Employing GIS data for sustainable tourism: A review of the environmental impacts of marine tourism and how GIS data can be used to make marine tourism more sustainable in California

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Tourism is known as one of the biggest and fastest growing economic sectors in the world. Although it provides many job opportunities, there are negative consequences when tourism is not properly managed such as overtourism and degradation of the destination's natural resources. This study provides an overview of how marine tourism impacts the marine environment and a case study on how GIS-data can be employed to reduce these impacts in California. Impacts of tourism on the marine environment were divided in 4 different categories: coastal development, physical damage, impact from water-based activities and wildlife interactions. All 4 categories were found to have negative impacts on the local biodiversity and ecosystem stability. GIS-data was obtained containing the following delimitations for the coastal areas of California: coral reefs, Marine Protected Areas, critical habitats, areas with anchoring restrictions, Biological Important Areas, Important Bird Areas, areas with fishing restrictions, no discharge zones, seabed types, and areas with shipping restrictions. The proposed implementations include the creation of a vulnerability index, the creation of snorkelling trails in combination with artificial reefs and the most promising approach is found to be using GIS-data for on board education.

Keywords: GIS, marine tourism, endangered species, California

Introduction

Tourism is one of the biggest and the fastest growing economic sectors in the world (WTTC, 2019). Due to a continuous rise in the number of middle-class households and in global consumer spending, the sector was able to reach a growth of 3.9% in 2018, outpacing the global economy for 8 years straight. More specifically, 1 in every 5 new jobs created over the last 5 years originates from the tourism industry. In 2018, the sector accounted for 10.4% of the global GDP (Gross Domestic Product) and 10% of total employment (WTTC, 2019). A report by the World Tourism Organization shows that the number of international tourists has continued to grow by 3-5% a year. If this growth continues, this means that by 2030 there are expected to be 1.8 billion tourists globally (UNWTO, 2018).

Although tourism provides many job opportunities, there are negative consequences that can be attributed to this fast growing pace. When not properly managed, an increasing influx of tourists can lead to overtourism and mismanaged tourism destinations. Overtourism can be defined as “the maximum number of people that may visit a tourist destination at the same time, without causing destruction to the physical, economic and sociocultural environment and an unacceptable decrease in the quality of visitors’ satisfaction” (UNWTO et al., 2018). As more and more destinations are struggling with overtourism, the word even became one of Oxford Dictionary’s “Words of the Year” in 2018.

The island of Boracay provides a good example of what badly monitored tourism can do to a destination. Boracay, one of the islands at the north-western tip of Aklan Province in the Malay municipality in the Philippines, had to close as a result of mismanaged tourism practices. Tourism in Boracay started growing in the late 20th century and increased almost 25 times between 1995 and 2017 (Department of Tourism, 2011; Aklan Provincial Tourism, 2018). In the peak moments of 2017, the number of resorts and hotels exceeded the carrying capacity by almost 73% (Arboleda, 2018). This excessive number of visitors led to a host of health and environmental problems that caused the government to close the island for 6 months in 2018.

The natural capital is an important indicator to determine the health of a destination. The natural capital of a destination can be defined by the state of natural assets including geology, soil, air, water and all living organisms. This natural capital is used for a variety of services, otherwise referred to as ecosystem services. To properly manage these resources, destinations need to take an operational approach to obtain a correct overview. This allows decision makers to target specific Key Performance Indicators and prevent the natural capital

from degrading to the point that vital ecosystem services are threatened. Research has shown that the natural capital found in protected areas can generate up to \$600 billion in direct tourism revenue (Balmford et al., 2015). However, these protected areas chronically lack investment and face a growing threat from fuel explorations, logging and mining (Kirkby et al., 2012).

GIS can be used for the analysis of this natural capital and for master planning. Master planning is used worldwide to prepare regions for development and growth as it helps guide government policies on the management of tourism. Traditionally, tourism master plans use economic and tourism visitation data to generate an orderly plan. These procedures can be guided using GIS-data. However, there are few studies performed on the management of tourism using GIS (Cvetkovic & Jovanovic, 2016). GIS-driven master plans can track the environmental impacts of tourism and will most likely be increasingly crucial for destinations experiencing rapidly growing tourism demands.

The aim of this study is to create an overview of how marine tourism impacts the marine environment and to provide a case study using the coastal environment of California on how GIS-data can help reduce these impacts.

Materials and methods

California harbors a wide variety of habitats and species and is financially also dependent on marine tourism. There was also found to be a lot of data available on this state. This is why California was chosen to be the main focus point for this study. To reduce the negative impacts of marine tourism, GIS-layers of coral reefs, Marine Protected Area's including Marine Parks, areas with endangered species including Critical Habitats, areas with anchoring restrictions, Biological Important Areas (BIA's), Important Bird Areas (IBA's), areas with fishing restrictions including Essential Fish Habitats (EFH's) and Habitat Areas of Particular Concern (HAPC), No Discharge Zones (NDZ), seabed types and areas with shipping restrictions were considered relevant in this study (Table 1).

For the case study of California, exclusively open source GIS data was used. To gain a better perspective on the amount of GIS data available for this study, data was gathered from a range of different platforms including ArcGIS Hub, data.gov and BIOS (Table 2). These data platforms were searched for any datasets related to the 10 layers of interest. For datasets on biodiversity, only datasets published or updated after 2015 were used during this study as species biodiversity or distribution is likely to change over the course of a couple of years. For every dataset, the date of publishing was checked along with the research method used to gather the data and the reputation of the organisation funding the project. All GIS-data was visualised for a quality check using QGIS Desktop 3.4.4. Data that was not available in shapefile format was first converted prior to uploading the data into QGIS.

Results

Main impacts of tourism on coastal areas

The tourism industry has a wide range of impacts on the coastal systems. In this study, impacts of tourism on the marine environment are divided in 4 different categories: coastal development, physical damage, impact from water-based activities and wildlife interactions.

Coastal tourism development

Increased tourism requires more effective transport links between infrastructures. Many coastal roads are built only to connect resorts and sight-seeing attractions and many promenades and walkways replace the natural dune and rocky habitats. All of these developments lead to increased habitat loss and habitat fragmentation. Additionally, increased demand of yachts, leisure vessels and water taxis has boosted the marina development. These structures are known to change the water currents and can change the sand supply to beaches often leading to unexpected changes (Klein & Zviely, 2001).

Tourism developments can also directly impact species survival. Turtles are one of the species groups that are most strongly impacted by coastal developments. Two-hundred years ago, green, loggerhead and leatherback turtles were widely abundant in the Mediterranean islands, southern Europe and North Africa. Their breeding success has declined as a result of coastal development. As hatchlings will naturally seek out the lightest part of the horizon, they are often attracted by the lighting on coastal roads instead of the ocean (Tuxbury & Salmon, 2005; Arianoutsou, 1988). Turtle nests are naturally dug close to the fringes at the top of beaches where the dunes start to form. These areas have become more and more developed as they've been replaced with roads and buildings. These developments overshadow the sand area, reducing the temperature in the nest, which effects the sex of the offspring (Davenport, 1997).

Physical damage

Ships can directly harm the environment through their practices. The anchoring of cruise ships has been associated with long-term damages to local coral reefs. Besides causing anchor damage, the propeller action in shallow waters can also damage seagrass meadows. A large study performed in Florida showed that 700 km² of seagrass was damaged by propellers which can take up to 3 to 4 years to recover (Sargent et al., 1995; Dawes et al., 1997).

Whale strikes or collisions are a significant cause of mortality worldwide. Especially northern right whales, fin whales and humpback whales are vulnerable to collisions. In some areas up to one third of all strandings of fin and right whale were caused by ship strikes (Knowlton & Kraus, 2001; Laist et al., 2001; Panigada et al., 2006). Necropsy of 40 North Atlantic right whales between 1970 and 2006 shows that the injuries fall into 2 categories: sharp and blunt trauma. Sharp trauma is often the result from contact with the propeller and blunt trauma mostly results from contact with the hull of the vessel (Campbell-Malone et al., 2008). Of all 40 whales examined, 52.5% were found to be killed by collision with a vessel.

Impacts from water-based activities

Walking over rocky or sandy intertidal zones and turning over boulders causes damages to the local fauna and flora. As rocks have very different community compositions on their upper and lower surfaces, frequent turning of boulders reduces the microhabitat stability and biodiversity which can take up to 2 years to recover (Brosnan and Crumrine, 1994). Coral systems are even more vulnerable to disturbances. Tourists often damage coral structures while snorkelling or diving (Liddle, 1975). Most damage is done by clambering over coral structures, accidental kicking with fins and stirring up silt that can suffocate the corals (Hawkins et al., 1999). Recent research has shown that these forms of damage are practically unavoidable.

Wildlife interactions

Over 70 marine species are targeted by marine tourism including whales, dolphins, turtles, sea lions, seals, penguins, fish species, sharks, rays, and cuttlefish (Birtles et al., 2001). A large survey of 376 marine tourism operators performed by McKegg et al. (1998) showed that in New Zealand marine wildlife is considered a key tourist attraction. Of these, marine mammals and sea birds were the two most popular categories.

Many seabird species can become habituated to visitors and some research suggests that the effects on their breeding success is limited if the number and type of interactions is regulated (Dunlop, 1996; Burger & Gochfeld, 1999; Nisbet 2000). However, different seabird species have different sensitivity to human disturbances and the response to human intrusion can also differ between colonies of the same species. Additionally, at coastal areas that are used for recreational purposes it is hard to implement specific guidelines, so seabirds are less likely to become habituated. Most negative effects on seabird reproduction are a direct

consequence of destruction of the nest and desertion of the eggs and chicks. Royal Terns and Cayenne Terns are known to leave their nests when disturbed by humans, which leads to egg losses to other predators (Yorio & Quintana, 1996; Yorio et al., 2001).

Snorkelling with whale sharks is a popular tourism activity in Ningaloo Marine Park, Australia. Despite restrictions put in place by the Department of Environment and Conservation (DEC), research indicates that there are behavioural reactions of whale sharks to tourism. Whale sharks are known to react to snorkellers and vessels by diving away from the disturbance, porpoising (i.e. alternately moving up and down in the water column), eye rolling, turning to expose their dorsal surface to the disturbance, and shuddering (Norman, 1999; Quiros, 2007; Pierce et al., 2010).

Tourism in California

California is one of the states of the United States that is most impacted by marine tourism. It is the third-largest and most populated state in the United States and is located in the Pacific region. San Francisco Estuary is the largest estuary on the Pacific side of the western hemisphere with a network of interior bays with roughly 1,609 km of coastline. In 2012, 80% of the state's total gross domestic product (GDP) was generated by its 19 coastal counties. Additionally, tourism and recreation contribute 75% of the ocean economy employment in 2012 (Adkins et al., 2015).

California is home to a wide variety of habitats and species, including about 30 species of threatened and endangered fish, invertebrates, marine mammals, seabirds and reptiles found in its ocean ecosystem. For example, the number of adult females of the Pacific leatherback turtle has declined from 115000 to around 20000 since 1982. Incidental catch by fishing gear, poaching of the eggs and ingestion of plastics are found to be the main causes of mortality (Oceana, 2019).

Using different platforms, (Table 2) all available GIS-data on California that was in line with the 9 areas of interest will be discussed in the following paragraphs.

(1) Marine Protected Areas (MPA')

Marine protected areas provide protective management of natural areas to help protect their natural state. MPA's can be conserved for different reasons including economic resources, biodiversity and species protection. As shown in Figure 1 & 2, fishing and anchoring restrictions can differ per MPA. In California the California Department of Fish and Wildlife is responsible for policing these areas. For this they use six large patrol boats based in Berkeley,

Moss Landing, Morro Bay, Ventura, Los Angeles, and Dana Point. Each boat has a lieutenant, an engineer, and four game wardens (Garrison & Rollinson, 2015).

Most of California's MPA's do not have any anchoring restrictions and none of the MPA's have a complete anchoring ban. Anchoring around the Channel Islands of California is restricted to certain areas as these islands are considered Marine Parks. Each island has specific restrictions. The shoreline around San Miguel for example is closed to landing to protect pinnipeds except for one designated landing area. Some beaches of Santa Rosa are closed all year while others are closed during specific time periods to protect wildlife. Also, Santa Cruz has a part of the shoreline closed off for public to protect nesting seabirds (National Park Services, 2019).

California has different regulations for finfish fishing and invertebrate fishing. For example, there can be restrictions on the bait used for fishing, restrictions on the number of fish caught in one day, species of fish, limits on the size of the fish, seasons and depth constraints (Fish and Game Commission, 2019).

(2) Critical habitats:

GIS data containing the critical habitats of the leatherback turtle, green sturgeon, rockfish, eulachon, black abalone, southern killer whale were found. The critical habitat of the Leatherback turtle and the Black Abalone are shown in Figure 3 (thin yellow lines along parts of the coast).

(3) Biologically Important Areas (BIA's)

GIS data containing BIA's were found for harbor porpoise (Small and resident populations), blue whales (feeding areas), humpback whales (feeding areas), Gray Whales (feeding and migration areas). Some BIA's for blue whales, humpback whales and harbour porpoise are shown in Figure 3. In total, 28 BIA's are defined for these four cetacean species within the West Coast region (Calambokidis et al., 2015).

(4) Important bird areas (IBA)

The whole state of California counts 149 Important Bird Areas (IBA's) including coastal IBA's (Figure 4). In total, all IBA's of California combine to over 4 million km² (Audubon, 2019). All of which meet following criteria:

- They support over 1% of the global or 10% of the state population of at least one sensitive species.
- They support more than nine sensitive bird species.
- They hold 10,000 or more observable shorebirds in on day.
- They hold 5,000 or more observable waterfowl in one day.

Additionally, data on pelagic IBA's also exists but is not readily available to download and we were not able to contact the data owner to request access to the data (Jones, 2017).

IBA's are recognised worldwide as practical tools for conservation and aim to focus conservation efforts to the right places. Not all IBA's have defined restrictions on the activities that take place in these areas.

(5) Essential fish habitat (EFH)

Fish and invertebrates living in essential fish habitats (EFH's) are managed on federal level to maintain a healthy habitat for commercial and recreational fisheries. Enclosed freshwater habitats are not considered EFH's and are managed by state or local authorities. EFH's are protected in two main forms; there can be limitations on fishing methods and gear in these areas as well as restrictions on development operations that can take place in these areas. The NOAA Fisheries department offers consultations to federal partners such as the U.S. Army Corps of Engineers to help them minimize or avoid environmental impacts during construction that could impact marine fisheries and their essential habitats (NOAA, 2002). Fish stocks are managed under different management plans. For the Westcoast there are four different plans: Coastal Pelagic Species Management Plan, Pacific Coast Groundfish Management Plan, Salmon Fisheries Management Plan and the West Coast Highly Migratory Species Management Plan. Together these management plans comprise a Code of Federal Regulations (GPO, 2019) with different restrictions on fishing methods that can be used by both commercial and recreational fishing (Figure 5).

(6) Habitat areas of particular concern (HAPC):

Habitat Areas of Particular Concern (HAPC) were identified for Atlantic Cod, Bluefin Tuna, Dolphin, Wahoo, Penaeid shrimp, Sandbar Shark, Snapper Grouper, Spiny Lobster and Tilefish (Figure 6). As mentioned before, HAPC's are part of Essential Fish Habitats defined by NOAA Fisheries. These areas are considered especially vulnerable to degradation and have a high priority for conservation, management or research. An HAPC designation does not necessarily mean that there are additional protection measurements or restrictions, the aim is to prioritize and focus conservation efforts.

HAPC's in front of the coast of Los Angeles are protected by amendment 19 of the Pacific Coast Groundfish Fishery Management Plan. This underlines that the use of setnets is prohibited in all waters north of 38° N. latitude. Additionally, the area shoreward of the 100 fathom depth contour are permanently closed for fishing. In fishery management areas, the use of dredge gear, beam trawl gear, and bottom trawl footrope gear with a footrope diameter larger than 19 inches is prohibited (Pacific Fishery Management Council, 2008).

(7) No Discharge Zone (NDZ):

No GIS data on these zones was accessible for download, therefore existing maps with the different restrictions on the discharge of vessel sewage were used (EPA, 2019). No Discharge Zones (NDZ) are enforced by the U.S. Coast Guard which inspects vessels for compliance. Penalties for violating of the California NDZ are determined by the U.S. Coast Guard and the State of California itself (EPA, 2012). From 2012, discharge of vessel sewage is prohibited for all large passenger and oceangoing vessels in the coastal waters of California (Figure 7). Vessels are considered large passenger vessels from 300 gross tons that have berths or overnight accommodations for passengers. Large oceangoing vessels include private, commercial, government, or military vessels equipped with a holding tank with remaining capacity or containing sewage generated prior to entry into California marine waters (EPA, 2012).

(8) Seabed types:

Both for seagrass and kelp data was available to download (Figure 8). Data on inorganic seabed substrates such as pebbles, hard bottom, mud and sand is also present from Pt. Arena to Pt. Sal in central/northern California (Conservation Biology Institute, 2017). As this data was not available for downloading and we were unable to contact the data owner to request access to the data, no inorganic seabed substrates are included.

(9) Shipping lanes

In 2015, some shipping lanes in California were changed by the International Maritime Organization (IMO) with the goal in mind to reduce whale strikes. Shipping lanes were changed in San Francisco Bay, Santa Barbara Channel and the ports of Long Beach and Los Angeles (Figure 9). Traffic lanes are used for a specific traffic flow, traffic separation zones for opposing streams of marine traffic. Precautionary areas represent areas where ships must navigate with caution, and artificial structures are prohibited in shipping safety fairways. Recommended Routes are predetermined routes for shipping for safety reasons. Particularly Sensitive Sea Areas need special protection because of their vulnerability to damage by international maritime activities. Areas to be avoided are defined limits where navigation is particularly hazardous, or it is exceptionally important to avoid casualties and should be avoided by all ships or certain classes of ships (NOAA et al., 2015). Additionally, it was recommended to put speed restrictions in place to give whales the opportunity to identify the danger and move away from it (Nowak, 2015).

Discussion

This literature review specifies that the main impacts of tourism on the marine environment can be categorised as: coastal tourism development, physical damage, impact from water-based activities, wildlife interactions and impact on climate change. In the following paragraphs different possible approaches to reduce these impacts will be discussed using GIS-data.

There are different ways to reduce the impact from coastal tourism development. For example, the damage caused to the natural habitat and biodiversity by beach grooming can be reduced while maintaining high recreational use of the beach areas when a beach grooming scheme is implemented. A grooming scheme contains designated stretches of beach that are left ungroomed year round. This represents a far more ecologically effective approach than seasonal grooming of the entire stretch of beach (Dugan & Hubbard, 2010). Increased conservation of these beach areas can help retain sediment, promote the formation of dunes, and maintain biodiversity, wildlife, and human use as well as providing protection against rising sea levels (Feagin et al., 2005). The use of grooming schemes is based on “living shoreline” principles. These principles aim to maximize the ecological connectivity between land and sea and protect coasts from erosion through long-term protection, restoration or enhancement of shoreline habitats (Center for Coastal Resources Management 2010). This approach uses wetlands, natural stones, and sturdy plants along shore margins as components of a protective strategy against erosion and sea level rise.

To help guide coastal tourism development and tourist activities a coastal vulnerability index to tourism can be created and implemented for management plans. Coastal vulnerability indexes already exist to highlight their vulnerability to sea level rise. The coastal vulnerability index from Hammar-Klose and Thieler (2014) was created based upon the coastal geomorphology, regional coastal slope, tide range, wave height, relative sea-level rise and shoreline erosion and accretion rates. They used the combination the variables and the relation of the variables to one another to create an overview of areas where physical damage is likely to occur because of sea-level rise (Figure 10). However, their approach only included physical damage to the coastline, and does not account for damage to the coastal biodiversity.

The GIS-data gathered during this project, in combination with geomorphological data, can form a basis to model the coastal vulnerability to tourism impacts. However, more detailed mapping of coastal areas is necessary to develop a clear sense of coastal vulnerability and to determine where tourism activities should be banned or regulated. These areas should include measurements of physical risk, an inventory of structures, and an identification of habitat areas that are particularly threatened or particularly valuable to protect.

A possible option to reduce the negative impacts of snorkelers and divers is to create artificial reefs. This can be done on the reef itself by deposition of calcium minerals from the seawater by electrolysis. This technology sends low voltage electricity through metal structures placed underwater which causes calcium minerals to deposit onto the frame. Corals growing on these electrified artificial reefs tend to grow 3-4 times faster, and survive much better during bleaching events, disease outbreaks, and other disturbances (Hilbertz, 1979; Goreau & Hilbertz, 2012). This can be done on a template of any desired shape, after which living coral fragments are transplanted. With this method, different structures can be designed and formed on the seabed which can serve different needs such as diver training, environmental education and recreation as well as reef rehabilitation. Through this approach a recreational underwater park can be formed which is well suited to function as a diver aggregation area and therefore, reduce the diver pressure from the natural reef (van Treeck & Schuhmacher, 1999).

The creation of artificial reefs can be combined with GIS-data to plan snorkel trails. Snorkel trails have been proposed to restrict impacts of snorkellers or divers to small areas. Plathong et al. (2000) found that even with a low amount of 15 snorkelers per week there was a clear difference in the number of corals being damaged between the trails and control sites. The authors suggest that providing education to manage the behaviour of snorkelers, careful site selection, and periodic rotation of trails could be a successful management strategy. GIS data can be used to plan and select the proper sites for the trails. Detailed data on the health and presence of coral reefs can efficiently be gathered using intelligent underwater cameras. For example, PlanBlue combines hyperspectral imagery with machine-learning algorithms which can be used to analyse the seafloor composition and perform environmental impact analysis (PlanBlue, 2019).

Finally, the GIS-approach demonstrated here can help reduce the negative impacts of marine based tourism by increasing awareness and reducing the direct damage caused by vessels. We propose the use of GIS-data for on board education of skippers and tourists. For this, an application programming interface (API) can be used as a platform to provide this

GIS-data to third parties, including navigation companies. For example, Sea Going Green developed an API called Econavis which is built specifically to make it possible for navigation companies to incorporate these vulnerable locations into their on board navigation software so that they can be visualized on board the ship. The target audience for this data is skippers and tourists. By visualizing these areas, on board education can be provided to this target audience and the awareness for the marine environment can be increased. Through this approach direct damage can be reduced and tourists can become more aware of their impact on marine wildlife and the different habitats. Also, it will make it easier to communicate proposed management strategies and help captains follow certain restrictions in these areas.

For example, the United States Environmental Protection Agency (EPA) estimates that imposing No Discharge Zones will prohibit the discharge of over 22 million of the 25 million gallons of treated sewage that large vessels could otherwise legally discharge into California marine waters each year (EPA, 2012). Making these boundaries clearly visible on board of vessels will help captains to comply with these rules and protect the coastal waters of California. Also, areas such as coral reefs and seagrass beds are not always easily visible from on top of a vessel making it hard to avoid these areas. Having accurate boundaries for where seagrass beds and coral reefs or other vulnerable habitats are can help captains reduce the direct damage caused by anchoring and motoring.

However, increasing awareness does not always translate in a change of behaviour. In their article, Cristiano and Niemand (2017) discuss the different pitfalls in creating awareness and on how to achieve behavior change. To achieve the best response on an awareness campaign, Cristiano and Niemand found that a narrow audience needs to be targeted with a compelling message with a clear call to action (Cristiano & Niemand, 2017). By providing education on board of tourism vessels a very precise and narrow audience of marine tourists is reached and by providing them with accurate data and information they are given a clear and achievable call to action. The calls to action will depend on the area and can include refraining from anchoring in vulnerable marine habitats (for example, coral reefs and seagrass beds), dumping gray water, but also reducing noise pollution around breeding seabirds, avoid damage to critical habitats and minimizing wildlife interactions.

To successfully use GIS-data to reduce the negative effects of marine tourism more detailed and up-to-date data is needed and data accessibility needs to be improved. For educational purposes on board on the ship detailed data containing clear regulations and a clear metadata file to interpret the data correctly is crucial. Furthermore, improvements of

data accessibility would strongly increase the reach of possibilities for the applications of Econavis. Currently, to use services of a data providing platform such as Esri, expensive fees need to be paid. As not all data is found within one platform, multiple fees will need to be paid to different data providers to access the relevant data. The other option to gather the data and to discuss licensing on the data is to contact every data owner privately, which is highly time-consuming and inefficient. Finally, finding up-to-date data on some of the layers can prove to be difficult because restrictions in different areas changed, new areas were added, or the species distribution changed over time. When false or out-dated data is used, people on board of the vessels would be wrongly educated and the changes they make in their behaviour based on this data could fail to protect the marine environment.

Conclusion

This study reviewed the different direct impacts of tourism on the marine environment and provided an overview of different approaches to minimise these impacts using GIS-data. The different forms of damage were divided in 4 different categories: coastal development, physical damage, impact from water-based activities and wildlife interactions. All 4 categories were found to have negative impacts on the local biodiversity and ecosystem stability. Up to date GIS-data was found for all areas that were considered relevant to protection of the marine environment in California except for Coral reef areas. However, not all GIS-data was readily available to download and obtaining high quality data remains challenging.

We conclude that the GIS-data gathered during this study can be applied in multiple ways to reduce the negative effects of marine tourism. The proposed approaches include the creation of a vulnerability index to tourism, creating snorkel trails in combination with artificial reefs, and finally the data can be used for on board education and to form more strict sustainable tourism policies. Using GIS-data for education of on boats is found to be the best way to reach a narrow audience and provide them with a clear and achievable call to action.

Acknowledgements

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Appendix

Figures

Figure 1. Marine protected areas with different anchoring restrictions in front of the coast of Los Angeles, CA (California Department of Fish and Wildlife, 2019). The solid purple lines indicate administrative boundaries.

Figure 2. Marine protected areas with different fishing restrictions in front of the coast of Los Angeles, CA (California Department of Fish and Wildlife, 2019). The solid purple lines indicate administrative boundaries.

Figure 3. Critical habitats and Biologically Important Areas (BIA) in front of the coast on Los Angeles, CA (U.S. Fish and Wildlife Service, 2017). The solid purple lines indicate administrative boundaries.

Figure 4. Important Bird Areas in front on the coast of Los Angeles, CA (National Audubon Society, 2016). The solid purple lines indicate administrative boundaries.

Essential Fish Habitat

Groundfish EFH in the Pacific Coast EEZ shoreward of 100 fm	Santa Barbara Island EFH Conservation Area
Hidden Reef/Kidney Bank EFH Conservation Area	Harris Point EFH Conservation Area
Catalina Island EFH Conservation Area	Richardson Rock EFH Conservation Area
Potato Bank EFH Conservation Area	Scorpion EFH Conservation Area
Cherry Bank EFH Conservation Area	Painted Cave EFH Conservation Area
Cowcod Conservation Area East EFH Conservation Area	Anacapa Island EFH Conservation Area
East San Lucia Bank EFH Conservation Area	Carrington Point EFH Conservation Area
Point Conception EFH Conservation Area	Judith Rock EFH Conservation Area
Footprint EFH Conservation Area	Skunk Point EFH Conservation Area
South Point State EFH Conservation Area	7 Big Sur Coast/Port San Luis EFH Conservation Area

Figure 5. Essential Fish Habitats according to the Code of Federal Regulations (CFR) (GPO, 2019; NOAA, 2017). The solid purple lines indicate administrative boundaries.

Figure 6. Habitat Areas of Particular Concern with fishing restrictions in front of the coast of Los Angeles, CA (NOAA, 2017). The solid purple lines indicate administrative boundaries.

Figure 7. No Discharge Zones for large passenger and oceangoing vessels (blue) and No Discharge Zones for all vessels (yellow) in the coastal waters of California. In the public domain (EPA, 2012).

Figure 8. Kelp areas (green) (NOAA Office of Coast Survey, 2014) along the coast and seagrass areas (yellow) (Merkel et al., 2015) in Anaheim Bay of Los Angeles, CA.

Figure 9. Different shipping lanes and their recommendations in front of the coast of Los Angeles, CA. Traffic lanes define specific traffic flow, while traffic separation zones assist opposing streams of marine traffic. Precautionary areas represent areas where ships must navigate with caution, and shipping safety fairways designate where artificial structures are prohibited. Recommended Routes are predetermined routes for shipping adopted for reasons of safety. Particularly Sensitive Sea Areas need special protection because of their vulnerability to damage by international maritime activities. Areas to be avoided are defined limits where navigation is particularly hazardous, or it is exceptionally important to avoid casualties and should be avoided by all ships or certain classes of ships. (NOAA et al., 2015). The solid purple lines indicate administrative boundaries. Note that the Area to be Avoided covered by the biggest polygon with is not well defined and is covering San Miguel Island and part of Santa Rosa Island.

Figure 10. Coastal vulnerability to sea level rise of the coast of Los Angeles, CA (Hammar-Klose & Thieler, 2014). The solid purple lines indicate administrative boundaries.

Tables

Table 1. Overview of the GIS-data found to be relevant to this study and its biological relevance.

Marine Protected Areas	Effectively managed marine protected areas (MPA's) have the power to reverse the effects of overfishing and destructive fishing methods (Lester et al., 2009). Highly protected MPA's have up to 4 times more diversity and abundance of marine species. These wildlife refuges provide a source from which species migrate into surrounding areas and benefit the surrounding human communities (Guidetti, 2007). As there is no federal agency or authority charged with the oversight of marine protected areas, policing these areas is challenging.
Areas with endangered species	A critical habitat is a specific area that contains key features that are essential to the conservation and survival of endangered species. Once an area is designated as a critical habitat in the United States, federal agencies must consult with NOAA (National Oceanic and Atmospheric Administration) to ensure that none of the activities authorized in this area are likely to destroy or negatively modify the critical habitat.
Areas with anchoring restrictions	Because of the increasing pressure of anthropogenic activities including tourism, anchoring damage has become a great concern within coral reef management. Sites with a high frequency of anchoring only support 60% of the coral species and have half of the structural complexity compared to sites with little anchoring. The damage from anchoring is not only caused by the anchor itself but also by the cables and chains dragging across the substrate or winding around reef structures (Dinsdale & Harriott, 2004).

Biological Important Areas	BIA's are well-defined areas where marine species are known to aggregate to display biologically important behaviour such as breeding, feeding, resting or migrating. For example, the BIA's for grey whales are based on their migratory corridor between their primary feeding grounds in northern latitudes and breeding areas off Mexico.
Important Bird Areas	Important bird areas are globally recognised as important sites for the conservation of bird species and are crucial for their survival. These areas are often protected under national legislation however, 33% of IBA's don't have any form of official protection and another 45% are only partially protected (Marnewick, Retief, Wright, & Theron, 2015). Making tourists and visitors aware of these areas can help protect their wildlife even without official regulations or restrictions.
Areas with fishing restrictions	Essential fish habitats consist of all waters and substrate necessary for spawning, breeding, feeding or growth to maturity of fish species. Cooke and Cowx (2004) estimated that recreational fish harvest potentially represents 12% of the global fish harvest. Recognizing and respecting the importance of these areas by both commercial and recreational fishing is a first step towards contributing to the sustainability of marine ecosystems and their resources.
No Discharge Zone	A No Discharge Zone (NDZ) is a defined area where discharge of any sewage by boats is prohibited. NDZ's help to reduce nutrient pollution as they prevent organic matter from entering enclosed areas such as marinas or bays. Additionally, they reduce the number of faecal coliform bacteria, which can transmit diseases to humans and filter feeders (Sealand technologies, 2001).
Seabed types	Multiple ocean habitats are considered threatened worldwide. In the North-east Atlantic 6 habitat types are listed as endangered or declining including coral gardens, mussel and oyster beds, as well as seagrass beds (OSPAR Commission, 2008). In Europe 19% of marine habitats are considered threatened (Basso, 2016). Considering the kinds of seabed types that are present while boating can be a crucial step in protecting the marine habitats the species that depend on these different habitats.
Areas with shipping restrictions	Because of the increasing number of ships and the increasing speed of ships, the number of collisions of with great whales (baleen whales and sperm whales) has increased since the 1950's (Laist et al., 2001). Ship strikes can negatively impact small populations of whales, which is why special care is taken when defining shipping lanes. Shipping lanes can be moved or have speed restrictions which must be followed to reduce the number of collisions.

Table 2. Overview of platforms providing open-source GIS-data

https://www.natureearthdata.com/
https://hub.arcgis.com/pages/open-data
https://freegisdata.rtwilson.com/
https://www.nasa.gov/?_ga=2.187422888.1071600562.1562236203-715992873.1562236203
http://maps.tnc.org/gis_data.html
https://www.protectedplanet.net/country/HR
https://www.eea.europa.eu/data-and-maps/data#c0=5&c11=&c5=all&b_start=0
https://www.gbif.org/
https://ec.europa.eu/maritimeaffairs/atlas/maritime_atlas/mindmap_EN.html
https://www.iho.int/srv1/index.php?option=com_content&view=article&id=296&Itemid=287&lang=en
http://marineregions.org/
http://www.ices.dk/Pages/default.aspx

<https://obis.org/>

<https://nbn.org.uk/the-national-biodiversity-network/archive-information/nbn-gateway/>

<https://www.emodnet-seabedhabitats.eu/access-data/download-data/>

<https://www.eucc-d.de/coastal-gis.html>

<http://marine.copernicus.eu/getting-started/>

<http://arcgis.cisr.ucsc.edu/pacificrockyintertidal/>

<https://databasin.org/>

<https://news.grida.no/mapping-marine-debris-on-the-lofoten-coast>

<https://litterbase.awi.de/litter>

http://seadatanet.maris2.nl/v_cdi_v3/search.asp

<http://www.nationaalgeoregister.nl/geonetwork/srv/dut/catalog.search#/home>

<https://www.emodnet-humanactivities.eu/>

<https://www.pangaea.de/>

<https://www.wri.org/resources/data-platforms>

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