Coastal high-tide shorebird habitat management guidelines

Image: Neil Fifer

Guidelines for maintaining and managing natural or artificial (i.e. human-created) coastal wetlands to provide suitable high-tide roosting conditions for shorebirds in the East Asian-Australasian Flyway

Summary

- Many coastal shorebird species in the East Asian-Australasian Flyway are threatened and declining.
- Coastal shorebirds are very dependent on coastal wetlands for habitat.
- Decision-makers, landowners and wetland managers increasingly recognise the importance of conserving wetland biodiversity, including shorebird populations. Maintaining and managing high-tide habitat is essential if shorebird population declines are to be halted and reversed.
- "Roosting" is an important period of sleep, rest, digestion and preening that shorebirds require in between feeding periods.
- Coastal shorebirds generally roost for a few hours around high tide when intertidal flats, which are important feeding areas, are flooded by seawater and therefore inaccessible.
- At many sites, on days when the high tide is not too high, shorebirds can roost in the intertidal zone above the water level of the high tide. However, during higher high tides when the intertidal zone is totally flooded with seawater, shorebirds may have no alternative but to roost in "supratidal" areas (those parts of the coast that are never naturally flooded by seawater), or in structures above the water level in intertidal areas (for example mangrove trees).
- Supratidal habitat can be either natural (for example natural salt pans, claypans, or freshwater wetlands) or artificial (for example aquaculture ponds, salt production ponds, dredge spoil ponds, wastewater treatment areas, or human recreation areas). As well as providing roosting habitat, some supratidal areas also provide an additional food source for shorebirds that they can access at high tide when intertidal feeding areas are inaccessible.
- Shorebird roost sites can provide additional benefits to waterbird conservation because they may be suitable for other types of waterbirds that feed in coastal areas to use for roosting, or provide breeding habitat for some shorebird, coastal tern and/or gull species.
- Shorebirds may use different high-tide roost sites at night than those used during the day.
- There are several key features that are important to shorebird roost site choice. These include predation avoidance, disturbance avoidance, energy cost minimisation and supplementary feeding opportunities. Weather conditions, especially strong wind, can also influence where shorebirds roost, and artificial lighting may reduce the suitability of roosts used at night.
- Features of supratidal habitats can usually be managed or maintained to benefit shorebirds, and there is guidance available for doing so that is summarised in this document. Nonetheless, there are several issues related to shorebird high-tide habitat management that require further research, and these are outlined in the appendix.
- Artificial (i.e. human-created) supratidal habitats like aquaculture and salt production ponds are very important to local communities, economies and livelihoods, and were created for this reason. Decisions about management in these areas will often be driven by human needs. Nonetheless, it is often possible to manage ponds to benefit shorebirds without major disruptions to production activities. Indeed, the presence of birds in artificial habitats may provide additional opportunities for local communities and livelihoods, for example by providing opportunities for ecotourism or nature education at the site.
- It is important to consider that individual sites do not operate in isolation from the perspective of the birds. Shorebirds may need to travel between high-tide roost sites depending weather or feeding conditions, or if disturbed at one site. Therefore, regions that support large numbers of shorebirds require multiple supratidal roost sites to ensure that there is adequate habitat available during every high tide period.

Throughout this document, major points that have been established through scientific research are linked to an appendix that lists relevant research documents. If you see "[Ref 1]" in the text, it means please refer to the first document in the section of the appendix called "Useful reference documents" for more in-depth information on this topic.

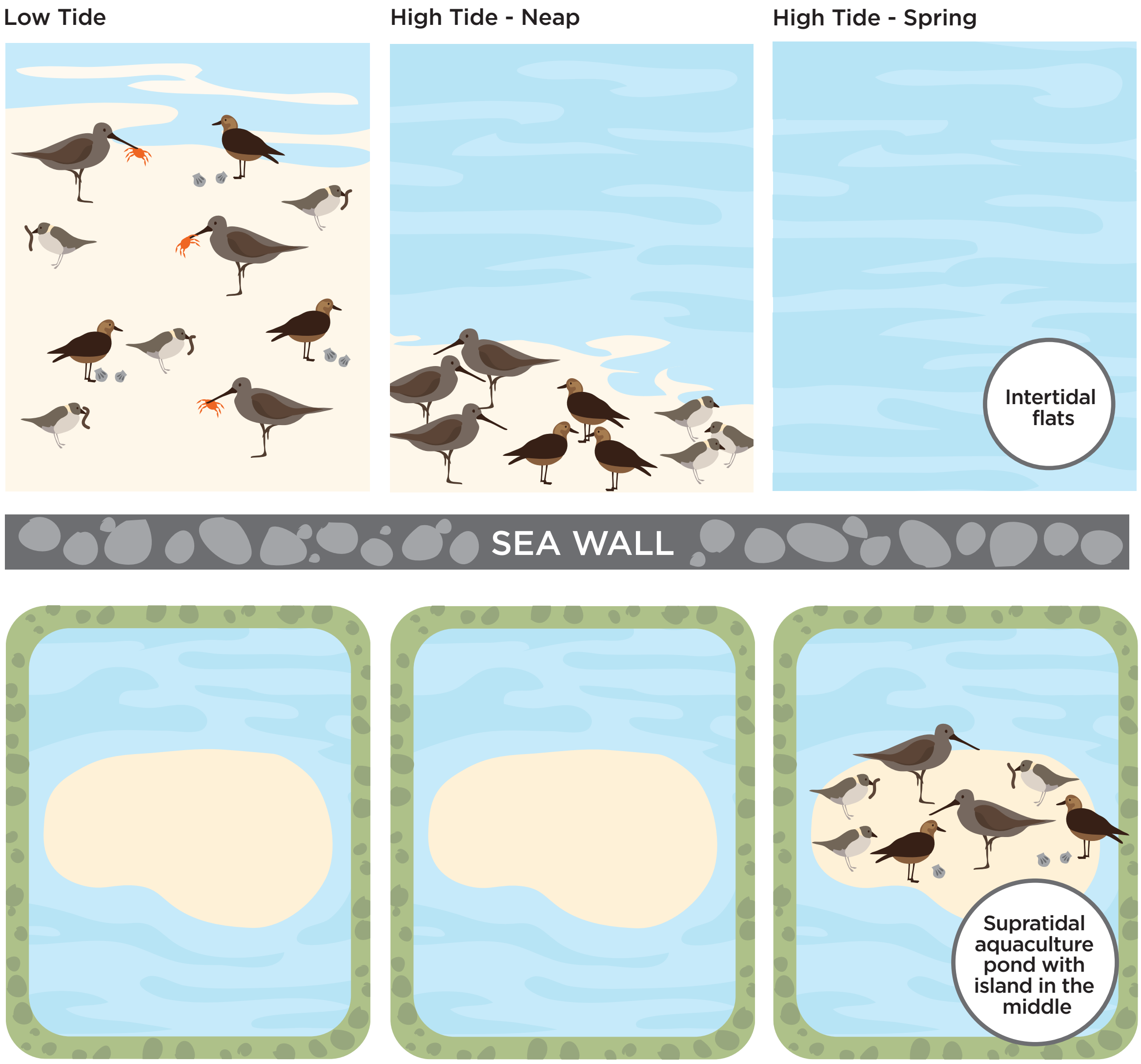
1. Background

What is roosting and why is it important?

Shorebirds (see Box 1) are often associated with very long-distance migration flights and busy feeding movements in shallow, muddy water. However, they also spend up to several hours every day doing something else – "roosting".

Roosting is an important period of sleep, rest, digestion and preening (i.e. feather maintenance) that shorebirds require in between feeding periods [Ref 1]. Shorebirds that are normally widely dispersed for feeding often roost in large, tight flocks in a relatively small area. This is particularly the case for coastal shorebirds, which generally roost during the high-tide period when intertidal flats are flooded by seawater and therefore inaccessible for feeding. In this way, coastal shorebirds – as with other species specialised to living in tidal ecosystems – are different from other animals because their daily movements are more driven by the tidal cycle than the day/night cycle. At lower high tides (called "neap" tides), shorebirds may roost on upper intertidal flats that are not flooded by seawater, while at higher high tides (called "spring" tides) they may have no alternative but to roost in supratidal areas – i.e. those parts of the coast that are never flooded by seawater (Figure 1).

FIGURE 1. TYPICAL COASTAL SHOREBIRD BEHAVIOUR AT DIFFERENT TIMES IN THE TIDAL CYCLE



Like all animals, shorebirds have a physiological need to sleep. Shorebirds most often sleep at roost sites, though little is known about their precise requirements (for example how much sleep they need every day). However, it should be recognised that sleeping is not the only thing that shorebirds do at roost sites. They also "loaf", which means being still and expending as little energy as possible, and do maintenance behaviour such as bathing and preening, which can be particularly important when shorebirds are "moulting" – the time when they shed old feathers and grow new ones.

If there are not enough roosting sites in a region, it may limit the number of shorebirds that can use that area for feeding [Ref 2].

Excessive disturbance of shorebirds at roost sites is detrimental to their physical well-being. Increased energy expenditure caused by flying during roost periods in response to disturbance can reduce energy reserves to levels below those that can be replenished by their food intake rates, and thus negatively affect survival or reproductive success [Ref 3]. This may be particularly the case for migratory shorebirds (Box 2) when they are attempting to put on the extra weight that will be needed to migrate successfully.

Shorebird roost sites may provide additional benefit for waterbird conservation because they may also be suitable for other waterbirds that feed in coastal areas to use for roosting – for example terns, gulls, herons, pelicans, spoonbills and cormorants. Shorebird roost sites may also provide breeding habitat for coastal species including shorebirds (particularly plover, stilt or avocet species), coastal terns and gulls [Ref 4].

Whimbrels roosting on upper intertidal flats during a neap high tide (Image: Micha V Jackson)

BOX 1. WHAT IS A SHOREBIRD?

Shorebirds are a diverse group of waterbirds that share characteristics suited to feeding in shallow water and/or wet mud or sand. They generally have long legs compared to their body size and have evolved a variety of beak lengths and shapes to access different prey below or on top of muddy or sandy substrates. Most shorebirds rely on coastal and/or freshwater wetlands for at least part of their life cycle.

Some shorebird species are coastal habitat specialists that rarely move inland, some are generalists that can move between coastal and inland wetlands, and some are inland habitat specialists [Ref 7]. Coastal shorebirds frequently visit intertidal flats, the muddy or sandy part of the coast that is exposed at low tide and regularly flooded with seawater at high tide, to feed.

Examples of shorebirds (clockwise from top left): Ruddy Turnstone, Australian Pied Oystercatcher, Pacific Golden Plover, Bar-tailed Godwit (images Micha V Jackson).

Shorebird roost choice

Before any decisions about roost site management can be made, it is important to first understand shorebirds' behaviour and preferences in relation to roost sites. In general, shorebirds choose where to roost based on several key features (Figure 1, Figure 2) [Ref 1, 13] including:

Tide height: in some regions, shorebirds have several roosts to choose from. They may only make use of supratidal roosts on the highest tides when alternative intertidal sites are flooded. It is important to understand local shorebird behaviour in relation to tide height to be able to ensure the availability of appropriate roost sites throughout the tidal cycle and under different conditions.

Predation avoidance: shorebirds are hunted by birds of prey and sometimes by land-based mammals such as foxes, cats and weasel species. One benefit of roosting in large flocks, which shorebirds often do, is that there are more shorebird eyes looking for sources of potential danger. To further reduce predation risk while roosting, shorebirds favour sites with good visibility around the roost. For this reason, they prefer large open ponds, or islands, spits or sand bars surrounded mostly by water. They typically avoid sites with tall vegetation or structures, which limit sight lines and can be used by predators to conceal their approach. Trees and built structures also tend to be avoided because birds of prey may use them as perches. Nonetheless, in particular circumstances small groups of shorebirds may "hide" in dense vegetation, and may also crouch to avoid casting body shadows and even choose to roost in areas that match their feather colours.

Disturbance avoidance: shorebirds are highly sensitive to disturbance while roosting, which may cause them to take flight or abandon otherwise suitable roost sites. Disturbance can be caused by human recreational activities near the roost site, for example walking, off-road driving, birdwatching or photography too close to birds, or operating aerial devices like kites and drones. Human recreational activities are a very common cause of disturbance to shorebirds at high tide. Disturbance can also be caused by human production activities like aquaculture harvest, vehicles and machinery, and helicopters. A further important source of disturbance can be domestic animals such as cats, dogs, horses or livestock. There are also natural causes of disturbance like birds of prey and ground predators.

Energy cost minimisation (travel): shorebirds tend to minimise the energy cost of roosting by choosing sites as close as possible to feeding areas (i.e. close to intertidal flats for coastal shorebirds), providing those sites meeting other requirements such as predation avoidance and lack of disturbance.

Energy cost minimisation (thermoregulation): there may also be a cost to shorebirds from thermoregulatory requirements – that is, keeping themselves cool at hot roosts or warm at cold roosts. In the East Asian-Australasian Flyway, many shorebirds spend the non-breeding season in hot, tropical climates – but for many, especially migratory shorebirds that breed in the artic, their internal physiology and plumage also has to keep them warm in the near-zero temperatures they experience on their breeding grounds. A commonly used heat-avoidance behaviour is roosting on damp substrates or in shallow water, so heat can be dissipated from the legs to cooler surroundings. When roosting in cold conditions or in strong wind, group formation can be especially compact as birds seek to shelter with each-other, and shorebirds may choose locations that reduce the loss of energy (for example the leeward sides of a wall or dike).

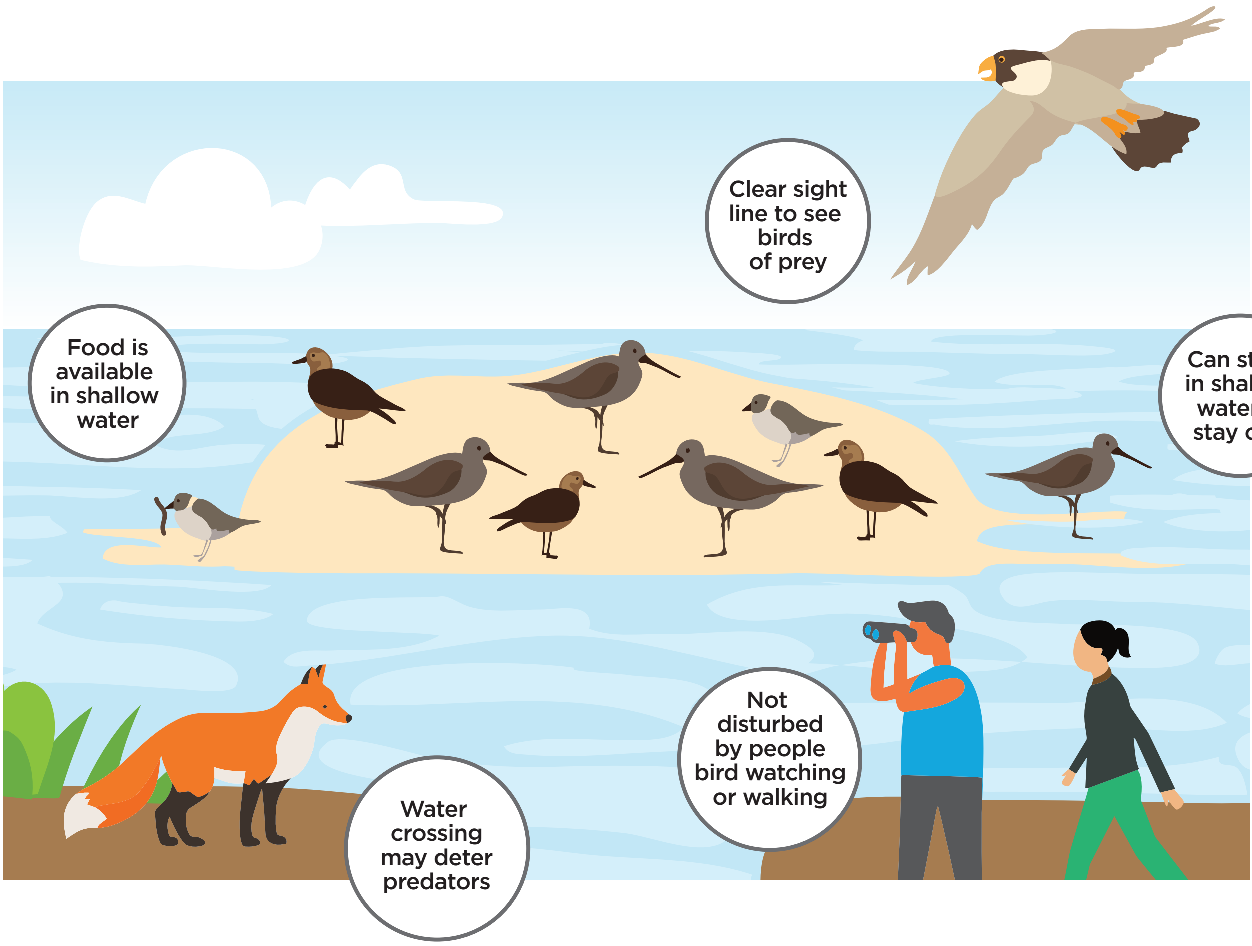
Feeding opportunities: some roost sites, especially ponds with shallow water, provide opportunities for some shorebird species to continue feeding regardless of the tide state. Shorebirds may favour roost sites that provide such opportunities, or even spend the entire tidal cycle in supratidal ponds, if there is sufficient prey. In general, shorebirds that can feed on the water's surface or in the water column (for example avocets and stilts) and small shorebirds that take tiny prey (for example Red-necked Stint, Spoon-billed Sandpiper, Kentish Plover and Curlew Sandpiper) are more likely to find prey in supratidal environments [Ref 5]. In general, supratidal ponds do not support the larger, deep-burrowing prey preferred by the larger shorebird species (for example Far Eastern and Eurasian Curlew, Grey Plover, and Bar-tailed Godwit).

Roosting at night: in some areas, shorebirds use different roost sites by day than by night, and nocturnal roost patterns are often poorly understood. In general, shorebirds are likely to be more wary of predators at night, and may not use diurnal roost sites at night if predators are able to approach the roost site. Sites with shallow water might be favoured at night because this makes it harder for predators to approach undetected. At night, roosting shorebirds tend to avoid artificial lighting.

Accessibility of roost sites: the route that birds travel between feeding and roosting sites may contain barriers or risks, including human-built structures like wind turbines or overhead power lines. Such barriers may cause shorebirds to abandon otherwise suitable roost sites, but more importantly they can be a cause of mortality especially at night.

In general, roost site use patterns vary across months and seasons, so monitoring shorebirds over the whole year is important to gain an understanding of how they use the regional network of roost sites.

FIGURE 2. WHAT MAKES A SAFE HIGH-TIDE ROOST?



Natural and artificial roost sites

Shorebirds use a range of natural roost sites at high tide including upper tidal flats, salt marsh, claypans, and freshwater wetlands. A few species (for example Whimbrel, Grey-tailed Tattler, Terek Sandpiper) are able to roost on perches such as boulders or mangrove branches, though most shorebird species prefer to roost on the ground or in shallow water.

Sometimes, however, human areas also provide good high tide shorebird habitat "by accident", as a by-product of production activities (Figure 3). Artificial habitats in the East Asian-Australasian Flyway that are regularly used by shorebirds for roosting [Ref 6] include:

aquaculture ponds – for example shrimp, fish or crab ponds, and the walls of such ponds

agriculture areas – for example rice fields, drained lotus fields, or grazing fields

fishing poles and cages – horizontal poles used for supporting fish nets and floating cages in intertidal or supratidal areas

ports – dredge spoil ponds inside ports

power plants – dredge spoil or waste ash ponds within power plants

reclamation lakes and ponds – places that have been enclosed by a seawall and are no longer fully tidal, but do not have a clear land use

salt production ponds – evaporation ponds used for commercial production of salt, and the walls of such ponds

wastewater treatment (i.e. sewerage) ponds – ponds where treatment processes and natural biological breakdown are used to treat (clean) sewage, effluent or greywater

building roofs – generally used as a last resort when no other roost sites are available

In addition to artificial roost sites that were not built specifically for shorebirds (see list above), some **constructed roost sites** have been purposely built or maintained through mechanical means specifically for high-tide shorebird roosting, for example as part of a nature reserve or as a development offset.

Of the artificial sites used by shorebirds for high-tide roosting, salt production ponds are most likely to also provide feeding opportunities.

FIGURE 3. EXAMPLES OF ARTIFICIAL SITES THAT SHOREBIRDS USE FOR HIGH-TIDE ROOSTING IN THE EAAF

Clockwise from upper left: Shorebirds and Black-faced Spoonbills roosting in a shallow reclamation pond in the Republic of Korea (image: Nial Moores); shorebirds roosting in a dredge spoil pond in a port in Australia (image: Micha V Jackson); shorebirds and terns roosting on fishing poles in Indonesia (image: Yus Rusila Noor); shorebirds feeding in a salt production pond in Thailand (image: Pete Short).

BOX 2: MIGRATORY SHOREBIRDS IN THE EAST ASIAN-AUSTRALASIAN FLYWAY

The term "flyway" is a geographic concept that refers to the entire region through which migratory birds move annually from breeding grounds to non-breeding grounds, including stopover sites (i.e. feeding and resting places) in between the two [Ref 8]. Though they are widespread and highly diverse, migratory waterbirds have broadly similar movement patterns and their migration routes have been grouped into eight global flyways, of which the East Asian-Australasian Flyway (EAAF) is the largest. The EAAF stretches from Australia and New Zealand through East and Southeast Asia to northern Russia (including Siberia), northern China, Mongolia and Alaska, encompasses more than 20 countries, and supports more than 50 million waterbirds. Over 50 species of shorebirds that occur in the EAAF are migratory [Ref 9].

Because they travel tens of thousands of kilometres every year, migratory shorebirds heavily depend on the availability of suitable habitats, including roosting sites, all along the EAAF. This dependence has made them very vulnerable to habitat loss, which has occurred widely in the EAAF, especially in coastal zones that have large human populations and a lot of development. There are a number of conservation agreements at the global scale (for example the Ramsar Convention and the Convention on Migratory Species), at the flyway scale (for example the East Asian-Australasian Flyway Partnership), and at the level of individual countries, that have provisions aimed at protecting shorebirds and their habitats [Ref 10]. However, many shorebird populations continue to decline and some are now threatened with extinction [Ref 11, 12].

2. Important biophysical roost site features

Given shorebird roost site preferences (see Section 1.), there are some important biophysical site features that are strongly associated with whether or not shorebirds will use a site for roosting [Ref 13, 14]. These include:

Water cover and depth: shorebirds often prefer sites with areas of shallow water interspersed with bare mud or sand. Different shorebird species prefer or are able to rest and feed in slightly different depths of shallow water (albeit within a narrow overall depth range), related to their leg length. An average water depth of 0.5–15 cm across a relatively large area is generally recommended to maximise shorebird diversity.

Vegetation: in general, vegetation is a significant deterrent to most shorebird species using a site for roosting, especially if it is tall or dense. As general guidelines: (1) shorebirds rarely settle in areas with >50% total vegetation cover; (2) most shorebird species prefer vegetation to be less than half of their height; (3) shorebirds will not use the edges (for example bunds or walls) around a pond if they have vegetation on them.

Sight lines/structures: even if a roost site does not have a lot of vegetation within the site itself, tall vegetation like wooded areas or human-made tall structures around the roost can deter shorebirds from using the site if these features reduce visibility or interrupt sight lines.

Prey: shorebirds may continue feeding during some parts of the high-tide period if there is prey available. Shorebirds may favour roost sites with available prey over those without. In non-tidal areas, shorebird prey may include benthic fauna (i.e. invertebrates that live in the mud), or prey found in the water column (for example brine shrimp, brine flies).

Salinity: in general, shorebirds can tolerate high salinity because they can excrete surplus salts efficiently. Hypersaline ponds sometimes contain a super-abundance of shorebird prey like brine shrimp and brine fly larvae, but there is a delicate balance between salinities that support a few hyperabundant species and salinities that are too high for any invertebrates and therefore any shorebirds.

Temperature: in hot climates, shorebirds prefer ponds where they can stand in shallow water or on wet ground, using heat loss from their legs to dissipate body heat (this may be easier in areas exposed to a breeze) and minimise thermoregulation costs.

In many cases, the above features should be considered all together, rather than in isolation, as shorebirds may respond to multiple factors and interactions between them.

Finally, while not a feature of the habitat itself, **distance from feeding habitat** is also an important aspect of roost choice. While shorebirds are known to travel distances of maximum 5-20km from their primary intertidal feeding sites to roost sites (depending on the species), this can represent a significant energy cost. Shorebirds prefer roost sites closer to their feeding areas, if those sites meet their other requirements.

Figure 4 provides some examples of why some artificial sites are suitable for shorebird roosting while others are not, based on the roost site features discussed above.

FIGURE 4. EXAMPLES OF ARTIFICIAL SITES THAT ARE SUITABLE AND UNSUITABLE FOR SHOREBIRD ROOSTING

WORST

Image: Micha V Jackson

NOT USED

Why? Water depth is too high, and there is too much dense vegetation.

Image: Micha V Jackson

USED OCCASIONALLY

Why? While this pond wall provides a vegetation-free roost site with good sight lines, the high water level in the surrounding ponds means that they mostly cannot be used by shorebirds to roost or feed. Because of the high water, shorebirds are crowded onto the walls of the pond and may be highly susceptible to disturbance.

Image: Micha V Jackson

USED REGULARLY

Why? Shallow water provides some feeding opportunities and thermoregulatory benefits; expanse of bare mud provides a large area of open space and good sight lines. Surrounding vegetation may limit sight lines and deter some birds from roosting here.

Image: Amanda Lilleyman

USED REGULARLY

Why? Shallow water provides some feeding opportunities and thermoregulatory benefits; expanse of bare mud provides a large expanse of open space and good sight lines. There is nothing in the surrounding area to disrupt sight lines.

BEST

3. Managing shorebird roosts

In many cases, local site management can promote or create the biophysical roost site features that shorebirds prefer (i.e. shallow water, bare mud/sand), and reduce or remove barriers that prevent them from using a site for roosting (i.e. vegetation, disturbance, structures like power/telephone poles around the roost site) [Ref 15 - 19]. Such local management considerations are relevant at the design stage if a roost is being specifically constructed for shorebirds, or in terms of ongoing management of existing sites, or both.

Some of the key aspects of roost sites or potential roost sites that managers can influence include:

Vegetation management: keeping a roost site free from vegetation is often one of the most difficult challenges for managers of roost sites. If water is maintained at shallow levels for long periods, vegetation will usually develop that is too thick for shorebirds (especially in fresh water). Regular management in the form of water level management and physical, chemical or biological removal is often needed to keep a site free from vegetation for shorebirds to use. Much of the intrusive vegetation in wetlands can be killed or supressed by flooding it deeply for several weeks; invertebrate fauna become established while the wetland is flooded, and can be made available to shorebirds by drawing down the wetland to very shallow levels at strategic times. Flooding with saltwater (with subsequent draining) can be particularly effective at reducing vegetation survival. Nonetheless, the effectiveness of flooding/drying can diminish over time as some plants (for example from the genus Typha, also known as "bulrush" or "cattails" in freshwater, and Phragmites and invasive *Spartina* in brackish water) may develop extensive root systems and tubers enabling them to survive periods of long submersion. Managing roosts through a flooding/drying regime might therefore need to be supplemented in some cases by physical or chemical control which can include, for example, removing vegetation below the root level using machines, targeted herbicide spraying of vegetation, and use of grazing to limit vegetation growth.

Water management: in addition to the use of flooding to prevent vegetation build-up (see above), to maintain optimal roost conditions for shorebirds (i.e. an area comprising shallow water and bare mud/sand) managers may need to flood a site if it is subject to drying, or drain it if significant rainwater is acquired at some times of the year (note that rainwater accumulating can affect both water levels and salinity in brackish ponds).

Particularly if the objective is to create a roost site where shorebirds can also do some feeding at high tide, gradients and water levels can be used to optimise feeding opportunities. Because shorebirds feed in a very narrow band of water depths, the 'flatter' a wetland is, the broader the potential feeding zone will be. When water levels are static and shorebirds feed in the same place for several days, they can rapidly deplete all potential prey. However, if water levels are receding slowly, they will gradually expose 'fresh' mud for shorebirds to exploit. Rising water levels temporarily have the opposite effect: when previously dry mud is flooded, it takes several weeks for benthic fauna (i.e. shorebird prey) to colonise the just-flooded mud and build up to the point where they become a profitable food source. Managers able to implement fine-scale water depth manipulations may be able to use these insights to enhance habitat outcomes for migratory shorebirds by synchronising the time of optimal water depths to coincide with migration timing. This could involve flooding a site for 2-3 months before birds arrive on southward migration (which will help to build up benthic fauna and reduce vegetation build up), and then slowly drawing down water levels to coincide with bird arrivals. It could also involve some draining to expose mud in the 2-3 weeks before shorebirds depart on northward migration when their energy requirements are higher than usual because they are building up fat to support their migration.

Size: larger roost sites (usually ponds in the case of artificial roost sites) may lessen the effects of vegetation, structures around the site, or mild disturbance that may deter shorebird use of the site. If feasible, for example within an aquaculture or wastewater treatment complex, removing some unused walls to create larger flat open ponds with greater sight lines and with shallow water and bare ground will encourage larger numbers of shorebirds to use a roost. Nonetheless, shorebirds may also favour small roost sites if conditions are optimal or if alternatives are not available.

Minimising disturbance: in many cases, the reason that artificial habitats such as ports, saltworks and constructed roosts provide good habitat for shorebirds is because human recreational activity is limited or banned within these sites. In some regions shorebirds favour artificial sites over natural ones such as beaches, because natural sites are subject to much higher levels of human recreational disturbance. In constructed wetlands with public access, it may be beneficial to restrict access to some areas where disturbance could be problematic for roosting or breeding birds.

It may also be possible to add design features that limit human disturbance – for example, most people don't like getting their feet wet, so situating roosts on islands or separating roosts from footpaths with deep channels may keep most people at a safe distance from the birds, which is at least 200m [Ref 20]. Another option could be to include screens in between foot paths and roost areas. Finally, signage explaining the importance of the site for shorebirds, why disturbance is detrimental, indicating how people should behave, could influence peoples' behaviour.

Visitor access: In some cases it may be desirable to allow visitor access to a roost site to promote nature experience and shorebird conservation. Options for management include constructing a bird hide (Figure 5) that allows people to view and photograph birds without disturbing them, use of disturbance-limiting physical features like islands, and restricting the use of drones.

Goals, monitoring and adaptive management: It is vital for managers to identify and document what the goals are for high-tide roost sites before taking management actions so that it's possible to assess whether birds have responded to management as expected or not. Without clearly documented goals, it is impossible to determine whether management is "working" or requires improvement, especially for future managers who may not have been directly involved in initial construction of management activities. It is also critical to document which management actions are undertaken over time; this will help future managers of the site and add to the overall knowledge in the flyway of how shorebirds respond to habitat management. Finally, it is important to keep monitoring local habitat conditions and shorebird populations to determine whether/how they change over time, so that improvements or changes can be made to management practices if needed. Changes at other roosting or feeding sites within the local network may also affect what management is needed. Where relevant at artificial sites, it may also be important to monitor any use of invasive techniques such as traps or mist nets that may have been installed at the site to deter birds from using the site.

Community engagement: In many cases high-tide roost sites occur outside of protected areas. In the case of artificial habitats such as aquaculture ponds, salt production ponds or ports, they may be very important to local jobs and livelihoods, and people may perceive that there is a conflict between their activities and bird conservation. In such cases it is very important to engage with the community and pond managers. In the case of production sites such as aquaculture ponds it may be important to talk to fishermen about shorebird diet, and the potential benefits of having birds using the ponds. Some compensation may be required to make it feasible to manage the pond for birds (for example, draining the pond(s) during migration). In the case of sites with public access that people use for recreation, it is important to educate people about the impacts of disturbance (see above).

FIGURE 5. EXAMPLE OF A "BIRD HIDE"

At this bird hide in the Mai Po Nature Reserve, people can observe and photograph birds in the wetland without disturbing them. Image: WWF-Hong Kong.

4. Other considerations

While this document is focussed on how to manage supratidal sites so that they provide good roosting habitat for shorebirds, it is essential to recognise that artificial (i.e. human-created) supratidal habitats like aquaculture and salt production ponds are very important to local communities, economies and livelihoods, and were created for this reason. Decisions about management in these areas will often be driven by human needs. Nonetheless, it is often possible to manage ponds to benefit shorebirds without large disruptions to production activities. Indeed, the presence of birds in artificial habitats may provide additional opportunities for local communities and livelihoods, for example through providing opportunities for ecotourism or nature education at the site. There is also guidance available for developing these types of programs, but this is outside the scope of this document, which is focussed on how to manage high-tide sites for shorebirds.

It is also important to remember that individual sites do not operate in isolation from the perspective of the birds. Shorebirds may need to travel between high-tide roost sites depending on weather or feeding conditions, or if disturbed at one site. Therefore, regions that support large numbers of shorebirds will require multiple high-tide roost sites to ensure that there is adequate habitat available during every high-tide period.

Finally, there are some aspects of shorebird roost habitat and its management that are not yet fully understood. Some areas that need additional research are explored in the appendix, which also includes useful references for the materials compiled in this document.

To develop this document, evidence from scientific literature and technical documents was combined with the experience of practitioners and researchers from multiple countries, including through compilation of expert advice during a workshop at the 2020 East Asian-Australasian Flyway Shorebird Science Meeting and identification of actions through a search of the website conservationevidence.com. Reference documents are compiled in the "Useful reference documents" section of the appendix. We sincerely thank everyone who provided input through various forums. Additional thanks to the following individuals who contributed significant written input to this guideline document: Tatsuya Amano, Fion Cheung, Jimmy Choi, Nicola Crockford, Vivian Fu, Richard Fuller, Ward Hagemeijer, Roz Jessop, Katherine Leung, Jing Li, Amanda Lilleyman, Sora Marin-Estrella, David Melville, Nial Moores, Tong Mu, Taej Mundkur, Danny Rogers, William Sutherland, and Xianji Wen. Technical input of Wetlands International is supported by Arcadia, a charitable fund of LIsbet Rausing and Peter Baldwin.

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SUPPORTING ORGANISATIONS