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Review

Ecosystem Services and Disservices of Mangrove Forests: Insights from Historical Colonial Observations

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Abstract: Ecosystem services are now strongly applied to mangrove forests, though they are not a new way of viewing mangrove-people interactions; the benefits provided by such habitats, and the negative interactions (ecosystem disservices) between mangroves and people have guided perceptions of mangroves for centuries. This study quantified the ecosystem services and disservices of mangroves as written by colonial explorers from 1823–1883 through a literature survey of 96 expedition reports and studies. Ecosystem disservices were most commonly discussed (60%), with settlers considering mangroves as reservoirs of diseases such as malaria, with wide-ranging implications, such as the global drainage of wetlands in the 19th–20th centuries. Multiple ecosystem services were discussed, especially provisioning services for export, representing colonial views of new lands as ripe for economic use. Interestingly, regulating services of mangroves such as erosion control and sediment accretion that are a focus of much contemporary research were recognized as early as 1865. This study shows that the ecosystem service paradigm has a long history in mangroves. We should not underestimate mangrove ecosystem disservices, and how contemporary perceptions of mangroves may be influenced by such historical viewpoints. Archival materials provide a rich resource to study human-environment interactions, and how they change through time.

Keywords: cultural services; disease; dis-service; forest; malaria; provisioning services; wetland

1. Introduction

The ecosystem services paradigm—the benefits that ecosystems provide to human populations [1] is now strongly applied to threatened tropical coastal forested ecosystems such as intertidal mangrove forests. A huge amount of research is currently focusing on the range of ecosystem services that mangrove forests provide, and their regional distribution [2–4]. Mangrove forests have commonly been shown to provide multiple provisioning services that increase the economic or food security of local communities [5] such as timber, fuelwood, medicinal, and food resources. Regulating services such as wave attenuation [6], and more recently carbon sequestration and storage [7–9] have also become important in the contemporary mangrove forest research agenda. These regulating services are potentially important at very large scales, with carbon storage in Indonesia being so high that mangrove deforestation may account for as much as 10%–31% of all carbon emissions related to national land cover change [10]. Mangrove forests also provide a broad suite of cultural ecosystem services to coastal populations living close to mangrove forests, ranging from the tangible (tourism, recreation, education) to the abstract (cultural heritage, aesthetics, sense of place) [11,12]. While huge challenges to quantifying and valuing ecosystem services remain, mangrove forest ecosystem services have been tentatively estimated at an average of US 4185 per hectare per year [13], though substantial spatial and temporal variation in this value would be expected.

Despite its utility in communicating the importance of mangrove forests to a variety of stakeholders, the sole focus of the ecosystem services approach on societal benefits belies the potential negative influences and perceptions—or 'ecosystem disservices'—that mangroves can have on surrounding populations. The concept of ecosystem disservices attempts to define and understand ecosystem functions that have negative impacts on human well-being [14], whether these impacts are real or perceived. These may include habitats as reservoir of disease, as perceived areas of danger or as a harbor of pests. Ecosystem disservices have been criticized for being too subjective [14] and hampering conservation efforts [15], and the broader ecosystem services/disservices dichotomy has been criticized for overly simplifying a range of complex and non-linear interactions and processes [16]. Thus, ecosystem disservices have received scant attention within research and decision-making circles [17]. However, insufficient consideration of ecosystem disservices may reduce the success of habitat management [17], and disservices are a useful tool to understand the overall view and perception of ecosystems by a variety of stakeholders, especially for non-monetary aspects and services. Perceived ecosystem disservices may be influenced by historical and cultural norms, with historical interpretations of nature as an "*enemy to civilization, something to be tamed and cultivated in order to be useful for human well-being*" [14] (p. 309).

Mangrove forests are a useful lens through which to investigate historical perceptions of ecosystems and their services, as they have historically been a focal ecosystem of study [18], and early insights are possible through colonial records such as ship logs and expedition reports. Mangrove forests were included in such reports because they were a prominent feature of many of the tropical coastlines that were surveyed during the 19th century, and were noteworthy potentially because of the ecosystem services and disservices they provided. This study quantifies the uses and colonial perceptions of mangrove forests between 1833 and 1883, through the lens of ecosystem services and disservices (both perceived and actual). Such information provides an important baseline with which to further analyze how contemporary perceptions of mangroves now differ from, or were formed by early written (albeit, colonial) views of this ecosystem.

2. Sources of Historical Information on Mangrove Ecosystem Services and Disservices

To provide a foundation with which to discuss colonial uses and perceptions of ecosystem services and disservices, this study conducted an in-depth literature search, supported by a semi-quantitative analysis of key words, temporal change in key word use, and the geographical distribution of key word use.

This study utilized the digital library and archive JSTOR. This digital library was created in 1995 and allows the full text search of articles from thousands of different journals. Searches were conducted in April–May 2016, using the search term "mangrove" to collate all accessible articles. The search term was kept intentionally broad (instead of searching for "mangrove ecosystem services", for example) to capture all mangrove-related articles. Other terms to narrow down the search would not have been appropriate, as the term "ecosystem services" has only been used in the last few decades [1], so is not a phrase that colonial writers would have used. Instead, all 329 articles were read manually for phrases and other search terms that denoted ecosystem services or disservices.

Only articles between the years 1823 and 1883 were included in the literature search. This covers a time period that encompasses the exploration and early colonization of many regions (e.g., East Africa, Southeast Asia, Australia) and their increasing colonial industrialization. Articles prior to this period were also searched, though when these articles were read manually, no specific mention of explicit mangrove ecosystem services were found. Articles after this period were not considered as the volume of material to analyze was too great. Only English language articles were considered for this study; while this biases the results towards experiences in Anglophone countries and colonies, and excludes voices from other European colonies and especially local indigenous groups, it is largely representative of the resources available in digital libraries such as JSTOR. This search initially produced 329 articles.

The 329 articles were searched manually for discussions relating to various classes of ecosystem services as defined by the Millennium Ecosystem Assessment (MEA) [1]; provisioning services (fisheries, timber, and non-timber forest products); regulating and supporting services (wave attention, erosion control/sediment accretion); and cultural ecosystem services. Three main ecosystem disservices were classified during this study: negative perceptions of darkness/gloominess; mangroves as an area of danger (by animals or other human populations); and mangroves as a reservoir of disease. While an authoritative classification scheme for ecosystem services exists through the MEA [1], a similar classification of ecosystem disservices does not currently exist. In this study, broad categories were used that matched those identified by Shackleton et al. [17] along a spectrum of ecosystem origin (biological versus abiotic) and primary dimension of human wellbeing affected (economic, physical health, and aesthetic/cultural), and are broadly similar to disservices previously identified for mangroves in Panama City by López-Angarita et al. [19]. The three categories of darkness/gloominess, danger, and disease were tested through a pilot study of 20 documents.

In total, a final set of 96 articles described one of the listed ecosystem services or disservices between 1823 and 1883 (Table 1, Figure 1). This result confirmed previous anecdotal evidence that historically mangrove forests were considered with ambivalence or as a nuisance [20]. The majority of ecosystem disservices discussed in these reports (59%) referred to the role of mangroves as a reservoir of disease; since these reports were written before the advent of germ theory in medicine, the main vector of disease was thought to be "miasma", poisonous vapors emitted from decaying matter [21]. Of the ecosystem disservices reported, 28% referred to the general view of mangrove forests as gloomy (or other similar words), suggesting a negative cultural and aesthetic response to the mangrove environment [17]. Ecosystem services were explicitly described in 41% of the reports, 73% of which referred to provisioning services, especially for timber and fuelwood. Regulating and supporting services are a focus of much contemporary mangrove ecosystem service research [3], though were not of much concern to colonial explorers, mentioned in only seven articles. Cultural ecosystem services were only discussed in three articles, in predominantly anthropological journal articles, mirroring a similar lack of attention and research on cultural services of forested ecosystems today [11].

Table 1. Results of a literature review for historical mangrove ecosystem services and disservices between 1823 and 1883.

Ecosystem Service or Disservice	Definition	Number of Articles 1823 to 1883
Provisioning	Direct, consumable products derived from the mangrove	29
(*Fisheries*)	The provision of fish and shellfish for consumption	(*7*)
(*Timber*)	The provision of wood for construction and fuel	(*13*)
(*Non-timber forest products*)	Commodities obtained from mangroves that do not require logging	(*9*)
Regulating/supporting	Services that regulate ecosystem flows or support other ecosystem services	7
Cultural	Spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences	3
Gloominess/scariness	Negative biological and/or abiotic impact on aesthetic and cultural aspects	16
Danger	Impact on health and wellbeing through harm by animals or other human populations	7
Disease	Biological impact on physical health and wellbeing through pathogens	34
Total		96

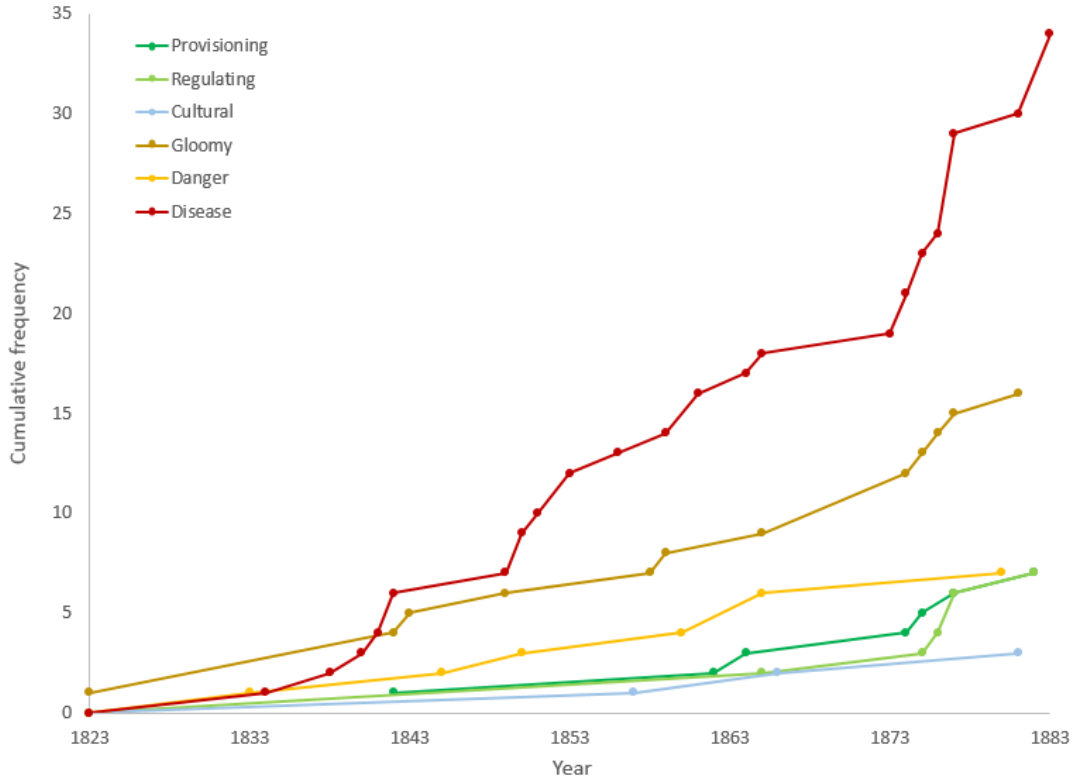

Figure 1. Changes in the reporting of mangrove ecosystem services and disservices between 1823 and 1883.

Geographically, articles were distributed across the tropics (Figures 2 and 3), though clustering of reports do occur in Africa, especially in Tanzania and Zanzibar. While Tanzania was not a British colony, several British expeditions explored this coastline in the mid-19th century before the formal establishment of German East Africa (corresponding roughly to the area of modern Tanzania). These expeditions were led by explorers such as David Livingstone to find the source of the Nile. A number of reports also originated from West Africa, such as the Gambia (and surrounding countries), which was an important British colony and trading post for forest and mining products since the early 1800s.

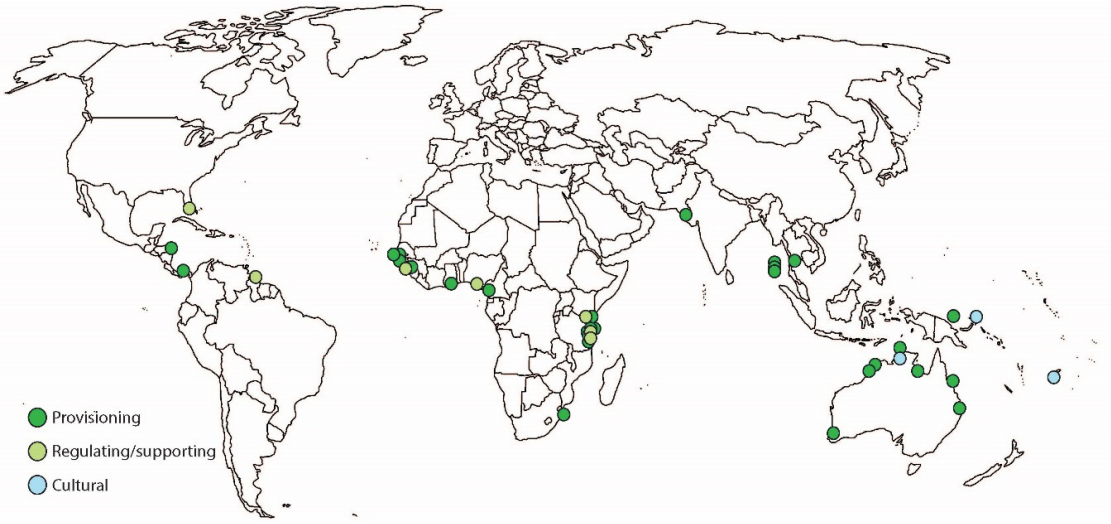

Figure 2. Approximate geographical distribution of historical reports of mangrove ecosystem services.

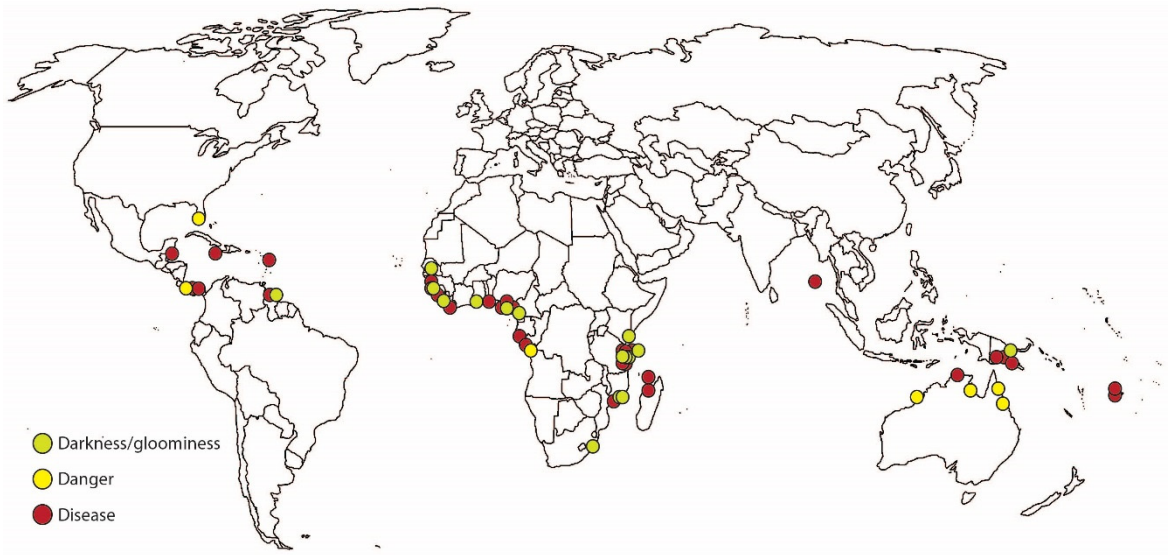

Figure 3. Approximate geographical distribution of historical reports of mangrove ecosystem disservices.

It is important to note the type of author that wrote these articles, and the audiences that these articles were intended to reach, as this has implications for the perception and interpretation of historical ecosystem services. All articles were written by colonial explorers and administrators, who were predominantly from Europe. A large proportion of the articles presented were published in the *Journal of the Royal Geographical Society of London* (established in 1830), due to its role in establishing and funding a number of colonial expeditions. This journal was also one of the few venues available where expedition reports could be published and made publicly available. The intended audience of this journal would have been similar colonial researchers, many of whom may have been relatively unfamiliar with the mangrove ecosystem.

Since the articles were written by colonial researchers, local viewpoints and perceptions of ecosystem services may not be adequately reflected. Some of the articles do describe local uses of mangrove ecosystem services (see Sections below for relevant examples) so would encompass local users, though the focus in many articles was on ecosystem services that were of importance to colonial users. Information on ecosystem disservices may be particularly skewed as some of the writers may have been less familiar with the mangrove setting. To address this, it would be suitable to consult alternative sources of information created by local mangrove users during this time period, including local records and oral histories [22]. However, this was outside for the scope of the current study. Focusing on colonial records only, researchers are increasingly aware of the potential biases in the type of user that is represented in such analyses [23], though it is interesting to note that recent high-profile conceptual frameworks that have been posited to study historical ecosystem services have highlighted the importance of personal perspectives in assessing historical ecosystem services, but still do not adequately take such biases into account [22].

3. Ecosystem Services of Mangrove Forests

3.1. Provisioning Ecosystem Services

Mangroves provide a range of provisioning ecosystem services to local coastal communities that encompass food (e.g., fish), timber, and non-timber forest products [24,25]. Provisioning services were discussed in 29 articles in this study (74% of all ecosystem services discussed) and described in three main ways. Firstly, provisioning services were a subject of anthropological study, describing how indigenous groups used various mangrove forest resources for food, construction, and boat building; Secondly, a large number of reports described the potential export value of mangrove resources,

especially timber and tannins for leather production. This is to be expected, as many of the colonial expeditions were for commercial exploitative purposes; Thirdly, a smaller number of colonial reports described how mangrove forest products were utilized by the local colonial population, for fire wood for ships, or for the production of shellfish. Shellfish were perhaps not viewed as an exportable commodity as long-distance export was only possible after the advent of refrigeration.

3.1.1. (Shell) Fisheries Provision

Seven reports described food provision extracted from the coastal mangrove forest, with most focusing on shellfisheries, specifically oysters. Oyster fisheries provided by mangrove forests are an important safety net as a source of food for impoverished coastal communities in west Africa today [26]. Oyster fisheries were recorded as early as 1842, where it was a particular focus of those writing about the Gambia [27–29] where they described an abundance of oysters growing on the aerial roots of the *Rhizophora* spp. In all reports, shellfish were described in the context of local colonial consumption, as opposed to local indigenous use or the potential for shellfish export.

The contemporary research community attributes substantial importance to mangroves for supporting fisheries [30], though the provision of fish by mangrove forests received scant attention in reports between 1823 and 1883. When describing the 'Mosquito Territory' of modern day Honduras and Nicaragua, Bell [31] noted how dense mangrove forests abounded with fish populations, and noted how they varied with tidal stage. This article was interesting as it began to investigate particular features of the mangrove forest environment (vegetation density, hydrodynamics) that were important for sustaining large fish populations. These factors have been confirmed in contemporary mangrove-fisheries research as important in controlling fish population density and diversity at different life stages [32,33].

3.1.2. Timber and Fuelwood Provision

Mangrove forests are still used today for the production of timber and charcoal (e.g., Figure 4), either for local subsistence use [25] or through large state-controlled and commercial forestry concessions, for example in Malaysia [34] and West Papua, Indonesia [35]. Some of these sites are now Forestry Stewardship Council-certified in order to promote the sustainable use of forest timber resources. Timber and fuelwood provisioning services extracted from mangrove forests were particularly important between at least 1823 and 1883, featuring in 13 articles (45% of all provisioning services articles, and 33% of all ecosystem service articles). Genera such as *Rhizophora* were particularly desirable for timber because they were "*uncommonly hard, and of a specific gravity heavier than water, some upwards of seventy feet high*" [36] (p. 198) and were "*incorruptible in water and impervious to insects*" [37] (p. 88). *Rhizophora* were preferred over other genera such as *Avicennia*, because the latter were softer wood and more susceptible to pests [38].

A range of Indigenous uses of timber products were described from mangrove resources, such as the production of aboriginal canoes [39,40]. Wilson also describes a novel use of a mangrove trunk (probably of *Bruguiera gymnorhiza*), as its buttressed above-ground root structure made a suitable canoe oar [39]. Timber was also important for house construction [41] due to the perceived strength and durability of *Rhizophora*. The wood of *Avicennia marina* was used to fuel rudimentary kilns that could burn invertebrate shells to create a lime render for house walls in East Africa [42], which forms a stronger shelter and reduces maintenance costs compared to wooden buildings. Mangrove products are still important for house construction today. Lime is still used as a house render in East Africa and Madagascar, with ongoing research suggesting its production may be driving local patterns of deforestation as increasing affluence causes a shift from wooden to lime render houses [43].

The importance of timber for export to Europe and other colonies was soon noted as economically important in the 19th Century, and this trade caused substantial tension with local communities in terms of forest governance and access in many locations [44], as Forest Reserves were established in many colonies that excluded local extractive uses. In 1834, Campbell [45] noted the burgeoning export

of numerous mangrove products, including timber, from the Australian colonies to China. Other trade routes existed between East Africa and the Middle East (a common trade route for centuries), where famous "Zanzibar rafters" were made from *Rhizophora* spp. and exported widely [38], Export was possible due to the "*almost inexhaustible supply of wood*" for timber from East Africa [46] (p. 454).

Figure 4. A household charcoal kiln at the edge of a mangrove forest in north Sumatra, Indonesia. Photo by author.

Many mangrove forest species, especially the genus *Rhizophora* were also highly valued as firewood due to its high calorific value [24] (Figure 4). Firewood supplies were important for colonial trade, as many steamer ships required regular supplies of wood for fuel. An expedition in the Indus Delta, Pakistan specifically identified locations of mangrove for fuel wood for the resupplying of steam ships [47], as this location was on an important trade route between Europe and Asia. Thus, mangrove resources were an important contributor to large-scale and economically important colonial trade.

3.1.3. Non-Timber Forest Products

A range of non-timber forest products are extracted from the mangrove forest by local communities today, including food, animal feed, and medicine [24,25]. Perhaps as a curiosity, colonial writers wrote about similar indigenous use of mangroves in nine articles (31% of all provisioning service articles and 23% of all ecosystem service articles). Mangrove propagules such as *Avicennia* can be a food source, though are often boiled for a few days to reduce bitterness [48]. In 1866, Thozet [49] described the preparation of *Avicennia* propagules by Australian aborigines; a fire pit was dug and covered with heated stones, upon which the *egaie* (=*Avicennia*) fruit were placed with a sprinkling of water. This was covered by mangrove bark to allow the *egaie* to steam for two hours. The *egaie* were then rinsed twice with freshwater before they were fit for eating. Thozet [49] described how this was used as a food source during the north Australian wet season when other food sources were not available.

In the 19th century, colonial use of mangroves also focused on economically important and exportable non-timber forest products, especially the use of mangroves in tanning leather, which was referred to in three articles between 1823 and 1883. Species such as *Rhizophora mangle* were used due to their high tannin content. The tanning process is described by Stenhouse [50] in his review of tanning techniques published in the *Proceedings of the Royal Society of London*, where tannins were extracted from the bark by adding the wood to a solution of lead acetate and concentrated sulphuric acid. Tanning was a large and economically important industry in the 19th century, which mangroves contributed to substantially.

3.2. Regulating and Supporting Ecosystem Services

3.2.1. Wave Attenuation

Mangrove forest vegetation can attenuate incoming hydrodynamic forcing under certain conditions due to friction caused by the complex above-ground root architecture and the mangrove surface. Wave attenuation is an important focus in contemporary mangrove ecosystem service research, with numerous laboratory and field studies quantifying the processes contributing to wave attenuation, and the degree of attenuation under different hydrodynamic and meterological conditions [6,51]. An appreciation of hydrodynamic energy attenuation services by mangrove vegetation was only interpreted in one report in 1875, where mangroves in Tanzania were observed to "*grasp the depths and grapple with the floods*" in the Rufiji Delta [52] (p. 183). Regulating services, such as wave attenuation, are probably poorly recorded because they were not the focus of expeditions, which focused on ecosystem services of relevance to colonial economic enterprises, such as finding areas for settlement or identifying other ecosystem services for export), and they are largely 'invisible' and occur over different temporal scales, so are hard to observe and measure.

3.2.2. Erosion Control and Sediment Accretion

Mangrove forests provide a regulating ecosystem service through their role in the local sediment budget. A key foundational concept in mangrove science is the role of minergenic mangroves in trapping and consolidating sediment, leading to long term surface elevation change [53,54]. Positive elevation change allows mangrove vegetation to remain in the same relative position in the tidal frame as sea levels rise over the long-term, and a reduction in sediment input is a key factor in mangrove vulnerability to sea level [55].

Only seven reports (18% of all ecosystem service reports) commented on the ability of mangrove vegetation species to encourage sediment deposition and consolidation through their root systems, as roots cause friction against incoming hydrodynamics, slowing down the water and encouraging sediment deposition; a process quantified experimentally [56]. For example, on an expedition along the River Rovuma in Tanzania, Kirk [57] noted that mangrove vegetation was "*admirably adapted to consolidate and favour the deposit of alluvial matter*" (p. 156) coming down stream. A later expedition revisiting East Africa similarly noted that mangroves along the Kenyan coast were able to intercept alluvial silt, from which "*the level of the country was raised*" [58] (p. 505). It is interesting to understand how Kirk and Cameron observed this aspect of mangrove forest biogeomorphology, as observable accretion would take place over multiple years, so would not be readily observable in the same site by the same observer over the short period of their survey. Unfortunately, neither author elaborates on how these observations were derived.

Generally, it was considered that regulating services such as sediment accretion were only described in the early 20th century [20,30] with only isolated descriptions of such processes in the 19th century. Curtiss [59], writing in a local journal in 1888 is generally credited with being the first to describe soil and elevation processes, where the theory of biogenic mangroves as "land builders" (building land from the production of organic matter from dead roots) was first derived from observations in Florida, USA. The early descriptions by Kirk [57], Cameron and Burton [58] of

mangroves as 'land stabilizers', where mangrove roots consolidate and accrete mineral sediment, were largely absent from the early paradigms of mangrove biogeomorphology due to the poor accessibility of their reports and observations. Instead, mangroves were considered primarily of 'land builders' through autochthonous organic matter production, based on observations skewed towards biogenic mangrove systems in North America and the Caribbean. This paradigm held until the mid-1970s, when the role of mangroves in accreting and stabilizing sediment was more strongly appreciated, such that biogenic mangrove systems are now not considered representative of mangroves globally and the land building paradigm is no longer broadly accepted [30,60].

3.3. Cultural Ecosystem Services

Cultural ecosystem services refer to a range of tangible and non-tangible social benefits, including tourism, recreation, sense of place, and spiritual and aesthetic values [1]. Cultural ecosystem services are relatively neglected in contemporary ecosystem services research, and this is particularly the case when considering mangrove forests, where few contemporary studies exist [11,12]. This was also the case between 1823 and 1883, where only three reports (8% of all ecosystem services articles) discussed the cultural value of mangrove forests for local communities in the Pacific and Australia. It is important to note that the focus of these articles is not on cultural ecosystem services provided to the colonial writers, but rather their interpretation of cultural ecosystem services that are extracted by local indigenous populations. The relative lack of articles on this topic is perhaps surprising, as many anthropological texts existed during this period, though few focused specifically on the cultural role of mangrove forests and their products.

MacDonald [61] describes strong spiritual links between mangrove forest and local communities in Fiji, with particular deities and legends associated with different components of the mangrove ecosystem:

> "*A small portion of the mangrove-beach on the right hand bank, bounded by two small creeks, and pointed out to us as the residence of a foolish god, who once ordered the Mbau* [=tribe] *canoes to bring him food on one side of the river, and those of Rewa* [=tribe] *on the other. But this order was repelled, although both parties entertained a certain amount of respect for him. Another god, on the opposite side of the river, usually amused himself by making sarcastic comments on the people passing by in their canoes*" [61] (p. 324).

MacDonald continues in this article to explore other spiritual aspects of the mangrove forest. The spiritual importance of mangroves was so strong in this instance that it was taboo for people to touch (and presumably cut) the trees. Religion has been shown in other examples to be an important driver of forest conservation, either through taboo or sacred edicts [62]. The mangrove forest was also incorporated into fears of inter-tribal war, which were common in Melanesian culture [63]. As such, the mangrove became a place of warning and of offering:

> "*it is held so sacred that ever one passes through it in silence, it being tambu [= taboo] even to touch the overhanging boughs of the tree. The presiding deity of this canal is repute to possess a lali (drum) so large as to require eight persons to beat it. He is known by the name of Mburerua, and when his lali is heard, it is considered an indication from heaven that all the neighbouring tribes will be involved in war. The present Mbau chief is known to have propitiated* [=regained favour with] *this deity with turtle and large pigs in troublous times*" [61] (p. 324).

Mangrove forests have also played a spiritual role during burial ceremonies. The anthropologist Charles Staniland Wake described Australian aboriginal ceremonies where the dead were buried in a grave and covered with mangrove saplings [64], while in Papua New Guinea the dead were left exposed in the forest as a method of preservation [64]. The role of mangrove forest in such ceremonies may have declined in many indigenous communities, especially with the spread of Christianity during the Colonial Period, though some coastal communities still use mangrove forest resources for spiritual ceremonial use today [11].

4. Ecosystem Disservices of Mangrove Forests

Ecosystem disservices can result from the deliberate negative manipulation or disturbance of an ecosystem, or—as we assume is the case of mangroves in the 19th century—the negative functioning of a relatively undisturbed system [17,65]. Ecosystem disservices were described in 59% of articles, and in general, the tone of language used to describe the mangrove ecosystem in most of the 96 reports studied was negative—impenetrable, gloomy, monotonous, never-ending, etc. Two reasons may have accounted for this perception. Firstly, as colonial explorers, the focus on disservices as opposed to services may be because mangrove forests did not (with the exception of timber and selected other non-timber forest products such as tannins) readily supply exportable services of economic interest to colonial traders; Secondly, European colonizers were exploring new lands, where there was a stronger fear of the unknown and unseen. Several ecosystem disservices are explicitly described in these early colonial accounts, from gloom to disease to danger. These are a mix of actual and socially-constructed disservices [17]. It is unlikely that local indigenous populations inhabiting the mangrove environment would perceive the same list of ecosystem disservices. Such colonial perceptions of ecosystem disservices may still subconsciously influence perceptions of mangrove forests today, which have substantially less public awareness than 'charismatic' coastal ecosystems such as coral reefs [66].

4.1. Mangroves as Dark and Gloomy

During the 19th century, regions being colonized were often portrayed as unknown, isolated, dark, and savage. Euro-American discourses constructed during this time, such as the 'Dark Continent' of Africa, justified the colonization [67] of such hostile environments through the superiority and enlightenment of colonial nations [68]. The exotic mangrove ecosystem, different from any forested habitat encountered in Europe, was no exception. Mangrove forests were inhabited by dangerous and unfamiliar animals [68] and dangerous indigenous populations (Section 4.2), so were variously described in 16 articles (28% of all ecosystem disservice articles) between 1823 and 1883 as "dark", "gloomy", "fetid", "dismal", and a site of "melancholy". This was an important ecosystem disservice that discouraged exploration of mangroves, until they could be colonized [68] by conversion to agricultural development [69].

From the perspective of a ship-borne survey, mangrove forests "*line the bank with an impenetrable dark fence, cutting off all view of the land by the density not only of their foliage, but of the inter-weaving trunks, projecting roots, and rooting branches—characteristics of this singular tree too well known to need further description, but noticeable as giving one uniform sombre air to all the river scenery of the coast*" [70] (p. 198). Sailing along a coast, mangrove forests were perceived as a monotonous and impenetrable barrier, reducing access to the firm, dry land and its economically important resources beyond. The presence of *Rhizophora* in particular is described in this quote as contributing to its impenetrable nature, and was mentioned by other explorers, with "*the visible boundaries of the river in all these branches being an endless confusion of the arching roots of the mangrove, the only occupant of this swamp*" [71] (p. 483). Thus, the mangrove forest's iconic and uniquely adapted flora may have contributed to this perceived ecosystem disservice.

4.2. A Place of Danger

A particular disservice that contributed to the broader view of mangrove forests as unwelcome and gloomy by colonial explorers were the dangers contained in mangroves, specifically dangerous animals and perceived aggressive human groups inhabiting the forest. For example, Vice-Admiral Robert FitzRoy (the Captain of the HMS Beagle, accompanied by Charles Darwin between 1831 and 1836) discussed the dangers of mangroves when writing in 1850 about the potential for a canal across the isthmus of Central America (later becoming the Panama Canal). In his essay to the Royal Geographical Society, FitzRoy [72] describes the need to consider ecosystem disservices when determining the

proposed location of the canal. FitzRoy in particular highlights local traditional knowledge, where local guides avoid routes through mangroves due to the presence of dangerous animals such as snakes and alligators. In the same discussion, FitzRoy also alludes to the danger posed by other indigenous users of the mangrove forest.

The danger posed by indigenous communities frequenting the mangrove forest habitat is a theme continued in many reports. As most colonial explorers describe their travels along the coast by ship, mangrove forests provide a backdrop with which to observe initial contacts between colonial explorers and coastal indigenous communities. Mangrove forests were heavily used by many indigenous communities due to the provisioning ecosystem services described previously, though interactions between these groups in the mangrove zone meant that this was perceived by colonial writers as an ecosystem disservice of mangroves; mangroves and other forested habitats were viewed as dangerous as they were seen to be the refuge or hiding place of 'dangerous' indigenous communities [69].

Several reports describe contacts between British sailors and aboriginal communities in the 1860s–1880s during the expansion of colonies into northern Australia. For example, the newly formed government of Queensland explored the northeast coast of Australia around the mouth of the Burdekin River in August 1860, opening the area to two expeditions of settlers (overland and by sea) in 1861. The expedition between Gloucester Island and Halifax Bay is described by Captain Jacob William Smith. Smith describes a number of interactions with aboriginal groups along the coast during this expedition. None of these interactions occur in the mangrove forest, though mangroves are discussed negatively in this context. The presence of aboriginal groups was suggested through the appearance of footprints in the mangrove, and thus mangroves were avoided as at low tide the sailing exploration party would be placed "*in an extremely dangerous position, in the event of an attack from the natives*" [73] (pp. 8–9).

4.3. Sickness and Bad Air

One of the most common ecosystem disservices attributed to mangrove forests was their perceived role in acting as a reservoir for disease, either through 'bad air' or more rarely as a breeding ground for disease vectors such as mosquitoes. The perception of ecosystem disservices such as disease had a profound impact on mangrove forests historically, leading to the global drainage of wetlands throughout the early 20th century [15,74]. In this study, this ecosystem disservice was reported in 34 articles (60% of the ecosystem disservice articles, and 35% of all articles surveyed). Many of the commissioned survey ships were identifying suitable new locations for settlements, penal colonies or agricultural sites, so observations of health were an important determinant of settlement establishment [74,75]. Colonial settlements were used as early epidemiological case studies, with observations of basic, large scale patterns in disease epidemiology related to distance from mangroves [76,77].

For centuries, diseases such as malaria (its etymology derived from the Italian for *bad air*) were thought to be caused by vapors emitted from the decaying of organic matter, or miasma [21]. The miasma theory for malaria or 'marsh fever' transmission dominated for approximately 2000 years until the late 19th century, when in 1851 the link between malaria and marshes was first refuted in the medical literature by the American physician Charles E Johnson, with evidence for mosquito-borne transmission provided in 1883 -21]. This makes the time period of this study an interesting one to observe the shift in theories of transmission. Of the 24 articles that specifically ascribed a cause of malaria, 83% attributed malaria to miasma. Malaria was assumed to be caused by winds that were "*loaded with vegetable exhalations, with which it impregnates itself while sweeping over the immense uninhabitable swamps and oozy mangrove thickets of the sultry regions of Benin*" [27] (p. 266). While most observers attributed the miasma to decaying plant organic matter and peat soils of the mangrove, some attributed it to "*exhalations which are materially increased by the decomposition of numerous mollusca, insects, and crustaceous animals, which seek shelter from the waves among the interlaced roots, and frequently*

perish there" [78] (pp. 23–24). The miasma itself was assumed by Captain FitzRoy to be composed of compounds commonly associated with the mangrove forest, such as sulphur and carbonic acids [72].

Some articles began to disprove mangrove miasma as a cause of malaria, where it was observed by medical practitioners that malaria and similar diseases occurred in parts of Africa without extensive mangrove forests, and parts of Australia had extensive mangrove forests but no fever [79]. However, only two articles (8%) correlated malaria with mosquito populations in mangroves. For example, in East Africa, Kirk [57] noted this correlation when he wrote "*damp mangrove-forests, loaded with malaria and mosquitoes, where the sun seldom pierces through the leaves above*" (p. 155). Observations began to question the causal link between miasma and malaria, when in 1876 the surgeon WJ Eames suggested in the *British Medical Journal* that miasma or 'night air' as a cause of malaria was a fallacy, as sailors who slept below deck as opposed to sleeping in the open on deck still caught malaria [80].

5. Conclusions

Mangrove forests are located in a position in the landscape where human populations abound [81]; the myriad benefits mangroves provide to these coastal populations means that mangrove forests have long been viewed through the lens of ecosystem services and disservices, even if this paradigm is considered a recent one. This study has shown that ecosystem services and disservices were an important lens with which colonial researchers and explorers characterized mangrove forests since at least 1823.

This study showed that ecosystem disservices, relating to negative aesthetic perceptions (gloominess, monotonous, mangroves as a seemingly impenetrable barrier), or real danger and disease, were more predominant, which is different to our contemporary ecosystem services research agenda. A focus on ecosystem disservices during this period is not surprising, as colonial discourses during this time period focused strongly on colonizing areas as isolated, hostile, and dangerous, in part to justify their colonization [67]. However, while a focus on ecosystem disservices can be understood, it may be expected that provisioning services would be ranked more highly, due to the direct benefit that can be extracted. Ecosystems, and their services and disservices, can affect or be used by different communities in different ways [17]. The records used in this study are a colonial representation of mangrove forests and are thus skewed by this viewpoint, where mangroves were viewed as a barrier or home to dangerous animals, people, and disease. A literature more representative of all coastal users, such as indigenous populations (if available), would probably focus more on the ecosystem services that those populations derived from the mangrove.

In summary, historical accounts are important to understand how particular groups previously utilized and perceived mangrove forests, and how paradigms such as ecosystem services change over time. When moving forward with the ecosystem services agenda, it is important to consider how sources such as archival material can be used in a novel way to shed light on the rich history of ecosystem services (and disservices) research.

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