000 sheep. The island is very large, approximately 7000 km2, and it has many deep gulfs and fjords that could be used as harbors.

The main island has high mountains (over 1000 m) with an ice cap which could provide fresh water. Nearby ice-free mountains hundreds of meters high could provide protection against tsunamis. The highest mountain is volcanic, and was active 100 000 years ago (Weis *et al.*, 1998). However, residual geothermal heat could provide heating and energy for a refuge.

The main island has a continuous population of only about 45 people, who live at a scientific station. Scientists who are selected for long expeditions are more organized and educated than random people, so they may be better prepared for survival. Such a scientific base will not be a military target in case of war. There are several other South Ocean islands similar to Kerguelen, like South Georgia, Auckland Island, and Macquarie Island (Schalansky, 2010).

## 4.2. A “Martian base” on Devon Island

Billionaire Elon Musk has suggested creating a “backup drive” for humanity on Mars, in the form of a self-sustaining settlement there (Devlin, 2017). However, there are places on Earth with very similar conditions to Mars and it may be reasonable to build a model for a Martian refuge first on Earth. These places could serve two purposes: practice for the settlement of Mars, and protection against global catastrophes.

In fact, the beginnings of such a place already exists, at the Martian simulation base on Devon Island in Canada. The cold highland plateau in the middle of Devon Island is very similar to Martian conditions. Because of this it has become home to the *Flashline Mars Arctic Research Station* (FMARS)(FMARS, 2018). FMARS is small, seasonal, and cannot support itself by agriculture, but it is designed for survival in the harsh environment of a polar desert and is equipped with space suits, which could provide protection from certain types of catastrophes.

For Devon Island to become a more robust potential refuge from a global catastrophe it would need to be greatly expanded and developed into a self-sustaining community. This would not be impossible, as the hamlet of Resolute, 165 km southwest, has been in existence since 1947. As a scientific outpost for Mars simulation, Devon Island lends itself to this growth, because the knowledge gained from it will be of great importance to actual Mars exploration and settlement in the future. Importantly, if humanity is not able to build a self-sustaining base on Devon Island, it certainly will not be able to build one on Mars; therefore, it is worth trying.

Devon Island is located on the opposite side of the Earth from Kerguelen, and in a localized catastrophe one of the islands will be less affected. Devon Island provides a different protection profile than Kerguelen. Kerguelen is more suitable for indefinitely long survival after a complex catastrophe like a pandemic and social collapse, while Devon Island may be helpful for surviving a relatively short but intense event.

## 4.3. The case of New Zealand

New Zealand is located on large and remote islands. It has many natural resources and an educated population, which could allow it possibly to independently support a high level of civilization without major technological loss, at the level of at least the mid-20th century (i.e., without an advanced computer industry). This means that the total repopulation of the Earth, if only New Zealand survived, might take only several centuries without loss of knowledge during the new Dark Ages.

New Zealand possesses high mountains (approx. 3700 m) which could remain safe in the case of extreme tsunamis. However, New Zealand had a recent Taupo supervolcano eruption, only 26 000 years ago (Barker *et al.*, 2014), and has continuing volcanic activity that may be dangerous for its inhabitants.

New Zealand lacks strong air defense capabilities and might not be able to prevent the influx of airplanes with refuges, which could bring a dangerous pandemic to the nation. One solution would be to block runways so large planes could not land.

There are several other large and remote islands under New Zealand’s control, including Auckland Island to the south and Chatham Island to the east. Chatham has supported a population for over 1000 years (Department of Conservation, 1999), and so is a proven refuge.

As mentioned above, many “high net-worth individuals” have already sought to establish properties as refuges and shelters in New Zealand, though the efficacy of these “bolt-holes” is debatable (Siler, 2017) and the local population has grown resentful of the idea of foreigners fleeing to their nation.

## 4.4. Comparison of different islands

Based on the criteria listed in Section 2, 15 promising islands which could help humanity survive different types of catastrophes were selected; these islands are described in Table 1.

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| **Island name and control** | **Remote-ness** | **Stability** | **Self-sustain-ing?** | **Population** | **Comments** |
| Kerguelen, France | Very remote, no airport | Stable | Yes | 45 | Very remote and unpopulated, but able to support a human population for a long time; however, leaving the island may be difficult. |
| Spitsbergen, Norway | Airport | Next ice age will destroy all above ground | Yes | Thousands | Old mines are good for indefinitely long-term storage. Coal available as energy source. But the population is large, and the island is too accessible from the mainland. |
| Ellesmere, Canada | Airport | Vulnerable to ice age | Yes | Near 100 | Conditions are so harsh that even Inuit don’t live there constantly. |
| Devon Island, Canada | No airport | Vulnerable to ice age | Potential-ly, with develop-ment | 6, seasonal | Simulation of Martian base |
| Simushir, Russia | No airport | Strongly Volcanic | Yes | Currently unpopulated | Has remains of Soviet submarine base. |
| South Georgia, UK | No airport | Stable | Possibly | Currently unpopulated | Similar to Kerguelen, but smaller and harsher. |
| North Sentinel Island, India | Belligerent uncontacted tribe | Stable | Yes | Unknown, probably less than 100 | Natives attempt to kill all who approach. |
| St. Helena, UK | Airport | Stable | Yes | Thousands | Tropical |
| Easter Island, Chile | Remote, but has airport | Stable | Yes | Thousands | Historically proven capable of sustaining a population of several thousand people for over one thousand years. |
| Wrangel Island, Russia | No airport, accessible by water or ice | Stable | Possibly | Currently unpopulated | Inhospitable climate |
| Pitcairn Islands, UK | Very remote, no airport | Stable | Possibly | Around 50 | Small tropical islands in Pacific. Has sustained a small population for 200 years, previous population went extinct. |
| Caribbean islands  (e.g., St. Kitts) | Major islands have airports | Hurricanes, earthquakes, volcanos | Yes | Tens of thousands | Open to scientific experiments;  underground bunkers could help survival in case of strong hurricanes |
| Guam, US | Airport, military base | Earthquakes, tsunami | Yes | 160 000 | Few birds; large military base able to organize full protection against potential invaders |
| New Zealand | Remote, but many airports | Earthquakes, volcanos, tsunami | Yes | 4 700 000 | A developed country which could organize effective quarantine; it is remote and has some billionaire refuges |
| Japan | Not remote, major industrial nation | Earthquakes, volcanos, tsunami | Yes | 126 000 000 | Japan has been effective in warding off previous epidemics and pandemics. It has a history of and ability to isolate itself from outside threats. |

*Table 1. Different islands and their properties as possible refuges.*

## 4.5. Natural survival on unprepared islands

The law of large numbers and randomness creates the probability that humans may still survive in some unexpected places in the case of a catastrophe despite the lack of any preparation. There have been survivors in head-on mid-air collisions of aircraft, in basements near the hypocenter of the Hiroshima nuclear explosion, and on pieces of wood in the ocean. Unexpected survivals are not uncommon.

There are numerous examples of castaways surviving for long periods of time in isolation. New Zealander Tom Neale chose to live for 16 years on the coral island of Suwarrow in the Cook Islands, which has area of just under 10 km2, and an Inuit woman survived alone on an Arctic island for 2 years (Nati, 2014).

The diversity of different islands provides protection from the diversity of potential catastrophes that may be faced. There are tens of thousands of potentially inhabitable islands in the world and they can be tropical or cold, large or small, populated or unpopulated, mountainous or flat, and so on. In some ways, islands can almost be viewed as like small planets.

# 5. Comparison of different catastrophes and refuges

Island refuges might be helpful only in the case of rather weak catastrophes, and to estimate their usefulness, island refuges were compared with other possible types of refuge. In Figure 1, correlation between different types of shelters (in red) and the size and duration of a catastrophe they could help humans survive. There are two main groups of shelters: one that aims to repopulate (or return to) Earth when conditions improve, and another that assumes that Earth will be rendered permanently uninhabitable. Islands provide protection for long, but weak catastrophes. Submarines and bunkers provide protection for shorter and more intense catastrophes. However, the combination of submarine, island, and underground refuge provide the best protection for all types of catastrophes in which Earth eventually returns to habitability.

While Beckstead (Beckstead, 2015) thought that the gap between survival without refuges and complete overkill catastrophes was too small, and therefore refuges were useless, on the contrary, the quickly decaying tails on the probability distributions of catastrophes increase the chance that catastrophes may be survivable in refuges.

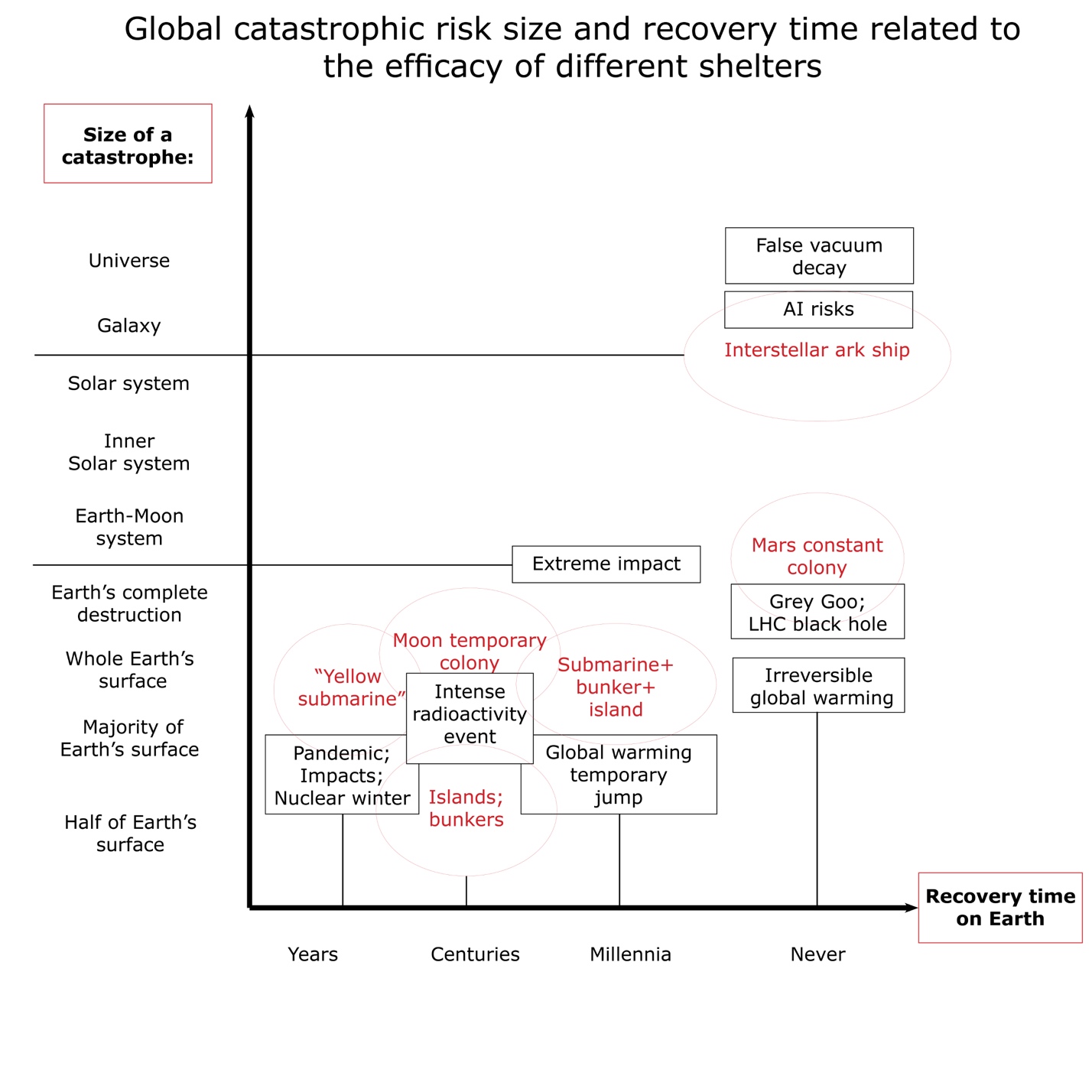


Figure 1. Global catastrophic risk size and recovery time in relation to shelter efficacy. Grey Goo – hypothetical catastrophe because of unlimited replication of nanobots (Freitas, 2000), LHC black hole – hypothetical catastrophe where Large Hadron Collider (LHC) creates small black hole that eats the Earth (Kent, 2004), false vacuum decay is another type of a global catastrophe, which could affect the whole universe (Krauss and Dent, 2008); interstellar ark ship is a way to escape global risks via interstellar space colonization, like project Orion (Dyson, 2002), which, however, will not be able to outrun high speed risks of dangerous AI and false vacuum decay.

# 6. Combining different refuge types to optimize protection on an island

One of the weaker aspects of islands as refuges is their inability to withstand short, intense disasters, such as a nuclear war or bolide impact. The stronger aspect of an island is its ability to provide long-term protection and isolation from weaker but lingering “post-apocalyptic” effects, like a pandemic, radioactive contamination, looters, and lethal autonomous weapons systems run amok.

Given these advantages and disadvantages, it is worth considering how shelter types might be combined in order to maximize their advantages, in ways that increase their overall effectiveness. The simplest solution would be to place a bunker on an island.

## 6.1. Subterranean refuge on an island

The idea of a subterranean refuge on an island appeared in Jules Verne’s 1874 *The Mystery Island*, where the titular island was the hideout for Captain Nemo’s submarine, the Nautilus (Verne, 1875). Thus, as foreshadowed in fiction, contemporary island refuges combined with underground bunkers would provide enhanced survivability. Due to its isolation, a subterranean refuge on an island might provide significantly increased protection compared to a bunker on a continent. Such refuges would be more isolated from looters and thus might be more freely connected with the surface. These connections would allow for improved heat flow, collecting objects on the surface, and easier communication. Underground shelters of this type could also use surrounding waters for heat removal, transportation access, and other purposes.

Such shelters would probably be better protected from biological hazards, as there are fewer such hazards on an island—though migratory birds would still present a possible threat from bird flu. Old mines (which exist on some islands, e.g. Spitsbergen) and caves could be used for the construction of such bunkers. Additionally, abandoned underground submarine docks exists on Simushir Island in the Kuril Islands.

## 6.2. Islands as a base for a submarine

As in Verne’s novel, and at the real-world locations mentioned above, islands can serve as submarine bases. These submarines could stay underwater for months or years and would have a reliable energy source, protection against the intense effects of bolide impacts and other “sharp” catastrophes, as well as providing shelter from strong radioactivity (Turchin and Green, 2017). But the weaker aspect of a submarine is that they cannot stay underwater indefinitely; they eventually need a harbor after a catastrophe. If most of the Earth’s land surface were to be seriously damaged, such a submarine refuge would need a place to start rebuilding civilization, or at least to temporarily resurface for repairs. A base on a remote island would be ideal for both of these needs, and so island refuges are quite complementary with such a submarine project.

## 6.3. Long-term data storage on islands and other similar ideas

Another idea is to use islands for very long-term data storage, perhaps in permafrost to maintain a cryogenic state. The most famous example of this which exists today is the Svalbard Global Seed Vault, the so-called “Doomsday Vault,” (Qvenild, 2008) on the Norwegian island of Spitsbergen. But this vault is designed to provide protection only for seeds, and for only 10 000 years. The Long Now foundation has created disks with text and drawings which could be read by a microscope (Rose, 2008).

There are other places on Earth similar to islands which may provide more protection and require additional study, like forest refuges in the wilderness and taiga, self-sufficient villages in the wilderness, the peaks of high mountains, desert oases, large vessels at sea and seasteads, Antarctic stations, refuges embedded within an ice sheet, refuges in rock under the Antarctic ice, caves and mines, Amish and other social groups, uncontacted tribes, and feral humans.

# Conclusion

Island refuges on their own could help aid the survival of humanity in a specific range of catastrophes. Smaller islands could provide shelter from more severe catastrophes but would require a longer recovery time with a higher probability of failure. Against weaker catastrophes, larger, more populated islands could become centers of civilizational reconstruction. Many isolated island populations already exist, a fact which could make such survival almost free. Alternatively, it could potentially be funded by independent private investors, who could have other goals: egoistic, scientific, or recreational.

Much more significantly, island refuges could help in a greater variety of catastrophes if they were combined with other survival projects: underground bunkers, refuge submarines, and/or civilizational data backup.

Building refuges on islands may combine egoistic and altruistic motives. The construction and promotion of island-refuge projects might also attract interest to the ultimately more important problem of global risk prevention. Thus, such refuges might not only save their inhabitants, but perhaps the world.

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