Chapter 10
Threats to Mangroves and Conservation Strategies

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Abstract Mangroves are productive and biodiverse ecosystems found in the intertidal zones of the tropics and sub-tropics which provide multiple goods and ecosystem services for humanity that are of ecological, economical, social and cultural importance. However, mangrove ecosystems are vulnerable because of several threats. The threats vary globally, regionally and locally. Mangroves can be affected by several different threats simultaneously, or over time as land use patterns change. There are some natural threats such as shoreline erosion and typhoons but predominantly they are human induced such as overexploitation, conversion and encroachment of mangrove habitats for agricultural and settlement purposes, aquaculture, a decline in freshwater and silt deposition and heavy metal pollution. Together with predicted climate change including global warming, sea level rise and extreme weather events, there will be further threats to mangrove ecosystems in the future. Mangrove conservation, restoration and rehabilitation are now being addressed through international agreements, protected areas, integrated policies and planning, reformed government structures, capacity development and environmental education but mangrove biodiversity conservation policies cannot succeed unless there is also consideration given to livelihoods and local communities are involved in all aspects of mangrove planning and management to promote sustainable conservation of mangrove biodiversity for the future.

Keywords Impacts · Pressures · Management · Restoration · Protection · Policy

10.1 Introduction

Mangrove ecosystems are found on the coastlines and river deltas of the tropics and sub-tropics and currently face many threats. Some threats are natural such as shoreline erosion and typhoons but predominantly they are human induced

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Table 10.1 Range and scale of the threats to mangroves in three major regions of the world

Threat	South and Southeast Asia	Central and South America	Africa
Natural disasters	Low-high *Increasing*	High *Increasing*	Medium *Increasing*
Climate change	Medium-high *Increasing*	Medium-high *Increasing*	Medium-high *Increasing*
Population pressure	High *Increasing*	Low-medium *Increasing*	High *Increasing*
Over-exploitation by traditional users	High *Increasing*	Low *Stable-decreasing*	Medium *Increasing*
Urban and industrial development	High *Increasing*	Medium-high *Increasing*	Low *Increasing*
Coastal pollution	Medium-high *Increasing*	Medium-high *Increasing*	Low *Increasing*
Hydrological diversions, e.g. dams	Medium-high *Increasing*	Low-high *Increasing*	Localised medium-high *Increasing*
Forestry	High *Stable*	Low *Stable*	Medium *Increasing*
Aquaculture	High *Increasing*	High *Increasing*	Low *Increasing*
Agriculture	High *Decreasing*	Low *Stable-decreasing*	High *Increasing*
Mining	Low-medium *Decreasing*	Low *Decreasing*	Medium *Increasing*
Tourism	Low-medium *Increasing*	Low-medium *Increasing*	Low *Increasing*
Management shortcomings	Medium-high *Decreasing*	Low-high *Stable*	High *Stable*

Adapted from Macintosh and Ashton 2005

(Goldberg et al. 2020; Thomas et al. 2017). Humans can exploit mangroves in many ways and have many impacts upon them. The threats to mangroves vary globally, regionally and locally (Macintosh and Ashton 2005). Mangroves can be affected by several different threats simultaneously, or over time as land use patterns change (Table 10.1). Together with predicted human-induced climate changes, global warming and rises in sea level, there are going to be further extreme weather events and shoreline erosion (Field et al. 2014; Maina et al. 2021) with further long-term implications for mangrove ecosystems (Feller et al. 2017).

Mangrove ecosystems were described by early explorers as smelly and hostile environments (Mastaller 1997), which lead them to being undervalued and converted to alternative uses by European colonisers such as the mangrove bark used for the production of tannins and manufacture of leather (López-Angarita et al. 2016). Traditionally, local communities exploit mangroves for timber, thatch and fuelwood. Extraction of certain sizes and species and physical disturbance of the habitat mean that most mangroves have been affected to some degree and few are now pristine (Hogarth 1999). Local subsistence use of mangroves for fishing, food and medicines is undervalued but can be substantial and important (Bandaranyke 1998). Over-exploitation occurs when population pressure increases and there are other threats to livelihoods from outside influences.

Increasing populations and intense urbanisation have made many mangrove deltas into large cities, for example in Asia: Mumbai and Kolkata in India; Bangkok, Thailand; Manila, The Philippines and Jakarta, Indonesia. As well as urban and industrial development mangroves have been converted to agriculture such as oil palm plantation, aquaculture including intensive shrimp farming, salt ponds, forestry and mining (Ashton 2008; Richards and Friess 2016). Sometimes mangroves have faced indirect and accidental threats such as coastal pollution by oil (Amarachi and Kabari 2020; Duke et al. 1997) or alteration of hydrological regimes further upstream. Other off-site activities can lead to mangrove degradation through siltation and changes in water flow and water quality, especially salinity change and changes due to water pollution (Pons and Fiselier 1991). Contaminants may be directly toxic to some marine organisms and their effects may be instantaneous or cumulative. Introduction of exotic species can also cause loss of biodiversity and habitat through competition with native species.

Threats to mangroves predominantly cause a loss of mangrove area. Baseline data for original mangrove extent are unclear from scant historical mentions and marine charts and may never be realised (Alongi 2002) but since satellite remote sensing in the 1970s, global estimates have been estimated and changes monitored (Bunting et al. 2018; Giri et al. 2011; Spalding et al. 1997, 2010; Thomas et al. 2017; Valiela et al. 2001; Worthington et al. 2020). There has been substantial loss in mangrove area with loss in some regions of 50% to 80% (Wolanski et al. 2000) and also declines in terms of biological diversity and forest structure (Bryan-Brown et al. 2020).

An increasing understanding of the importance and value of mangrove ecosystems for provisioning ecosystem services, such as timber and fuelwood and fisheries, supporting and regulatory services such as nutrient recycling, habitat provision, shoreline protection and carbon storage (Lee et al. 2014; Donato et al. 2011) and cultural services (Liquete et al. 2013) has led to recognition of the environmental, social and economic impacts associated with the decline and degradation of mangroves. This is now being addressed through legislative, management, conservation and rehabilitation efforts across mangrove regions (Macintosh and Ashton 2005).

10.2 Natural Threats to Mangroves and Climate Change

Natural causes were attributed to 38% of total mangrove loss from 2000 to 2016, with shoreline erosion (SE) and extreme weather events (EWE) attributed to 27% and 11%, respectively (Goldberg et al. 2020). All mangrove regions are affected by SE and EWE such as cyclones, droughts, heatwaves or extreme floods. However, the Sundarbans seaward edge in Bangladesh had the highest loss with SE contributing to nearly 80% national losses and Oceania lost almost 50% mangrove due to EWE (Goldberg et al. 2020).

Shoreline erosion occurs as a result of sea level rise, rainfall, temperature and wave activity and with predicted climate change scenarios this will increase (Gilman et al. 2007, 2008; Chap. 8). In future, the threats will increase from more severe and intense extreme weather and shoreline erosion and this should be taken into consideration in government policy. Mangroves helped mitigate the deleterious impact of the 2004 tsunami waves (Kathiresan and Rajendran 2005) and provided protection against May 2008 cyclone in Myanmar (UNEP Report 2009). There is mounting evidence to prove that dense mangrove forests are natural shields against cyclones, storm surges and tsunamis (Sandilyan and Kathiresan 2015). Greenbelts and buffer zones where natural phenomena such as typhoons, tidal surges and cylones and natural geomorphic erosion processes have a significant adverse effect on the coastline should be adopted and given strict protection. For example in the Mekong Delta in Vietnam, a 500 m to 1 km wide green belt (Full Protection Zone) was enacted to protect the coastline from storm and flood protection (Macintosh and Ashton 2005).

10.3 Population Pressure

The primary agent of mangrove loss from 2000 to 2016 was human activity 62%, although only 3% was due to conversion of mangrove forests to human settlements and the loss and threat are declining (Goldberg et al. 2020). Rapid urban expansion was still seen into adjacent mangrove forests in Ho Chi Minh City, Vietnam and Bangkok, Thailand, Lagos, Nigeria and Conakry, Guinea but it declined from 2000 to 2016 by 65% (Goldberg et al. 2020).

However, pollution from human activities and settlements, including garbage, plastic, sewage, oil and industrial effluents, solid and toxic wastes are major threats to mangrove ecosystems. Harris et al. (2021) identified 54% of mangroves are within 20 km of >1 ton/year plastic pollution source. Waste disposal from urban, industrial, agriculture or aquaculture sources should be carefully regulated. The inputs of organic matter, nitrogen and phosphorus compounds into estuaries' coastal waters should be kept to an absolute minimum through the use of adequate treatment before discharge. This is particularly true in the more stagnant mangrove channels where eutrophication can lead to anoxic (oxygen depleted) conditions, and severe degradation of the aquatic system. This requires that appropriate practices to eliminate, minimise or mitigate the impacts of pollution should be enforced (Macintosh and Ashton 2005).

The legal framework should also provide mechanisms to ensure that full and independent Environment Impact Assessments (EIAs) are conducted for development activities that could impact on mangroves. Physical infrastructures such as embankments, roads, dikes, ponds and canals may affect the normal tidal flow, surface run-off and sediment deposition dynamics along mangrove coastlines, even if they are not physically located within mangrove areas. Thus, EIAs should include assessment of the impact of infrastructure development projects on the hydrological regime both upstream and downstream of the proposed development site (Macintosh and Ashton 2005).

Local communities and traditional indigenous peoples who are highly dependent on mangrove resources for their livelihoods should be involved in their conservation and management. Education and involvement in enforcement of sustainable levels of extraction can lead to positive protection of mangroves. For example, the fishermen associations Agreements of Sustainable Use and Mangroves (AUSCEMs) in Ecuador (Chap. 19) and Joint Forest Management Committees in India (Chap. 11). Sustainable livelihood options should be identified and encouraged within prescribed limits (e.g. catch size, licenses, harvest quota, zoning) such as small-scale artisanal fishing, crab catching, shellfish harvesting eco-tourism and apiculture. Where existing activities result in unsustainable utilisation of mangrove resources, alternative livelihoods and income- generating activities should be suggested with basic training and support given.

The cultural, historical and other traditional associations with mangroves should be protected and integrated into mangrove conservation and management plans. The values and potential applications of traditional knowledge related to mangroves such as the use of traditional medicinal plants should be documented (Chap. 5).

10.4 Forestry and Silviculture

Logging was the second most prominent anthropogenic activity to cause 8.3% global mangrove loss from 1996 to 2010 and was almost exclusively in Southeast Asia (Thomas et al. 2017). Mangrove forestry for example for wood chip was very unsustainable in Malaysia in the 1970s (Ong 1995). Woodchips and pulp for the paper industry from mangroves are still a threat in Indonesia. Fuelwood collected by local communities and the use of mangroves for grazing by cattle can cause significant local threats in Africa and Asia. Energy plantations of mangrove or another fast-growing timber tree such as Acacia for fuelwood in adjoining areas to protected mangrove areas could be managed so as to discourage conservation areas being cut for fuel wood consumption. Also the use of fodder depots can help reduce pressure of livestock grazing in mangrove areas.

The cutting of mangroves for fuelwood consumption and the making of charcoal can be managed sustainably. For example, the Matang Mangrove Forest Reserve in Perak, Peninsular Malaysia has been under sustainable management by the State Forest Department since 1902 under a 30-year rotation for charcoal production with thinnings at 15 and 20 years for poles, although predominantly mono-specific *Rhizophora apiculata,* it does have some protected virgin forest areas within its 40,000 ha (Goessens et al. 2014; Ashton 1999).

The management of mangrove forests should have clear objectives. If the area is pristine virgin mangrove forest or near pristine, it should be immediately protected and conserved for biodiversity. Areas should also be protected for biodiversity conservation to maintain all endemic and rare species such as the Tiger Reserve in Sundarbans. Priority should also be given to protecting mature stands that are reproductively viable, even in disturbed areas reproductively active trees and shrubs are valuable as seed stands that are important in sustainable forest management and restoration and rehabilitation of mangrove forests.

Assessment of mangrove forest via aerial photographs, satellite mapping (Bunting et al. 2018; Giri et al. 2011; Spalding et al. 1997, 2010, Thomas et al. 2017; Chap. 4), ground truthing and an in depth understanding of species composition, structure, biology and ecology (Chaps. 2 and 3) should be used to assess the area for mangrove forest management, silvicultural utilisation, restoration and rehabilitation. Natural regeneration should be allowed wherever possible. If natural recovery and regeneration does not occur, active interventions such as restoring the natural hydrology and mangrove planting will be required. Use local mangrove species for rehabilitation and if large areas are required to be planted, the establishment of mangrove nurseries may be necessary. Involvement of the local people at all stages from planning, to site selection and design, seed and propagule collection, nursery management, planting and maintenance and protection of mangroves is important.

There are many successes and failures of mangrove forest restoration, although not all are documented, or are difficult to obtain in non-peer reviewed literature and project reports, but some examples are given in the Country case studies in this book and in several other papers (Ellison et al. 2020; Field 1998; Lee et al. 2019; Lewis et al. 2019; Worthington and Spalding 2018). Survival of mangroves is 60–90% over 10 years and reasons for failures are typically where there is poor planning, a desire for a rapid fix, or a lack of ecological understanding leading to restoration of the wrong locations, or planting with the wrong species (Worthington and Spalding 2018). Mangroves are mostly restored with one species (175 cases) typically *Rhizophora apiculata, R. mucronata or Avicennia marina* but mixed species had better restoration outcomes and biomass production (Su et al. 2021). Habitat complexity and diversity are important to maintain for ecological function, biodiversity and abundance of associated mangrove fauna (Ashton et al. 2003a, 2003b), although the actual extent of biodiversity-function relationship is not known and further research required (Lee et al. 2014). The precautionary approach for multi-species restoration is advocated where possible.

Mangrove restoration has substantial potential to contribute to multiple policy objectives related to biodiversity conservation, climate change mitigation and sustainable development and offers positive benefit-cost ratios making it an effective form of ecosystem management (Su et al. 2021). Mangrove restoration opportunities exist in every region and a Mangrove Restoration Potential Map (maps.oceanwealth.org/mangrove-restoration/ (Worthington and Spalding 2018)) provides information globally, by region and country on total restorable area and values obtained for restored areas by ecosystem services of soil organic carbon, aboveground carbon, people protected, commercial fish catch and commercial invertebrate catch enhancement value.

10.5 Fisheries

Mangrove fisheries have worldwide importance in providing subsistence food and income for a wide range of stakeholders and millions of people. The fisheries production value of mangroves is USD 708–987 ha^{-1} $year^{-1}$ (Barbier et al. 2011). Mangrove species, density, habitat quality, area and primary productivity are important components in maintaining fisheries and providing suitable reproductive habitat and nursery grounds and sheltered living spaces. Loss of mangrove areas and degradation as well as overfishing has led to a loss in mangrove fisheries production and livelihoods. However, mangrove restoration and rehabilitation can bring about a rapid return to fish and invertebrate fisheries, so mangrove nurseries and breeding habitats for fish, crustaceans and mollusc species important to subsistence and or commercial fisheries should be protected. In partnership with local fisher communities, areas should be clearly demarcated for regulated access for non-destructive fishing. Prohibiting fishing within clear defined areas and prohibiting and enforcing destructive fishing practices such as using very fine nets, dynamite and poison should be with full participation and education of local fisher groups.

10.6 Aquaculture

Fish and shrimp aquacultures in mangroves have been carried out for centuries (Ashton 2008) but in the 1960s and 1970s, conversion of mangroves to aquaculture ponds was encouraged in SE Asia (Thailand, Indonesia, the Philippines and Vietnam) to enhance food security and improve livelihoods (Hishamunda et al. 2009). Global shrimp production was 9022 t in 1970 (FAO 2021) but during the 1980s and 1990s, tropical coastal commercial aquaculture had a rapid expansion and displaced 54% of all mangroves that have been lost in Thailand, Indonesia, Vietnam, Brazil, India, Bangladesh, China and Ecuador although there are regional variations (Hamilton 2013). Increasing demand, supply and value of shrimp have led to unsustainable farming practices and large-scale commercial enterprises. Integrated, mixed or mangrove-friendly aquaculture practices with community-based management and stewardships and mangrove rehabilitation are more sustainable for example in Vietnam (Bush et al. 2010) and the Philippines (Primavera 2000). However, the current global market for shrimp is valued at USD 45 billion (FAO 2021), so aquaculture is still a dominant threat to mangrove deforestation especially in Indonesia (Richards and Friess 2016).

As well as the loss of mangroves due to conversion to shrimp farms, there is also a loss of important ecological and socio-economic functions, changes in hydrology, salinisation, introduction of non-native species and diseases and pollution from effluents, chemicals and medicines, use of wild fish for feed, capture of wild shrimp seed and loss of livelihoods and social conflicts (Ashton 2008). There is a removal of

C sequestration capacity and also an increase in C emission as with all clearing of mangroves (Sidik and Lovelock 2013).

Global awareness about the need to reduce the impacts of shrimp farming and the importance of sustainable use of mangrove ecosystems has led to a number of international, national and local guidelines, policies and certification schemes, such as organic or sustainable shrimp (Ashton 2008; Bagarinao and Primavera 2005). No further conversion of mangroves should be allowed for commercial aquaculture and abandoned aquaculture sites should be restored. Critical steps and examples are given by Stevenson et al. (1999). Policies banning mangrove utilisation for shrimp farms are now actively promoted in many countries but they are still not always enforced. Further, awareness raising of consumers in the USA and Europe will drive promotion of ecologically sustainable and socially respectable farmed shrimp (Ashton 2008).

10.7 Agriculture and Mining

Commodities, a combination of shrimp aquaculture and agriculture of rice and oil palm cultivation, were the primary global driver of mangrove loss 47% from 2000 to 2016 and non-productive conversions for petroleum extraction and resource mining caused 12% global mangrove losses (Goldberg et al. 2020). Agricultural expansion for rice production, primarily in Myanmar resulted in 20% mangrove loss from 2000 to 2012 and is expected to continue to be a large threat to mangroves in the future (Richards and Friess 2016). Oil palm plantations are also a continued threat to mangroves especially in Indonesia (Richards and Friess 2016). Sand mining and oil drilling have caused high rates of subsidence in Cameroon and Nigeria, respectively. The negative impacts from mining also include turbidity and siltation of waterways, smothering of mangroves with mining sediments and indirect pollution that can last for many years.

Agriculture is generally unsustainable due to the potential acid sulphate soils in mangrove areas and states should not sanction further conversion of mangroves. Full and independent EIAs should be prepared on existing sites so that changes in hydrology are minimised and there are safeguards against pollution with the polluter pays principle implemented to provide incentives for using appropriate technologies (Macintosh and Ashton 2005).

10.8 Tourism, Recreation and Education

Mangrove ecosystems can provide unique habitats and biodiversity opportunities and have great potential for bird watching, viewing wildlife and scenic boat trips but care should be taken not to allow unplanned and unregulated tourism. To minimise potential, negative environmental impacts from tourism on mangroves tourists should be educated and restricted to clearly defined areas such as board walks. The revenue from ecotourism should be used to pay for the conservation of the mangrove ecosystem. The local communities should be involved in all aspects of tourism development, management and associated activities from the beginning and should also benefit directly by being tourist and boat guides.

Education and awareness raising about mangroves are important at all levels from decision makers in national government agencies, regional officials, private sector, local community and school children. Field visits and workshops are good mechanisms for communities to exchange community experiences in mangrove rehabilitation and conservation. The Mangrove Action Project (MAP) has developed a Mangrove Educational Curriculum for school children from kindergarten to ninth grade in the Cayman Islands, and is taking it to other parts of the world, modifying it for local regions and translating into local languages (https://mangroveactionproject.org/marvellous-mangroves-workshops/).

NGOs, international organisations and academic institutions can all assist in developing and implementing practical training courses to develop regional capacity for sustainable mangrove management and monitoring, such as, the MAP Community-Based Ecological Mangrove Restoration (CBEMR) training services (Mangrove Action Project 2019). Visitor information centres, illustrated information boards, posters, brochures, video, social media and walkways have all been shown to be excellent ways for training and awareness for local visitors for recreation and international tourists.

10.9 Management Shortcomings

Historical causes of mangrove loss stem from lack of awareness, failures in policy, management and enforcement of protection measures. Mangroves being on the land water interface have often not had clear management as a whole ecosystem being assigned on a sectoral basis to government institutions either Forestry, Fishery or Agriculture, which has led to prejudices for objectives, conflicts of interest and unsustainable resource use (Friess et al. 2016; Macintosh and Ashton 2002). These limitations are now recognised and effective, and coordinated policy and legal frameworks supported with clear institutional and administrative responsibilities are understood to be required at local, national and transboundary levels to support mangrove management.

At the international level, there are a number of initiatives, conventions, treaties and agreements that can provide support to nations to sustainably manage and conserve mangroves (e.g. Ramsar Convention on Wetlands, Convention on Biodiversity, World Summit on Sustainable Development, FAO Mangrove Forest Management Guidelines and Code of Conduct for Responsible Fisheries, International Tropical Timber Organisation Mangrove Workplan, Mangrove Charter of International Society for Mangrove Ecosystems, World Heritage Convention, United Nations Framework Convention on Climate Change, Convention on Migratory

Species, Global Mangrove Alliance, etc). Protected area frameworks have been ratified at the national level and enabled mangroves to be protected as Ramsar sites, World Heritage sites, Man and the Biosphere Reserves and Marine Protected Areas. There are also a number of transboundary protected areas, e.g. Sundarbans in India and Bangladesh. Worldwide there are now 2500 protected areas with mangroves, equivalent to 54,000 km^2 or 39% world's remaining mangroves (Worthington and Spalding 2018).

It is important that the remaining 61% of mangroves not currently protected be evaluated. Worthington et al. (2020) provide information on a new platform for visualizing and disseminating datasets to the global science community, NGOs, government officials and rehabilitation practitioners through the Global Mangrove Alliance (GMA). This data is hoped to facilitate collaboration and support policy change that benefits both mangroves and the communities that depend on them. However, some mangroves will remain in private or uncertain ownership with no mechanisms to ensure their long-term future, although Sri Lanka has become a model example by being the first nation to protect all of its mangroves (Chap. 13). Accelerating pressures on coastal areas requires at the national level clear integrated coastal zone management plans and marine spatial planning. Penalties for violations should reflect the severity of the malpractices concerned and speedy disposition of cases involving violations of laws and regulation is strongly urged to protect mangroves resources and deter violators (Macintosh and Ashton 2005). Cross-sectoral coordination, planning and implementation are required which include all involved government departments at all levels, working together with all stakeholders (donor agencies, private, scientific, NGOs and local communities). Where local coastal communities are playing an increasing role in planning and development of mangrove biodiversity conservation and management, successful sustainable management results are found around the world.

The corporate sector also has a role to play through corporate social responsibility (Worthington and Spalding 2018). Payments for Ecosystem Services (PES) or blue carbon hold great promise for mangrove conservation by providing a clear policy objective and incentivizing collaboration (Friess et al. 2016). REDD+ (Reduced Emissions from Deforestation and Forest Degradation) creates a financial value for the carbon stored in forests such as mangroves and could enable countries to receive financial payments for reduced emissions through protection and restoration of mangrove forests (https://www.iucn.org/news/asia/201711/mangroves-and-redd-new-component-mff).

10.10 Conclusions

Mangrove ecosystems continue to be under threat and can be from several different activities simultaneously or over time as land use patterns change. Threats can be localised, regional or global and depend on the location and industries such as urban and industrialisation, forestry, fisheries, aquaculture, agriculture and mining. Off-site activities can also lead to mangrove degradation through siltation or changes in water flow and water quality. Natural threats and increased predicted impacts from global climate change of shoreline erosion, sea level rise and extreme weather events provide further future threats to mangrove ecosystems. Loss of mangroves has led to lost livelihoods, food insecurity and lost coastal defence.

There is now recognition of the value essential ecosystem services such as food provision and coastal protection mangroves deliver (Friess et al. 2016; Liquete et al. 2013). The environmental, social and economic impacts associated with mangrove loss and degradation have been realised and mangrove conservation, restoration and rehabilitation are now being addressed through international agreements, protected areas, integrated policies and planning, reformed government structures, capacity development and environmental education.

The primary goal is to stop the threats and reverse past destruction of mangrove ecosystems but mangrove biodiversity conservation policies cannot succeed unless there is also consideration given to livelihoods. Mangrove restoration and conservation policies must improve food security and livelihood opportunities by providing alternative sources of income for local communities dependent on mangrove resources, and together with the introduction of best practices (ownership and sustainability), and joint planning and management promote sustainable conservation of mangrove biodiversity for the future.

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