Yachts and marinas as hotspots of coastal risk

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Abstract

Despite being exceptional concentrations of valuable economic assets, yachts and marinas are typically overlooked in the geography of coastal risk. Focusing on the Mediterranean, which hosts the majority of the world's yacht activity, we examine three decades of yacht-insurance claims in the context of natural hazards and marina development. We find indications that yachts and marinas manifest the same generic relationships between exposure, hazard, and vulnerability observed in terrestrial coastal-risk systems. Given the fundamental importance of yachts and marinas to nautical tourism and strategies for "Blue Economy" growth, particularly in Europe, the role of yachts and marinas in the dynamics of coastal risk must be better understood – but any such insight will first require standardised, comprehensive datasets of yacht movements and marina infrastructure.

Keywords – yachts; marinas; coastal risk; safe-development paradox; Mediterranean; insurance

1. Look to the water

Research into coastal risk tends to stand with its back to the ocean. Risk can be framed as a compound function of hazard, exposure, and vulnerability (Crichton 1999; NRC 2014). Coastal hazards push landward in the form of storm events, sea-level rise, flooding, and chronic erosion. Exposure of physical assets to these hazards is measured by economic valuation of shorefront development and infrastructure. (Exposure of coastal populations can only be measured in human terms.) Vulnerability is a slippery term, but can indicate the integrity of a mitigating buffer between hazard and exposure (Armstrong et al. 2016; Armstrong and Lazarus 2019a, 2019b): engineering works like sea walls or beach nourishment, for example, intended to protect coastal development from environmental forces.

By contrast, few studies of coastal geography stand on the shore and look out to sea (Steinberg 1999; Steinberg 2001). Fewer still face the sea but focus on the foreground, to consider the stands of masts and rigging and cabin superstructures that rise from harbour quays all over the world (Kizielewicz and Lukovic 2013; Lukovic 2013). Marinas, and the yachts within them, constitute hotspots of exposure to coastal hazard – concentrations of high-value economic assets densely packed behind concrete breakwaters. Yet they are notably absent from critical examinations of coastal risk.

Here, we suggest that marinas and yachts reflect the same dynamics of risk that are more typically associated with coastal real estate, and therefore warrant the same kind of analytical scrutiny. Focusing on the Mediterranean Sea, where the majority of the world's yacht activity takes place (European Commission 2016a, 2016b), we explore a dataset of over 19,000 insurance claims filed for yachts in the Mediterranean between 1987–2017. We supplement those data with contextual evidence of coastal hazard in the Mediterranean Sea, along with trends in Mediterranean marinas and global production of superyachts >30 m in length. We offer that marinas and yachts represent an unexplored domain of coastal risk, with vital economic implications for nations – and multi-national regions – that have become dependent on revenue from tourism and service sectors.

2. Marinas are not ports

In academic literature, topics related to commercial ports exist in a mixed-disciplinary space between engineering and business management. A broad swath of research into ports may include or apply indirectly to marinas because both contend with the same issues of basic operation (Nursey-Bray et al. 2013; Asaroitis et al. 2018; de Langen et al. 2018): maintenance of navigational access; efficiency of use; maximum allowable vessel size, and strategies to allow ever larger maxima. Work at the interface of oceanography and coastal engineering applies climate-change scenarios and hydrodynamic modelling to explore the physical impacts of sea-level rise, storm surge, and wave attack on port infrastructure (Casas-Prat and Sierra 2010; Nursey-Bray et al. 2013; Androulidakis et al. 2015; Chhetri et al. 2015; Sierra et al. 2015; Sánchez-Arcilla et al. 2011, 2016; Christodoulou et al. 2019). A deep literature examines environmental impacts of port operations, and efforts to regulate them (Paris-Mora et al., 2005; Davenport and Davenport 2006; Darbra et al., 2009; Petrosillo et al. 2009; Ng and Song, 2010; Di Franco et al. 2011; Gómez et al. 2017).

Relative to ports, marinas and the boats they host receive little formal academic attention. Instead, they sustain a swarm of glossy trade and marketing publications. Where ports host all types of vessels, marinas cater to private pleasure-craft (Piccinno and Zanini 2010; Lukovic 2013). That difference is more than a technicality: if the principal function of a port is shipping or commercial trade (such as a fishing fleet), then the principle function of a marina is hospitality. A marina is a hotel to which guests bring their own suite (Honey, 2018). A less glamourous analogy is a floating RV park. So when marinas do appear in academic analyses, they are the denizens of tourism and leisure studies, in which typical concerns include opportunities for market growth and the benefits of competitive optimisation (Oehmichen and Bourdais 2007; Raviv et al. 2009; Vlasic et al. 2019). Yacht design and construction are scientific processes (Larsson 1990; Lazarus 1999, 2007, 2012; Eliasson et al. 2014) that involve complex hydrodynamic modelling (Milgram 1998; Lombardi et al. 2012; Blount 2014; Dawson 2015), physical experiments in towing tanks (Fossati et al. 2015), and production techniques at the frontier of materials science (Lazarus, 1997, 2015; Bailey et al. 2015; Cucinotta et al. 2017). However, upon completion, yachts as subjects of academic research shift from being showcases of maritime industry to trophies of the marinas they frequent.

Nautical tourism is a nascent academic field that focuses on the marina, charter, and cruise industries (Lukovic 2013), and is a branch of maritime tourism – the "water-based" counterpart to "land-based" field of coastal tourism (Hall 2001; Agarwal 1997, 2002; Jennings 2004; ECORYS, 2013). During the past decade, in Europe, nautical tourism has ridden a wave of interest in the "Blue Economy" as an emerging source of potential economic growth (ECORYS, 2012; European Commission 2016a, 2016b). Between 2006–2011, the gross value added from yachting and marinas increased by approximately 37%, from an estimated €28 billion to €39 billion (ECORYS, 2013). Employment in the sector increased 29% over the same period, from 291,000 to 372,000 jobs – and it is unclear whether these figures even account for the yacht-charter market (ECORYS, 2013). In 2014, "the nautical sector" – including specialised services such as "boat repairs and services, boat and watersports charter/rental, sailing schools, boat dealers/brokers, chandleries, marinas, and financial and other professional services" – posted an estimated annual turnover between €20–28 billion (European Commission, 2016a). Marinas alone may deliver 14–20% (€4 billion) of that turnover (ECORYS 2015). By any measure, marinas are big business – and indivisible from their clientele.

3. Consider the yacht

Not every vessel in a marina is a yacht, but yachts are the symbionts of the marina industry. Although there is no formal definition for what makes a vessel a yacht, most descriptions emphasise that a yacht is for pleasure and recreation (Piccinno and Zanini, 2010), defined more by their culture of use than by technical specifications. Yachts are the economic lifeblood of nautical tourism because of charter hire. The beating heart of the global charter market is in Europe, where the yacht-charter industry posts annual turnover figures of €6 billion (ECORYS 2015).

Yachts 24 m or longer, termed "superyachts", comprise a tiny fraction of the recreational boating fleet – around 0.1% of all recreational boats in Europe (European Commission 2016a) – but marinas compete for their patronage (Gorman 2015; Mathieson 2016; European Commission 2016b). Twenty-four metres is an arbitrary threshold, except that special regulations and "large vessel" safety codes come into effect at that length overall (Lorenzon and Coles 2012; Paolo Moretti 2015). Industry trackers like *Superyacht News* and *Superyacht Times* tend to follow vessels >30 m. In 2019, the global fleet of superyachts >30 m in length was estimated at 5,096 vessels (**Fig. 1a**). Deliveries of completed superyachts >30 m dropped after the 2008 financial crisis but has been stable, if reduced from its pre-crash high, for nearly a decade. The annual "casualty rate" of the global superyacht fleet is low: one trade source counted only 158 superyachts >30 m lost since 1980, a total that includes projects under construction (**Fig. 1a inset**), or loss a rate of ~0.1% of all superyachts per year. Yachts >40 m have accounted for a comparatively larger proportion of yacht deliveries since 2009, including a increasing number of yachts >80 m (**Fig. 1b**). The largest vessels are large enough to skew metrics like mean superyacht length through time (**Fig. 1c**), when median length might more accurately describe the fleet (Jackson 2019).

Nevertheless, as the size and number of superyachts increase (Fig. 1), so does demand for services to accommodate them (European Commission 2016b). In Europe, prospects for economic growth effectively assume that the total number of marinas has saturated but that berths in a marina can be reorganised, at least within the physical constraints of harbour geography (de Swart et al. 2018; European Commission 2016b). The emerging business opportunities are therefore in the upgraded services and amenities that marinas may provide (ECORYS 2015), alongside improved coastal defences to better protect the assets of nautical tourism from climate-driven hazards (de Swart et al. 2018).

4. The breakwater effect

In terrestrial settings, the promise of asset protection is the key driver of a feedback known as the "safe-development paradox" or the "levee effect" (Burby, 2006; Di Baldassarre et al. 2013a, 2013b), such that investment in hazard protection may have the unintended consequence of stimulating further development behind that protection. This dynamic echoes "Jevons' paradox" (Jevons 1865; Alcott 2005; Sorrell 2009; Armstrong et al. 2016), a counterintuitive theory in environmental economics named after the English economist William Stanley Jevons, who argued that more efficient steam engines drove more coal consumption, not less (Jevons 1865). Reframed in terms of coastal risk, investment in "better" protection from coastal hazard may stoke more intensive development of coastal real estate, which in turn will demand further investment in protection (Armstrong et al. 2016).

Here, rather than houses popping up on nourished beachfronts or leveed floodplains (Di Baldassarre et al. 2013a, 2013b; Armstrong et al. 2016; Armstrong & Lazarus 2019a), yachts tie up behind marina breakwaters. Higher-value assets demand bespoke accommodation – super-berths for superyachts – and additional protection. Although hazard intensification like sea-level rise and storminess can drive increased coastal risk, so can a feedback between exposure and vulnerability – even in the absence of any change in hazard (Criss and Shock 2001; Werner and McNamara 2007; Lazarus 2014). If marinas build for the yachts they want rather than the yachts they have (Raviv et al. 2009; ECORYS 2015; Gorman 2015; Mathieson 2016), then the risk feedback between assets and protection, between exposure and vulnerability, ratchets forward.

5. The Mediterranean case

To explore signatures of risk feedbacks in the yachting sector, we look to the Mediterranean. Half of the gross value added and employment totals for the nautical sector spring from the Mediterranean, along with an estimated 40% of the global charter-boat market (European Commission 2016a). In 2011, an industry analysis reported that 60% of the world's superyachts are based in the Mediterranean (European Commission 2016b), with 217 of 401 "high-quality" marinas capable of receiving vessels >24 m long (ECORYS, 2013; European Commission 2016b). In 2017, *Superyacht News* reported that 75% of the global superyacht fleet is in the Mediterranean during the northern-hemisphere summer (and 56% in the winter), creating a seasonal bottleneck in which the number of vessels >30 m cruising the summer Med exceeds the number of available berths in the entire region by ~15% (3,796 superyachts to 3,287 superyacht berths) (Mathieson 2017). Competition for superyacht berths has prompted the suggestion that berth ownership become the new economic model for marinas, with berth subletting as a new investment frontier (Redmayne, 2016). Even the European Commission, in its 2016 assessment of nautical tourism in Europe, notes that "while the number of superyacht berths berths is increasing…, the number of berths in the most popular cruising zones…lag behind demand" (European Commission 2016a). These conditions make superyachts the indicator species of nautical tourism, and the Mediterranean the epicentre of coastal-risk dynamics arising from marinas and yachts.

5.1 Three decades of yacht insurance claims

From Pantaenius Yacht Insurance, Europe's largest insurer of yachts, we obtained a record of over 19,000 yacht insurance claims filed with the company from the Mediterranean between 1987–2017. Each entry shows the date, the amount of the claim, and if the claim is associated with a storm event. Most claims noted the country in which the incident occurred, but spatial locations of claims (**Fig. 2**) are listed separately (divorced from their corresponding records) and not necessarily precise. The entries are otherwise anonymised, with no information about the client or the technical specifications of the yacht.

The most striking trend is the explosive increase in the total number (**Fig. 3a**) and total value of claims (**Fig. 3b**) over time, especially since 2000. Half the total number and half the total value of claims in the Pantaenius records are filed after 2010 (**Fig. 3; Table S1**). However, the relative proportion of storm claims, both in number and associated value, has remained effectively stable in the past 20 years, as has the proportion of "zero claims" – a claim below the policy deductible – related and unrelated to storm events (**Fig. 3; Fig 4a**). Claim counts reflect a pattern of seasonality, with more storm claims filed during the broad months of the Mediterranean winter, and most non-storm claims in the summer peak of July and August (**Fig. 4b**). Apart from growth in the sheer number of claims, the distribution profile of claim values appears to have changed little over time (**Fig. 4c**). This stability is also reflected in median claim value over time (**Fig. 4d**), which has been effectively flat since the 1990s for storms and non-storms alike (**Fig. 4e and 4f**). Mean claim values are more influenced by large outliers (**Fig. 4d–f**), and their time series reflects a subtle drift in the claim values toward distributions with heavier tails at the high end of the range (**Fig. 4c**).

5.2 A hazardous coast

The lack of disproportionality in storm-related claims over the past three decades is an intriguing result in the context of coastal risk. The Mediterranean is not exempt from coastal hazard.

"Medicanes" – a contraction of "Mediterranean hurricanes" – are intense cyclonic windstorms that for all meteorological intents and purposes look and behave like tropical cyclones (Romero and Emanuel 2013; Caviccia et al. 2014a). Modelling suggests that under future climate change medicanes may occur less frequently, but the number of violent storms may increase (Romero and Emanuel 2013; Cavicchia et al. 2014b) along with the magnitudes of storm surges in select Mediterranean subregions (Androulidakis et al. 2015). Analysis of the incident wave climate for the Catalan coast of Spain suggests a trend toward more storm waves from the south – problematic because most Catalan harbour entrances, by design, are open to the southwest to provide shelter from prevailing storms out of the northeast and east (Casas-Prat and Sierra 2010). Modelling of climate-driven changes in wave agitation for harbours along the northwestern Mediterranean suggests that future agitation may increase during the summer months, when harbours are busiest (Sierra et al. 2015). Even if storm intensity were to remain constant into the future, onshore impacts of Mediterranean storms, medicanes and otherwise, will likely increase regardless as a result of regional sea-level rise (Sánchez-Arcilla et al. 2011, 2016).

If wave agitation is one issue – a heaving marina is a dangerous marina – then breakwater and seawall integrity is another. The Ligurian coast of northeastern Italy is in one of the Mediterranean zones of "extreme wind tracks" (Nissen et al. 2010). During a "superstorm" in October, 2014, the Ligurian port town of Rapallo saw its breakwater collapse, releasing a surge of water and heavy waves into the harbour that swamped half of the approximately 400 vessels in the Carlo Riva Marina (McCabe 2018; Overton 2018; Superyacht Investor 2018). A representative of Pantaenius interviewed after the event estimated that damage to superyachts in the marina might top €75 million (Superyacht Investor 2018). Moreover, the breakwater at Rapallo had collapsed before, in November, 2000, when a "freak wave" wreaked similar havoc (Overton 2018; Superyacht Investor 2018). The marina had responded by raising the top of the new breakwater by 1.3 m, bringing the rebuilt height to 6.5 m – "But not enough with this exceptional event," the marina director said after the recurrence (Overton 2018).

In the Pantaenius data, five countries – Italy, Spain, France, Croatia, and Greece, respectively – account for 91% of the total number of yacht insurance claims and 92% of their total value (**Fig. 5a**). But there is no indication that any one Mediterranean country in the top ten, by volume of associated claims, accounts for an outsized number of storm claims relative to non-storm claims (**Fig. 5b**). For example, Italy is associated with more claims (27%) than any other country in the dataset, but shows a proportional number of storm (27%) and non-storm claims (26%) relative to the Mediterranean totals. If any subregional patterns of storm impacts are taking shape across the Mediterranean, they are not evident in these three decades of insurance claims.

5.3 Exposure is driving risk

We might have expected that insurance claims would be, if anything, an oversensitive metric of storminess. Industry coverage remarked on the superyacht insurance market "operating at an unsustainable loss ratio" for much of the past decade – that is, yacht insurance was relatively inexpensive – such that in 2018, insiders were anticipating a market-wide rate hike (Jackson 2018. The ballooning of yacht insurance claims since 2000 (**Fig. 3**) is probably the emergent result of a number of drivers. Some maritime lawyers perceive that the yacht world has become more litigious over time, with a pile-up of claims over paint work and chartering mishaps (McCabe 2014). The trend in claims might therefore reflect a change in yacht-ownership culture – and the legal intermediaries that serve it – as much as any change in yacht-market volume. But the absence of a clear storm signal still suggests that the "exposure" component of this maritime-risk system has rapidly outstripped any changes in natural hazard.

The quest for customer satisfaction may exert more influence on marina adaptation than the spectre of severe climate-driven hazards. Surveys of marina operators suggest that addressing direct, "tangible" forces like visitor numbers tend to outweigh comparatively indirect forces like climate change (Raviv et al., 2009; European Commission 2016b). The UK and Australia offer guidance on maritime industry adaptation to climate change (McEvoy et al. 2013; MCCIP 2014), but a recent report on infrastructure in European ports conveys adaptation to climate change as an afterthought behind drivers of more immediate investment related to trade volume and fleet accommodation (de Langen et al. 2018). When adaptation actions are mentioned, traditional "hard engineering" solutions, like breakwaters, predominate (Asaroitis et al. 2018) over "soft" or "green" adaptations, such as cultivated seagrass meadows to dissipate wave energy (Sierra et al 2017). An international survey of port authorities in 2009 (Becker et al. 2012) found that fewer than 10% of respondents had specific climate-change planning in place, ~10% had climate adaptation funded as budget line-item, and ~15% had climate change addressed in the port strategic plan. Most of the ports used a design standard of a 100-year flood event. Regarding expansion and improvement projects for the coming decade, 19% of respondents reported that they were building new storm protections – and 78% reported plans for the construction of new quays or berths.

Unfortunately, the marina sector has a data problem. The summative "Assessment of the impact on business development improvements around nautical tourism" for the European Commission laments a lack of "comprehensive information relating to the size, type and capacities of the marina industry in Europe; assessments of the direct and indirect economic impacts of marinas and boating activities across the EU; data showing the frequency of boating participation and the movements of boaters between marinas and between Member States" (European Commission 2016a). National statistics aside, even for commercial purposes like pre-booking berths for cruising yachts "there is still no comprehensive database of yacht harbours, marinas, or yacht clubs" (Siches, 2016). Try to determine, as we did for this analysis, how many marinas there are in the Mediterranean, and the numbers are wildly scattershot. Estimates quoted in European Commission reports (European Commission 2016a, 2016b) and in the thin academic literature that exists on nautical tourism (Lukovic 2013) come from searching listings by country in the website *portbooker.com*. The International Council of Marine Industry Associations (ICOMIA) publishes an annual "global data summary" stats-book and has a "Marinas Group", but categories and responses by country vary from year to year.

The only apparently consistent, multi-annual record of marinas and berths that we found comes from Spain (FEAPDT 2016), which shows a 41% jump in the number of Mediterranean marinas and a 23% increase in the number of berths between 2003–2014/15 (**Fig. 6a**). The number and value of claims registered in Spain in the Pantaenius database climbed steeply over the same period (**Fig. 6b**). To the extent that we might use Spain as an index for the rest of the Mediterranean, plotting claims in Spain as an function of annual berth density (**Fig. 6c**) – the number of berths divided by the number of marinas – suggests that growth in claim numbers slows with corrections toward lower berth density. We might hypothesise that berth density might saturate or increase again in the future as the number of Spanish marinas reaches a geographic maximum (de Swart et al. 2018; European Commission 2016b). But if the size of the Mediterranean yacht fleet continues to grow, claims registered in Spain may increase more dramatically still. While an apparent relationship between insurance claims and berth density does not prove unequivocally a feedback between yacht exposure and marina protection, it indicates a vital link – which more specific information at the marina scale (berths, occupancy rates, attributable claims) can only clarify.

6. Before the pandemic, and after

Our analysis reflects a pre-pandemic past. None of the economic forecasts for European "blue growth" consider the ramifications of a world in lockdown – a grand mal seizure in global tourism. How the direct and indirect economic shock of the COVID-19 pandemic will affect the multiple, nested industries of nautical tourism – from vessel production to marina services – is as unknown as the impact of the virus on every other globalised market. That said, we can safely assume the damage will be disproportionate. The dishwashers at luxury marinas will be harder hit than the diners. In 2008, the global financial crisis upended superyacht production (**Fig. 1a**); what this new global crisis will force onto production trends remains to be seen. In stark contrast to their emerging-tech clientele, marinas are notoriously slow innovators. In a 2016 assessment of the European marina sector, access to wireless internet was still listed as a leading issue (European Commission 2016b). If climate-change-proofing marina infrastructure was already a low priority, then triaging a mid-pandemic business model has made it even lower.

In a cancelled tourist season, berths of empty yachts start to resemble rows of abandoned buildings. No one is living aboard. Apart from someone who might come once a day, if that frequently, to check that the bilge pump is working, the crews are gone. If the yacht is a charter vessel, the owner is a company. For insurers, the nail-biting concern is fire. Most superyacht losses are the result of fires (Wood 2019). And while the possibility of a marina fire is worrisome, a blaze at a shipyard is worse. In September 2018, when a fire struck the Lürssen shipyard in Bremen, Germany, yacht insurers braced for an expected loss of €600 million, attributed to a 140 m project that was nearly finished (Blazeby 2018; Jackson 2018). Superyacht owners may use the empty time of the pandemic to send in their vessels for repair and refitting, but only a handful of shipyards are equipped to handle the largest superyachts. According to one marine insurance director, present circumstances make it more likely that multiple super-large superyachts will be in the same shipyard at the same time: "If you take the top ten largest superyachts in the world, it is possible for at least five or six of them to be in one of these yards at any single time. Those six boats alone could have an aggregate value of two to three billion, plus other boats in the yard, in the event of a fire" (Jackson 2020).

This scenario, in particular, illustrates how yachts – and where they reside – can represent an especially concentrated form of asset exposure in the context of coastal risk. The scenario also illustrates the scale of wealth disparity that superyachts embody. In September, 2019, Hurricane Dorian razed the Bahamas as a Category 5 storm, leaving behind an estimated USD$3.4 billion in damages. In a strictly by-the-numbers tally, the money parked in a handful of super-superyachts is the direct financial cost of a Caribbean hurricane.

Yachts and marinas will survive the COVID-19 pandemic – which means they will still be woven into the complicated fabric of coastal risk, as they have been for decades, even if research into coastal risk has not accounted for them. And given the magnitude of economic exposure they represent, yachts and marinas should be accounted for more deliberately. Much the way mobile phone data can reveal the mass movements of people in disaster-prone settings (Deville et al. 2014; Wilson et al. 2016), perhaps a new generation of vessel transponders will track the movements of pleasure craft and reveal spatio-temporal patterns of exposure to marine hazard events. Much as remote-sensing efforts are underway to map every building on the planet (George 2019), comparable mapping must be within reach for the world's marinas and an estimate of their berth capacities, in concert with standardised census-taking. Documenting changes in the spatial footprints of yachts and marinas over time would contribute to a growing body of research into the phenomenon of marine sprawl (Duarte et al. 2012; Dafforn et al. 2015; Firth et al. 2016; Bishop et al. 2017; Lazarus 2017). If maps of commercial shipping routes and industrial-scale fishing activity are providing a novel perspective of the global ocean, both modern and historical (Burn-Murdoch 2012; Shipmap 2016; Kroodsma et al. 2018), then yachting itineraries must likewise describe an overlapping but distinctive geographic space, a gilded network that contracts and expands, surges and slows by season – and grows and densifies by the year.

For all that yachts and marinas remain a largely uncharted part of marine geography (Steinberg 1999; Smith 2000), their co-dependence may drive the same systemic dynamics of risk that pertain to subdivisions on leveed floodplains or duplexes on nourished beaches (Stevens et al.

2009; Armstrong et al. 2016; Armstrong and Lazarus 2019a). Fundamentally, these settings spur the same paradoxical feedback (Burby 2006; Werner and McNamara 2007): a physical asset of significant economic value demands protection from environmental hazard; investment in engineered defences fosters a sense of safety rather than precariousness; that projection of safety indirectly attracts and encourages more – and more valuable – physical assets, which in turn demand a greater level of protection. Future stimulus plans for blue growth and the nautical-tourism sector need to consider how those same strategies may serve to intensify coastal risk, with potentially disastrous economic consequences.

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Figures & Captions

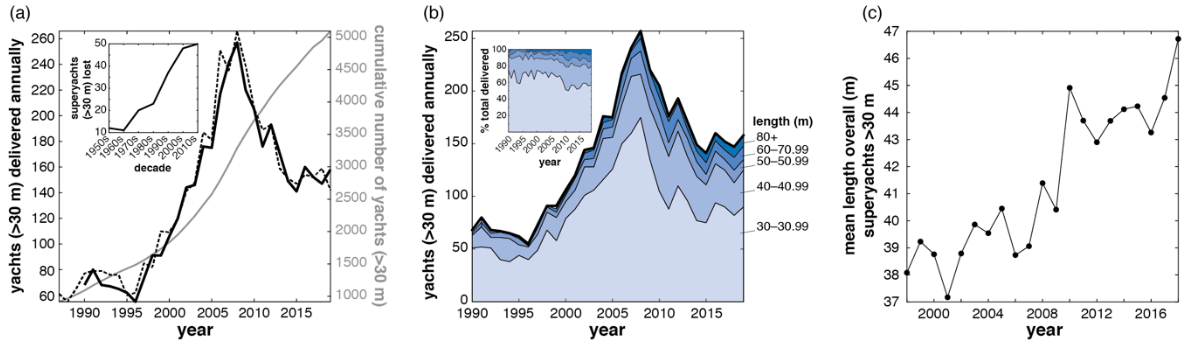

Figure 1. Trends in global superyacht production (for vessels >30 m in length overall). *(a)* Annual time series (left axis) of all superyachts delivered since 1987, according to independent counts by *Superyacht Times* (black line) and *SuperyachtNews* (dashed line). Grey line (right axis) shows estimated total size of superyacht fleet over time, as a cumulative sum of the *Superyacht Times* annual data. Losses to the superyacht fleet over this period (inset; data from Wood 2019) have been minimal – only 158 vessels since 1980, including projects under construction. *(b)* From the *Superyacht Times* dataset, a breakdown of annual deliveries by vessel length overall. Inset shows relative proportions of the different length categories over time. Since 2008, fewer superyachts have been delivered but a greater proportion have been 40–50 m and >80 m in length. *(c)* This shift toward larger yachts is reflected in a time series of mean superyacht length overall (data from Jackson 2019). Although the majority of superyachts are 30–40 m, the annual mean length overall of the superyacht fleet gets pulled up by a small number of especially large vessels. For data, see **Tables S1 and S2**.

Figure 2. Map of Mediterranean Sea region showing locations of yacht insurance claims filed with Pantaenius Yacht Insurance between 1987–2017, for damages related (red dots) and unrelated (open circles) to storm events.

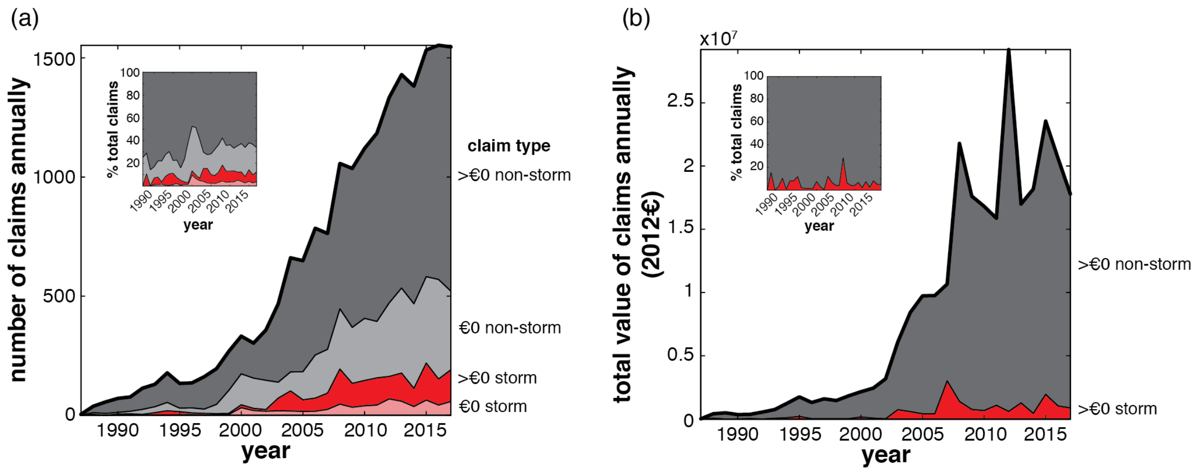

Figure 3. Data from over 19,000 yacht insurance claims in the Mediterranean between 1987–2017, filed with Pantaenius Yacht Insurance. *(a)* Annual number of claims, differentiated by four types: zero-value claims related to storm events (pink); storm-related claims valued >€0(red); zero-value claims unrelated to storm events (light gray); and claims unrelated to storm events valued >€0 (dark gray). Black line tracks total number of claims per year. Inset shows relative proportion of each type of claim over time. *(b)* Annual total value of claims related (red) and unrelated (dark gray) to storm events. All claim values in our analysis are adjusted to 2012€. Black line tracks total value of claims per year. Inset shows relative proportion of storm-related and non-storm-related claim values over time. Although the number and value of storm-related claims has increased in the past two decades, the number and value of storm-related claims has not increased disproportionately relative to claims unrelated to storm events. For data, see **Tables S3 and S4**.

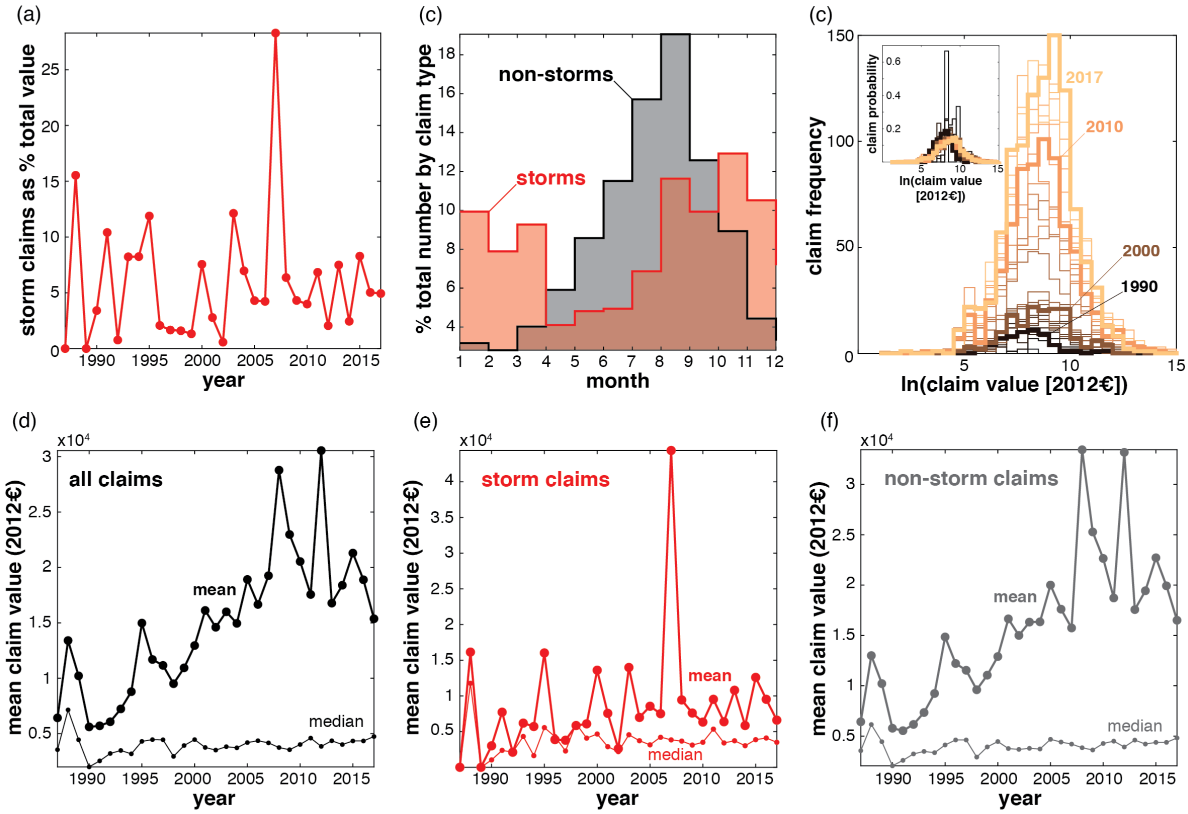

Figure 4. Statistical characteristics of the claims time series. *(a)* Value of storm-related claims as a percentage of total claim value annually (from Fig. 3b inset). The spike in 2007 comes from a single claim for nearly €1.7 million. The relative stationarity of the time series suggests no disproportionate increase in storm damage in the Mediterranean in the past three decades. *(b)* Claim types (related and unrelated to storms) by month of occurrence, as a percentage of the total number of claims in the dataset. More storm-related claims occur during the Mediterranean winter months. *(c)* Distribution of all claim values per year, with claim value plotted on a log-scale. Gradient in line colour from dark to light tracks with time; decadal years are denoted in bold. Dominant pattern is the growth in number of claims, with a more subtle shift toward higher mean values. Normalising by the total number of claims each year (inset) shows relatively little change in the distribution shape over three decades. *(d)* Although mean claim value has increased over time, median claim value has not, illustrating the sensitivity of the mean to a small number of especially high-value claims. *(e)* With the exception of 2007, neither the mean nor median value of storm-related claims has increased notably since the 1990s. *(f)* The upward drift in mean claim value overall (panel *d*) appears to be driven by claims unrelated to storm events. Median claim value for non-storm claims has remained effectively constant for 20 years. For data, see **Table S5 and S6**.

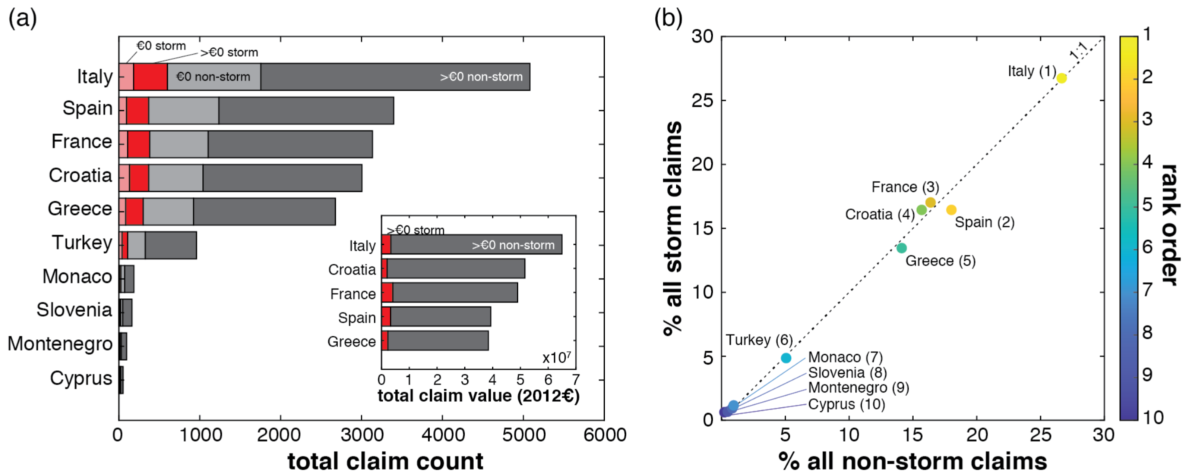

Figure 5. Insights from Mediterranean subregions. *(a)* Five countries – Italy, Spain, France, Croatia, and Greece – account for 91% of the total number of yacht insurance claims in the Pantaenius dataset and 92% of their total value (inset). *(b)* Plotting for each country its proportions of storm-related claims (relative to the total number of storm-related claims in the dataset overall) versus non-storm-related claims (relative to the total number of non-storm-related claims in the dataset overall) shows that no single country accounts for a disproportionate number of storm-related claims in the Mediterranean. For data, see **Table S7 and S8**.

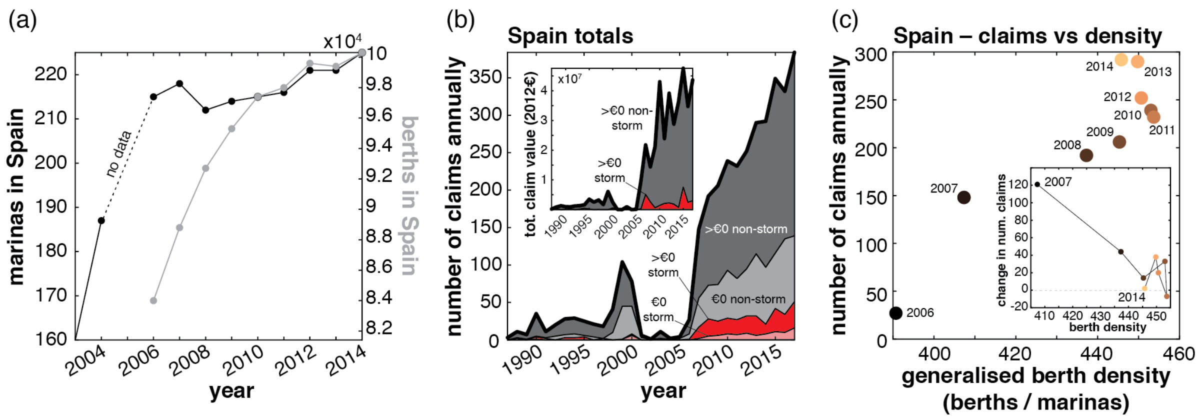

Figure 6. Insights from Spain. *(a)* Growth in the number of marinas (left axis) and berths (right axis) in Spain since 2003 (data from FEAPDT 2016). *(b)* Total number and value of claims per year from Spain in the Pantaenius dataset, showing explosive growth since 2005. *(c)* Number of claims versus generalised berth density per year (from panel *c*, total number of berths divided by total number of marinas per year) in Spain since 2006. Gradient in dot colour from dark to light tracks with year (labelled). Claim growth appears to slow following adjustments toward lower berth density (inset). For data, see **Table S9 and S10**.

Supplementary Information for:

Yachts and marinas as hotspots of coastal risk

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Table S1. Superyachts (≥30 m) completed annually, by length overall. (Data courtesy of *Superyacht Times.*) Corresponds to **Fig. 1** in main article.

year	30 < 40 m	% total	40 < 50 m	% total	50 < 60 m	% total	60 < 70 m	% total	≥ 80 m	% total	annual total	annual total[a]	mu LOA (m)[b]
1987	-		-		-		-		-		-	61	-
1988	-		-		-		-		-		-	55	-
1989	-		-		-		-		-		-	65	-
1990	51	75.0	12	17.6	0	0.0	2	2.9	3	4.4	68	77	-
1991	52	65.0	19	23.8	4	5.0	5	6.3	0	0.0	80	79	-
1992	51	75.0	10	14.7	4	5.9	3	4.4	0	0.0	68	79	-
1993	40	59.7	21	31.3	5	7.5	1	1.5	0	0.0	67	76	-
1994	38	58.5	22	33.8	4	6.2	1	1.5	0	0.0	65	76	-
1995	44	71.0	10	16.1	6	9.7	2	3.2	0	0.0	62	60	-
1996	40	72.7	12	21.8	1	1.8	2	3.6	0	0.0	55	62	-
1997	49	67.1	15	20.5	6	8.2	0	0.0	3	4.1	73	85	-
1998	68	74.7	17	18.7	5	5.5	1	1.1	0	0.0	91	82	38.08
1999	58	63.7	22	24.2	5	5.5	3	3.3	3	3.3	91	110	39.23
2000	79	74.5	16	15.1	6	5.7	2	1.9	3	2.8	106	109	38.76
2001	88	73.3	18	15.0	11	9.2	2	1.7	1	0.8	120	120	37.17
2002	101	70.1	27	18.8	7	4.9	6	4.2	3	2.1	144	141	38.79
2003	106	72.6	22	15.1	8	5.5	8	5.5	2	1.4	146	148	39.86
2004	116	65.9	39	22.2	9	5.1	6	3.4	6	3.4	176	187	39.54
2005	126	72.0	30	17.1	10	5.7	7	4.0	2	1.1	175	181	40.45
2006	150	69.1	37	17.1	12	5.5	15	6.9	3	1.4	217	251	38.73
2007	160	66.4	54	22.4	17	7.1	7	2.9	3	1.2	241	235	39.06
2008	175	68.1	41	16.0	22	8.6	12	4.7	7	2.7	257	266	41.39
2009	135	61.4	49	22.3	20	9.1	14	6.4	2	0.9	220	239	40.41
2010	105	51.2	57	27.8	18	8.8	14	6.8	11	5.4	205	206	44.91
2011	88	50.0	50	28.4	13	7.4	20	11.4	5	2.8	176	189	43.7
2012	110	57.0	52	26.9	11	5.7	16	8.3	4	2.1	193	193	42.9
2013	96	56.1	42	24.6	17	9.9	9	5.3	7	4.1	171	159	43.69
2014	77	51.7	42	28.2	14	9.4	10	6.7	6	4.0	149	151	44.12
2015	75	53.2	36	25.5	10	7.1	11	7.8	9	6.4	141	147	44.23
2016	94	58.8	37	23.1	12	7.5	10	6.3	7	4.4	160	154	43.26
2017	90	59.2	35	23.0	10	6.6	9	5.9	8	5.3	152	152	44.54
2018	82	55.8	31	21.1	12	8.2	12	8.2	10	6.8	147	159	46.72
2019	90	57.0	35	22.2	10	6.3	13	8.2	10	6.3	158	142	-

[a]Data from *SuperyachtNews* (superyachts database: https://www.superyachtnews.com/intel/).
[b]From *SuperyachtNews* (Jackson, 2019).

Table S2. Losses to the global superyacht fleet (> 30 m) per decade, via *Superyacht Times* (Wood, 2019). Totals include vessels under construction but not yet delivered. Corresponds to **Fig. 1b inset**, in main article.

decade	losses
1950s	12
1960s	11
1970s	20
1980s	23
1990s	37
2000s	48
2010s	50

Table S3. Annual total numbers of yacht insurance claims in the Mediterranean (via Pantaenius). Corresponds to **Fig. 3a** in main article.

year	storm: zero value	% total	storm: >0 val	% total	non-storm: zero value	% total	non-storm: >0 value	% total	annual total	cumulative total
1987	0	0.0	0	0.0	1	25.0	3	75.0	4	4
1988	0	0.0	4	10.5	7	18.4	27	71.1	38	42
1989	0	0.0	0	0.0	8	14.3	48	85.7	56	98
1990	1	1.4	4	5.6	7	9.9	59	83.1	71	169
1991	1	1.3	5	6.5	11	14.3	60	77.9	77	246
1992	2	1.8	2	1.8	21	18.4	89	78.1	114	360
1993	1	0.8	10	7.7	25	19.2	94	72.3	130	490
1994	1	0.6	18	10.1	35	19.7	124	69.7	178	668
1995	2	1.5	13	9.7	15	11.2	104	77.6	134	802
1996	3	2.2	7	5.1	21	15.4	105	77.2	136	938
1997	1	0.6	7	4.3	18	11.1	136	84.0	162	1100
1998	3	1.5	4	2.0	39	19.9	150	76.5	196	1296
1999	4	1.5	4	1.5	97	36.1	164	61.0	269	1565
2000	32	9.6	12	3.6	130	39.2	158	47.6	332	1897
2001	20	6.6	9	3.0	127	41.9	147	48.5	303	2200
2002	17	4.7	7	2.0	123	34.4	211	58.9	358	2558
2003	19	4.1	53	11.3	67	14.3	329	70.3	468	3026
2004	18	2.7	84	12.7	80	12.1	479	72.5	661	3687
2005	16	2.5	49	7.6	118	18.2	466	71.8	649	4336
2006	17	2.2	55	7.0	181	23.1	532	67.8	785	5121
2007	25	3.3	68	8.9	184	24.1	486	63.7	763	5884
2008	47	4.4	147	13.9	253	23.9	610	57.7	1057	6941
2009	34	3.3	100	9.7	235	22.7	667	64.4	1036	7977
2010	40	3.6	106	9.5	261	23.3	713	63.7	1120	9097
2011	43	3.6	114	9.6	237	20.0	790	66.7	1184	10281
2012	69	5.2	94	7.0	309	23.2	862	64.6	1334	11615
2013	59	4.1	118	8.3	357	25.0	896	62.7	1430	13045
2014	37	2.7	76	5.5	355	25.7	913	66.1	1381	14426
2015	64	4.2	155	10.1	363	23.7	951	62.0	1533	15959
2016	43	2.8	109	7.0	418	26.9	983	63.3	1553	17512
2017	58	3.8	133	8.6	330	21.3	1025	66.3	1546	19058

Table S4. Annual total values (in 2012€) of yacht insurance claims in the Mediterranean (via Pantaenius). Corresponds to **Fig. 3b** in main article.

year	storm: >0 value	% total	non-storm: >0 value	% total	annual total	cumulative total
1987	0	0.0	19268	100.0	19268	19268
1988	64543	15.5	350952	84.5	415495	434763
1989	0	0.0	490240	100.0	490240	925003
1990	12038	3.4	341071	96.6	353109	1278112
1991	38591	10.4	332229	89.6	370820	1648932
1992	4226	0.8	548160	99.2	552386	2201318
1993	61864	8.2	690099	91.8	751963	2953281
1994	102832	8.2	1144853	91.8	1247685	4200966
1995	208266	11.9	1544113	88.1	1752379	5953345
1996	27145	2.1	1282126	97.9	1309271	7262616
1997	26519	1.7	1569137	98.3	1595656	8858272
1998	23399	1.6	1440417	98.4	1463816	10322088
1999	24336	1.3	1812784	98.7	1837120	12159208
2000	163173	7.6	1996645	92.4	2159818	14319026
2001	68025	2.8	2377537	97.2	2445562	16764588
2002	18272	0.6	3164727	99.4	3182999	19947587
2003	741045	12.1	5370435	87.9	6111480	26059067
2004	586641	7.0	7831611	93.0	8418252	34477319
2005	418971	4.3	9321972	95.7	9740943	44218262
2006	412928	4.2	9349356	95.8	9762284	53980546
2007	3017770	28.3	7650551	71.7	10668321	64648867
2008	1387261	6.4	20400488	93.6	21787749	86436616
2009	760021	4.3	16860287	95.7	17620308	104056924
2010	671126	4.0	16147768	96.0	16818894	120875818
2011	1085278	6.8	14789924	93.2	15875202	136751020
2012	599514	2.1	28607229	97.9	29206743	165957763
2013	1273528	7.5	15721670	92.5	16995198	182952961
2014	444814	2.4	17745981	97.6	18190795	201143756
2015	1951523	8.3	21600234	91.7	23551757	224695513
2016	1038113	5.0	19586870	95.0	20624983	245320496
2017	878570	4.9	16918653	95.1	17797223	263117719

Table S5. Annual mean and median values (in 2012€) of yacht insurance claims in the Mediterranean (via Pantaenius). Corresponds to **Fig. 4** in main article.

year	all claims: mean	all claims: median	storm: mean	storm: median	non-storm: mean	non-storm: median
1987	6423	3548	0	0	6423	3548
1988	13403	7142	16136	11768	12998	6148
1989	10213	4444	0	0	10213	4444
1990	5605	1995	3010	1033.5	5781	2045
1991	5705	2538	7718	2372	5537	2591
1992	6070	3205	2113	2113	6159	3229
1993	7230	3478	6186	4319.5	7341	3478
1994	8787	3174	5713	1632.5	9233	3353
1995	14978	4300	16020	5559	14847	4119
1996	11690	4457	3878	4297	12211	4617
1997	11158	4444	3788	2284	11538	4616
1998	9505	2943	5850	6119.5	9603	2915
1999	10935	3925	6084	4084.5	11054	3925
2000	12951	4459	13598	4660.5	12901	4459
2001	16118	3750	7558	2886	16645	3764
2002	14601	3512	2610	2188	14999	3680
2003	15999	3819	13982	4557	16324	3786
2004	14952	3717	6984	3722	16350	3717
2005	18914	4191	8550	3146	20004	4680
2006	16659	4358	7508	4236	17607	4409
2007	19257	4164	44379	3839	15742	4206
2008	28782	3741	9437	3672	33443	3844
2009	22973	3546	7600	3112.5	25278	3620
2010	20536	4016	6331	3500.5	22648	4266
2011	17561	4595	9520	5346.5	18721	4498
2012	30551	3847	6378	3410.5	33187	3917
2013	16777	4353	10793	3716.5	17566	4602
2014	18393	4012	5853	3021.5	19437	4209
2015	21295	4337	12590	3870	22713	4376
2016	18887	4338	9524	4102	19926	4378
2017	15369	4736	6606	3500	16506	4811

Table S6. Claim totals by month (1987–2017) for storm and non-storm claims (via Pantaenius). Corresponds to **Fig. 4b** in main article.

month	storm	% all storm	non-storm	% all non-storm
Jan	223	9.9	534	3.2
Feb	177	7.9	472	2.8
Mar	208	9.3	676	4.0
Apr	92	4.1	994	5.9
May	108	4.8	1441	8.6
Jun	111	4.9	1936	11.5
Jul	154	6.9	2641	15.7
Aug	261	11.6	3204	19.1
Sep	223	9.9	2114	12.6
Oct	290	12.9	1501	8.9
Nov	236	10.5	746	4.4
Dec	161	7.2	555	3.3

Table S7. Claim totals (1987–2017) for the top ten claim-related countries in the Mediterranean (via Pantaenius). Corresponds to **Fig. 5** in main article.

Country	storm: zero value	storm: >0 value	non-storm: zero value	non-storm: >0 value	total claims	% all storm	% all non-storm
Italy	182	418	1156	3326	5082	26.7	26.7
Spain	96	273	868	2161	3398	16.4	18.0
France	108	274	723	2031	3136	17.0	16.4
Croatia	132	237	672	1965	3006	16.4	15.7
Greece	85	217	622	1752	2676	13.5	14.1
Turkey	41	68	218	633	960	4.9	5.1
Monaco	10	16	46	114	186	1.2	1.0
Slovenia	6	15	27	114	162	0.9	0.8
Montenegro	5	10	17	64	96	0.7	0.5
Cyprus	2	12	9	29	52	0.6	0.2

Table S8. Total claim values (1987–2017) for the top five claim-related countries in the Mediterranean (via Pantaenius). Corresponds to **Fig. 5a inset** in main article.

	storm: >0 value	non-storm: >0 value	total value
Italy	3382327	61575803	64958130
Croatia	2051840	49545460	51597300
France	4067017	44941619	49008636
Spain	3248135	36083376	39331511
Greece	2279361	36167655	38447016

Table S9. Total numbers of marinas and berths in Spain, 2003–2014 (FEAPDT 2016). Corresponds to **Fig. 6** in main text.

year	marinas	berths
2003	160	81415
2004	187	-
2005	-	-
2006	215	84000
2007	218	88800
2008	212	92700
2009	214	95300
2010	215	97400
2011	216	98000
2012	221	99600
2013	221	99400
2014	225	100300

Table S10. Claim totals for Spain-based claims (via Panaenius). Corresponds to **Fig. 6** in main article.

year	storm: zero value	storm: >0 value	non-storm: zero value	non-storm: >0 value	annual total
1987	0	0	0	3	3
1988	0	2	1	8	11
1989	0	0	1	6	7
1990	1	3	1	30	35
1991	0	2	1	8	11
1992	0	0	5	15	20
1993	0	3	4	21	28
1994	0	3	5	21	29
1995	0	4	2	19	25
1996	0	0	4	17	21
1997	0	2	0	16	18
1998	0	0	10	31	41
1999	1	0	44	59	104
2000	6	2	37	33	78
2001	0	0	3	3	6
2002	0	0	1	0	1
2003	0	1	1	9	11
2004	0	0	1	1	2
2005	0	0	2	2	4
2006	0	1	7	19	27
2007	2	15	39	92	148
2008	5	23	45	119	192
2009	6	19	49	132	206
2010	8	21	64	146	239
2011	7	20	55	150	232
2012	9	23	63	157	252
2013	6	26	83	175	290
2014	8	13	76	195	292
2015	11	31	74	233	349
2016	10	24	101	197	332
2017	16	35	88	245	384