10. Heron Feeding Habitat Conservation

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Without food and suitable feeding locations, there is little to be done to conserve herons. On occasion heron habitat alteration is massive and obvious, such as the complete drainage and conversion of a highly productive marsh. Much of heron habitat alteration is more subtle, insidious, and prolonged. Although heron feeding habitat requirements can be generalised to a degree, the suitability of a site is very much a local matter owing to an array of factors including such variables as the species of heron, intraspecific and interspecific competitors, energy needs, seasonal nesting and migration schedule, prey type, abundance and availability, present and past hydrological conditions, vegetation cover and interspersion, distance to suitable nesting or roost sites, distance to other feeding patches, predators, and disturbance regime, all of which may vary within an annual cycle or from one year to the next. Habitat issues are complex for colonial herons in that they require a juxtaposition of nesting and roosting locations and feeding sites (Chapters 9, 11). This chapter seeks generalised patterns useful to local conservation action. The most critical finding is that, given increasing competition for land and resources, heron habitat availability and suitability cannot be taken for granted, but must be evaluated, monitored, and often explicitly managed if herons are to be conserved over the long term.

Habitats Used by Herons

Herons and wetlands

Wetlands are the typical habitat of herons, which are fundamentally adapted to feed by wading around in shallow water. Dry land habitats are used by a few species usually, and by many species facultatively. Even typically dry-land herons depend on damp conditions at least seasonally. The dependence of herons on wetlands places the larger issues of wetland conservation at the core of heron conservation. Wetlands are themselves diverse and changeable (Finlayson and Moser 1991, Kushlan 1993a, Livingston 1993). The international wetland conservation movement

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Little Egrets. These birds prefer open wetland habitat where they forage in the most profitable patches, often in large feeding aggregations. Photo: Jean François Hellio and Nicolas van Ingen.

is well developed, led by such organisations as Wetlands International, IUCN Wetlands Programme, and the Ramsar Bureau. Conservation of herons is tied to the success of these and other local, regional, national and international programmes of wetland conservation.

Most herons are surprisingly flexible in their ability to use various sorts of shallow-water aquatic environments, as well as other situations. Given some limits and notable exceptions, they may be considered generalist, at least as contrasted with storks and ibises. Herons of one sort or another at one time or another may be expected in almost any shallowly flooded place within their range. This flexibility is central to the continuing success of the group, which has seen few forms become extinct in historic times and has few species now endangered worldwide.

Herons and uplands

Uplands also are important to some species, and to other species periodically. One group of upland herons, epitomised by the Cattle Egret, depends on grasslands, both natural and managed rangeland. Maintenance of grassland habitat through grazing, fire and other forces, variability of the invertebrate prey base, and management of grazing commensal herds are also critical to its usefulness for herons. Another group of herons, epitomised by the Agami Heron, uses forests,

The Cattle Egret. This species is less dependent upon wetlands than other herons. It is often associated with grazing animals. Photo: Jacques Delpech.

especially streamside forest habitat. For these, forest conservation practices are critical, and also to heron populations depending on the forest stream itself.

Specific habitats used

In freshwater marshes and swamps, presence of surface water and a supply of suitable prey organisms are the principal features of importance to herons. Thus the range of wetland types used is great, and it is in some ways easier to characterise the wetlands in which herons are seldom found. Those include wetlands that have insufficient prey base for herons to access economically because they are too ephemeral, too far from other wetlands, too isolated from prey recruitment sources, too salty, too acidic, or too deep. This leaves a wide variety of freshwater wetlands that are used by herons, including various sorts of grassy marshes, wooded swamps, reed swamps, fens, wet meadows, shallow streams and stream edges, ponds, and lake margins. Wetlands which herons use more heavily can be characterised as being larger, better watered, well interconnected, having prey refugia, often naturally fluctuating, relatively productive, and having suitable feeding sites.

Some species are more particular in their wetland habitat preferences. Bitterns, Purple and Squacco herons prefer thick reed beds. The endangered Imperial Heron's natural habitat includes impenetrable, often marshy, elephant grasslands. Less thick herbaceous vegetation is attractive to most species of day herons, night herons, and tiger herons. Stream-edge forest is the preferred feeding site for Agami Herons, Zigzag Herons, pond herons, and Green-backed Herons. White-necked Herons and Whistling Herons appear to prefer more sparsely vegetated feeding sites where their views are unobstructed. Night herons and Boat-billed Herons frequent shallow pools, usually during their night-time feeding activities. Black Egrets and Goliath Herons use lake-edge marshes or shallow but open lake-edge zones. The Fasciated Tiger Heron prefers fast-flowing streams.

Estuarine wetlands support herons along both temperate and tropical coasts. Salt marshes, mangrove swamps, coastal lagoons, tidal flats, and shallow coastal streams are heavily used by many species of *Ardea* and *Egretta* herons and night herons that are very typically found along coasts. Swinhoe's Egret winters along tidal flats. Black, Yellow, and Cinnamon bitterns, Great White Egrets, medium-sized *Egretta* such as the Little, Snowy, Tricolored, and Intermediate egrets, the *Ardea* herons, and Green-backed Herons are typical mangrove species throughout the tropics wherever this habitat occurs.

Herons less use open marine habitats, but some species are found there characteristically. Eastern Reef Herons, Reddish Egrets, and Caribbean Great Blue Herons are specialists in using coastal marine lagoons. The Eastern Reef Heron uses shallowly exposed reefs. Seashores themselves are more difficult habitats for herons to use, as they must contend with tide and wave action. Rocky shores are used by coastal and island populations of the Green-backed Heron, Eastern Reef Heron, and Yellow-crowned Night Heron. Sandy beaches will on occasion be used by various species of medium to large day herons, notably Little and Great White egrets.

Green-backed Heron. Forested water margins and mangrove-bordered shores and estuaries are favoured habitat types for this species. Photo: Robert Bennetts.

Drier habitats are also important. It is likely that individuals of most species can be found feeding on dry land if sufficient quantities of catchable food are present. Yellow-crowned Night Herons, Great White, Snowy and Little egrets, and the *Ardea* herons are particularly adept at feeding on land occasionally. Snowy Egrets appear to have increased their use of dry land, as improved short grass pasturage increased in North America. Stream edges in forests are the typical habitat of several species, including the Agami and Zigzag herons and Fasciated Tiger Heron. The Cattle Egret is well known as a dryland heron, especially its association with grazing animals. Other savanna species, such as the Black-headed, Capped and Whistling herons, actually use a gradient of conditions from dry to wet habitats, depending on food availability. They generally occur in damp to moist conditions, and often take advantage of recently flooded pastures or short stature grasslands in addition to drier grasslands.

In fact, terrestrial herons generally require or benefit from association with damp or shallowly flooded habitats. The Cattle Egret is more appropriately thought of as a bird of the short-grass margins of damp sites, particularly floodplains subject to seasonal flooding and slow drying (Siegfried 1988). It uses aquatic sites for nesting. Cattle Egrets nesting near freshwater foraging areas raise more chicks than those depending entirely on terrestrial habitats for food (Siegfried 1972). So even this, the most terrestrial of heron species, depends on wet conditions.

Artificial habitats cannot be overestimated in their importance to herons, an importance increasing annually. Throughout their range, most heron species take advantage of feeding opportunities presented by human-made wet places having sufficient prey base. These locales are often shallow and productive, and may offer more prey than nearby natural habitats. Nearly any regional consideration of heron conservation needs to take into account the use and preservation of artificial feeding sites: some populations depend on them.

Ditches are perhaps the most commonly used artificial habitat, and their importance is usually overlooked. *Ardea* and *Egretta* herons, pond herons, and Green-backed Herons often use ditches, particularly seasonally when shallower wetlands dry or when prey become plentiful in the ditches for other reasons. In addition to fish, ditches house small mammals, amphibians, and invertebrates also eaten by herons. Territorially-feeding herons, such as *Ardea*, seem to stake out ditches as part of their foraging area. Heron use of ditches has been little studied.

Herons often use dumps and sewage ponds. Production is high in such locales, and feeding conditions often ideal. Pied Heron, Great White, Cattle and Snowy egrets are frequent users. At times such sites are important to nesting birds (Frederick and McGehee 1994).

The role of reservoirs and smaller water management sites must not be overlooked in regional planning for heron conservation. Reservoirs in dry areas have allowed the expansion of heron populations. For example, reservoirs in mid-continent North America have led to range expansion of the Green-backed Heron into this otherwise arid portion of the continent (Ryder 1979). Irrigation reservoirs have become important heron feeding habitats in South Asia (Chapter 3). Farm ponds in Australia have become important feeding sites for White-faced and Pied herons and Great White, Little and Intermediate egrets (Chapter 6).

Herons frequently use agricultural land. It is usual around the world to find herons, particularly Cattle Egrets, following tractors to take advantage of the prey

The Eurasian Bittern. This species is confined to densely vegetated freshwater wetlands. Phragmites stands are preferred nesting and foraging sites. Photo: Jean-François Hellio and Nicolas van Ingen.

stirred up by ploughing or cutting. Pastureland is often marshy, leading to seasonal use. The ability of Cattle Egrets to use hoofstock as beaters is well documented. Agricultural practices that flood land or supply concentrated prey can benefit herons.

The most important artificial heron habitat, worldwide, is the rice field. Rice cultivation covers 1.5 million km^2 with 40% of the world's human population depending on rice production (Forés and Comín 1992). Herons use (and even have come to depend on) rice fields in parts of North America, South America, the Mediterranean, and Asia. Grey Heron, Little, Intermediate, Great White, and Cattle egrets, Squacco Herons and other pond herons, Black crowned Night Herons, and *Ixobrychus* bitterns are usual rice field herons. Asian herons in some areas have become highly dependent on this habitat (Chapter 3; Subramanya 1990, Lansdown and Rajanathan 1993, Young 1993). Rice fields have replaced natural wetlands in many locales; for example in the critically important Ebro Delta of Spain, 74% of total submerged land is now rice fields (González-Solis et al. 1996). It has been shown that rice fields have substituted for the loss of natural wetlands in the Mediterranean and that the stability of heron populations now depends on them (Fasola and Ruiz 1996, Fasola et al. 1996). In Japan the rise and fall of egret populations was directly related to the expansion of rice cultivation, followed by its conversion to dry farming practices (Narusue 1992). Such impacts are undoubtedly the case in other regions where rice fields have come to dominate the wetland. Rice field management must be an active concern for heron conservation, wherever rice is cultivated in wetlands. Rice fields are often critical habitats for heron populations.

Fish farms are also a locally important agricultural habitat for herons (Chapter 13). These sites are the ultimate expression of the high production wetland patch that many herons are adapted to find and to exploit. *Ardea* and *Egretta* herons, night herons, and pond herons appear among the most common users of aquacultural facilities, particularly the Great Blue Heron, Grey Heron, and Black-crowned Night Heron. In some areas such as southern North America, aquaculture has positively affected wintering and breeding heron population levels (Fleury 1996). In Hong Kong, fish ponds have become critical habitats for feeding herons, particularly in winter (Young 1993). As aquaculture is rapidly developing worldwide, particularly in the tropics, similar effects can be expected elsewhere in the world. Fish farms often displace natural wetlands used by herons. The other severe adverse effect is the conflict of heron use with the fish farmer, which has led to killing, in the name of predator control, of substantial numbers of herons (in fact substantial portions of heron populations—see Chapter 13). It would be ideal to develop situations where herons are allowed to access excess aquacultural stock (perhaps in compensation for the loss of natural habitat) without severe economic consequences to the farmer. This in fact turns out to be the case in the instances that have been properly studied. In Hong Kong, and also elsewhere in Asia, there is little persecution of the many wintering herons that feed in ponds when they are being dried down, as the birds are understood not to seriously interfere with the fish harvesting (Young 1993).

In Spain, rice fields are flooded in winter in order to create habitat for hunting. They are favourable feeding habitats for Little Egrets. Photo: Emmanuel Vialet.

While it should not cause conservation complacency, the versatility of heron species should not be discounted as this provides flexibility for successful conservation action. Great White, Little and Cattle egrets, night herons, and Green-backed Herons are among those that appear particularly eclectic in their habitat use.

Conservation of Wetlands

Wetland loss and alteration

Wetlands and other shallow aquatic ecosystems have been under human pressure for thousands of years, a pressure accelerating in the present century. In the United States of America, for example, it has been estimated that 53% of wetlands have been lost since the late eighteenth century (Shaw and Ferdine 1956). In the Mediterranean, 80–90% have been lost (Fasola and Ruiz 1996—more details in Chapter 2). In various areas of Australia, the loss is 70–90% (Chapter 6). Wetland conversion continues throughout the world, although recently at a reduced rate in some developed areas, such as North America, where regulatory constraints are high (Dahl and Johnson 1991). Habitat losses in the past undoubtedly affected heron populations, in mostly undocumented ways. The extent to which wetlands continue to be lost can be expected to impact populations further.

Most loss of wetland habitat has been caused by its conversion to agriculture. Some of this is wetland agriculture, such as rice farming, aquaculture, or wet meadow grazing, that may continue to provide or enhance habitat for herons. However, much of the conversion has been by drainage, which eliminates heron habitat except for drainage ditches and other water control features. Once drained, wetlands almost inevitably come to provide additional living space for humans, which increases pressures for further flood control and competition with herons for the benefits of the water supply. A good example of this typical pattern is Hong Kong (Young 1993). Beginning 100 years ago, coastal mangrove wetlands were reclaimed, first for brackish water rice fields, then for intertidal shrimp ponds, then for intensive fish culture. All the while the herons were able to acclimatise to the changes. The last stage in this typical example is draining the fish ponds for urban development, which is the stage that must be resisted if herons are to persist—a conservation action being lead by WWF in Hong Kong.

Many of the remaining wetlands, while not drained completely, have been altered functionally by human intervention. This is the subtle, insidious, and prolonged part of wetland alteration. A bird that wades requires water depths within certain slim limits set by their own height. Plants, on which feeding herons have to perch and which provide cover for prey, require specific hydroperiods and water depths for germination, growth, and persistence. Heron prey, especially fish, amphibians, and aquatic invertebrates, also require certain water depths and certain patterns of seasonal water level fluctuations. It is probable that functional changes can adversely affect the usefulness of a site to herons nearly as much as its complete drainage.

Although heron extinctions are not explicitly attributable to loss or functional alteration of aquatic habitats, population changes and range changes certainly are. Population changes in Florida and Louisiana, both in the southern USA, are among the best-documented example (Frohring et al. 1988, Kushlan and Frohring 1986, Ogden 1994, Fleury 1996). South Florida heron populations decreased in recent decades despite the persistence of a million hectares of superficially suitable wetland habitat, the decrease being due to anthropogenic changes in the hydrologic cycle. Heron populations coincidentally increased in Louisiana due to habitat enhancements from aquaculture.

Influencing the pressures for wetland loss and functional transformation must be on top of every agenda for heron conservation. Preventing the further conversion of natural wetlands needs to be a central tenet of heron conservation worldwide. Heron conservation also requires the preservation of natural ecological processes or the beneficial manipulation of hydrological and vegetation variables by wetland managers.

Habitat availability

To be useful to herons, suitable wetlands must be available to them in appropriate size, dispersion, and temporal sequencing. The most fundamental finding from many studies is that feeding habitat area determines to a large extent how many herons can be supported in a region. This has been demonstrated at both landscape and local scales (Kushlan 1978a). For example: at the landscape scale, the number of herons in states along the Atlantic coast of North America is correlated with the area of coastal wetlands in each state (Osborn and Custer 1978); at the patch scale, habitat area available during nesting may be correlated to nesting numbers where habitat is limiting (Craufurd 1966, Fasola and Barbieri 1978, Gibbs et al. 1987, Gibbs 1991, Hafner and Fasola 1992, Gibbs and Kinkel 1997, Farinha and Leitão 1996), although not necessarily where habitat is more extensive (Erwin et al. 1987). Habitat quantity and its dispersion over the landscape must be taken into account in local and regional heron conservation planning.

For many species feeding habitat limitations become particularly acute during the nesting season, when herons become more place-bound. They are then limited in the distance they can feed from their nest by constraints of time and energetic cost/benefits. Generally 5 km is the usual flight distance for large to intermediate sized herons, shorter distances for the smaller, more localised species, and somewhat larger distances for larger herons (Chapter 9; Custer and Osborn 1978, van Vessem et al. 1984, Hafner and Britton 1983, Erwin and Spendelow 1991, Smith 1995). Competitive forces also come into play (Gibbs et al. 1987). Marion (1988) found that the distance travelled from the colony site to feed increases with the size of colony, suggesting an effect of local competition. Knowing flight ranges from nesting and roosting sites to feeding sites is critical for local area conservation, in order to determine an inventory of feeding sites that must be secured through conservation planning and also to understand habitat-mediated population size limitation for a local population. These data can be inferred from the literature or, better yet, determined for each area.

Evidence of the importance of habitat availability can be drawn from the recent history of several species, but none more dramatic than the Cattle Egret, expanding from southern Africa to much of four continents (Blaker 1971, Siegfried 1988, Telfair 1983, 1994, Maddock and Geering 1994). Its initial expansion in Africa is correlated with advances in irrigated farming, increasing its favoured moist ground habitat, followed by explosive range expansion into expanding areas of moist short-grass pasture nearly worldwide.

Patch dynamics

Understanding interactions of heron foraging ecology with selection and use of foraging patches is a critical aspect of determining heron habitat quality. Fortunately these issues have been well studied (e.g., Kushlan 1978a, 1981, 1989a,b, 1997, Erwin 1983, 1985a, 1989a, Hafner and Britton 1983, Kersten et al. 1991, Hafner et al. 1993, Hafner 1997a). Variables influencing patch use vary given the species of concern, interacting species, time, location, habitat variables, and prey availability. Also it appears that classical foraging theory has not often been shown to have predictive value for herons (e.g., Kushlan 1978a, Erwin 1985a). Yet it is clear that herons do not use available habitat or prey randomly.

The overriding conclusions to be drawn from the literature are that each species needs to be treated separately and that, based on knowledge of species biology, each foraging habitat or colony site needs to be evaluated. Armed with information on heron biology and habitat characteristics, local conservation and management plans can be drawn. Below (based on numerous studies) are discussions of some of the important habitat variables that need to be understood for heron habitat management.

Prey Fluctuations. Being highly mobile birds, herons choose to feed where prey is sufficiently available to meet their energetic and nutritional needs. So they select among locally-available foraging patches. Prey must be abundant enough that the heron can be sufficiently successful in its feeding. Prey must also be physically accessible. In many cases that means in sufficiently shallow water depths or at a place where perches or banks can support the feeding heron. If prey are not sufficiently available, herons go elsewhere.

Prey availability varies over time. Prey may become more available as their populations increase seasonally, as wetlands flood, as water depths fall and they are concentrated in remaining pools, as perches become available for herons to use, or as water conditions cause prey to surface or to move to other locations where they can be eaten more easily. Prey become less available when populations are low or well dispersed, when fish kills or episodes of intensive predation reduce stocks, when water is too deep for herons to feed, when perches or other means of access are unavailable, or when water temperatures decline or ice cover develops. Among water quality conditions affecting prey availability to feeding herons are diurnal oxygen and turbidity (Kersten et al. 1991, Cezilly 1992). Prey availability often varies with some periodicity, such as winter–summer cycles, dry season–wet season cycles, or daily cycles. Episodic events also occur.

Winter–summer cycles can limit seasonal habitat use by temperate species, which find that their predominantly poikilothermic prey become less available during the winter or that their feeding habitats become inaccessible due to ice cover (North 1979). Most herons respond to such seasonal changes in foraging habitat availability by short-distance shifts or long-distance migration. For those not migrating the severity of winter can have an impact on survival and subsequent population sizes (Hafner et al. 1994). Temperate species wintering in the tropics may encounter very different habitats. Many North American species, which nest in interior freshwater wetlands, winter along the mangrove swamps and other coastal wetlands of Central America. European birds of coastal and inland wetlands repair to the river swamps of sub-Saharan Africa. Similarly, dry–wet season cycles may limit distribution of subtropical and tropical species. Such populations may undertake intraregional movements seasonally that alter their habitat use patterns. In many areas, both temperate and tropical individuals participate in post-breeding dispersal, often related to seasonal water conditions, which brings them into habitats other than those they used during nesting.

Daily fluctuations affect herons inhabiting tidal environments. They must respond to changes in water depths and to prey movements by changing feeding locations with the tidal cycles. Prey also fluctuates over a period of days, as patches dry or are fed-out by herons, at which time the birds have to move to different sites (Hafner and Britton 1983).

Floods or droughts can drastically alter available feeding habitat by rendering large areas of usually suitable feeding habitat inhospitable to either prey or predator. Such events often cause widespread dispersion of heron populations.

In addition to temporal variation, prey availability varies over space. Differences and variation in the many factors affecting prey availability directly impact the spatial dispersion of feeding patches. As seasonal or daily fluctuations in water conditions make patches available or unavailable, herons must respond to these changes by moving. In large wetlands, herons may follow receding or rising water levels, as patches become available. In smaller wetland matrices, herons may have to change feeding patches. Along the coast, herons change feeding sites as tidal conditions fluctuate.

The Little Egret in the south of France (Pineau 1992, Hafner and Fasola 1992) can illustrate the flexibility of spatial and temporal habitat use exhibited by a single population. During nesting, egrets feed near the colony site in permanent freshwater marshes, temporary freshwater marshes, and coastal lagoons. Of these the permanent freshwater marshes appear to be more productive in supporting egrets, primarily because they have higher fish densities (Crivelli 1981). After nesting, herons disperse up to 100 km to drying wetlands which have easily accessible prey. When these wetlands dry, they move to staging areas, which are flooding at the time, prior to migrating southward. In winter in Morocco, egrets feed in permanently flooded coastal wetlands early in winter, moving to seasonally flooded freshwater habitats toward the end of winter. Little Egrets from France wintering in Spain use permanently flooded rice fields.

A different pattern of changing habitat use can be illustrated by the Great Blue Heron in western, coastal Canada (Butler 1991). Herons shift sites seasonally as dictated by food supplies and tides. During nesting, female herons respond to inshore movement of fish into tidal lagoons, by feeding along beaches. As food supplies decrease in winter, herons move to feed in marshes and interior grasslands, although some males feed along riverbanks.

Herons may require or benefit from a choice of alternative feeding habitats (Custer and Osborn 1978, Dimalexis et al. 1997). Choice of feeding sites within the matrix of those accessible depends on availability and also species-specific preferences. Custer and Osborn (1978), for example, showed how several species chose distinctive feeding sites, correlated primarily with their size. In New York, USA, Snowy Egrets use different feeding sites depending on water levels that are affected by tide and rainfall, whereas Great White Egrets are more consistent in their feeding site choice, being less dependent on very shallow sites (Maccarone and Parsons 1994). Having accessible a diversity of feeding habitats is probably beneficial to overall feeding success of herons. The proximity of colonies to different feeding habitats may affect productivity. For the Little Egret for example, egrets nesting near permanent freshwater marshes in the Camargue had higher rates of food return than those nesting near temporary marshes or saline lagoons (Hafner et al. 1986b).

Hydrology. The most universal determinant of prey availability is a wetland`s hydrology. Nearly all wetlands that herons use vary in water depth and areal extent of water cover, at least seasonally. This variation is fundamentally due to seasonality of rainfall patterns and resulting discharge variation. In the temperate zones, these may be modest. In the subtropics and tropics annual or biannual dry and wet seasons significantly constrain heron use of feeding habitats. In many cases, the seasonal cycle of heron nesting and migrations, and sometimes nesting success, are tightly correlated with hydrologic conditions in their foraging habitat (Kushlan 1989b, Maddock and Baxter 1991, Frederick et al. 1992, Hafner et al. 1994, Baxter 1994, McKilligan 1997). The specific correlations may differ among species and among areas. Some species in some areas nest when water levels rise, others when they fall. Some migrate into an area when rains begin, others migrate out. The communality is that an important portion of the heron's annual cycle in any location may be driven by local hydrology. The hydrologic cycle and the heron's responses to it must be understood in developing management plans for local heron habitat.

Vegetation. The structure of the vegetation is crucial for its use by certain herons. As noted above, different herons require perches, dense emergent plants, open fields, or water edge to feed. These must be provided in the habitat. To the extent that drought, burning, flooding, logging or other human activity affects habitat structure, heron use can be affected. These forces are also tools that can be used to create and maintain suitable vegetation structure within managed wetlands.

Wetland management strategies

Heron conservation, having a large part of its focus on wetland conservation and management, benefits greatly from the widespread and increasingly successful wetland conservation movement worldwide. Wetland management and conservation enjoys a substantial core of scientific information on wetland structure, ecological function, societal values, hydraulic engineering, modelling, water management and vegetation management (see for example Mitsch 1994). Programmes of wetland restoration and wetland creation provide new or improved wetland habitats, often for a specific function such as water quality improvement (Hammer 1989, Marble 1992, Moshiri 1993). These programmes can enhance a region's heron habitat inventory, especially if the needs of herons are taken into account in the design, construction and operations of the enhanced wetland. It is becoming clear that created wetlands seldom completely mimic their natural wetland models. Their value for herons deserve additional study, and it may be that the versatility of herons gives them the necessary scope to make good use of such artificial habitats.

Wetland conservation around the world is developing a common set of principles (Kushlan 1995) and common management goals and practices. Among these are: the importance of regional inventory and monitoring (Costa et al. 1996); the role of wetlands in preserving biodiversity (Giesen 1997); assessing wetland function and values (Kusler and Riexinger 1985); adopting wetland sustainability and sustainable use as overriding management goals (Frazier 1996); achieving multiple, sustainable use through local community involvement (Claridge and O'Callaghan 1997); mitigating for impacts and losses of wetlands and their ecological functions (Kusler et al. 1988); managing from a watershed or catchment perspective (Kusler et al. 1995); and the identification of wetlands of particular importance for preservation and sustained management (e.g., Frazier 1996).

Each of these conservation emphases can be of value to heron conservation. Wetland inventories provide a geographically explicit identification of potential heron habitat. Herons can be used in a symbolic role in conservation of wetland biodiversity. Planning for the sustainable use of wetlands places heron use in a broad ecological and economic context, which is especially valuable if wetland managers (Chapter 15) adopt their role as bioindicators of wetland health and function. Community involvement in wetland conservation is of particular value to species that are well regarded by participants, as herons often are. Mitigation requires the re-establishment of wetlands or their functions that can provide additional or enhanced heron habitat. Identification of wetlands of regional, national, and international importance provides the framework and international network of habitats of value to heron populations worldwide. Heron conservation planning must adopt, partner with, and encourage wetland-planning initiatives.

Conservation of Upland Habitat

Much of the basic understanding of heron biology and conservation in wetlands is undoubtedly applicable to terrestrial habitats. Patch dynamics, the role of prey abundance and availability, seasonal and other variability in habitat availability appear to be fundamental to heron biology and should provide a basis for conservation planning. As noted previously, little is known about the specific biology of herons in terrestrial habitats. As a result there is little to guide specific conservation planning for herons in these habitats. Clearly more information is needed if heron conservation is to be eventually integrated into the conservation of their terrestrial habitat.

Management of Artificial Habitats

Rice fields

Water management and related cultivation practices in rice fields totally determine their utility to herons (Fasola and Ruiz 1996). In traditional rice cultivation, fields are periodically flooded for the growing season, for renovation after harvest, or for waterfowl use in winter, and are also periodically drawn down for harvest and for cultivation. This variation creates a changing patchwork of habitat availability. Unless a rice field is double cropped with fish or crayfish, heron feeding is seldom detrimental to rice culture. Removal of crayfish can even reduce their undermining of the dikes. Water is manipulated by canals, ditches, floodgates, dams, and pumps, depending on the situation. These features too become part of the rice culture complex used by herons. Conservation planning should take into account the seasonal pattern of use of the aquacultural habitat mosaic and how the various practices benefit or are detrimental to herons.

A long-standing issue in the use of rice fields as feeding habitat is the effect of pesticides (Chapter 12). Increasing use of short-term, low-toxicity pesticides should reduce exposure and eliminate bioaccumulation. Heron conservation planning should encourage the use of non-persistent, highly targeted pesticides in rice culture.

Rice cultivation is changing in many parts of the world. In India the substitution of dwarf varieties for the tall indigenous varieties reduces field use by the Cinnamon Bittern and Green Backed Heron (Subramanya 1990). Small paddies are giving way to larger fields more suitable for mechanical farming, thereby reducing variation within the aquacultural mosaic that provides sequences of feeding opportunities (Chapter 3). Old varieties of rice needed prolonged flooding, but recently farming has been carried out in shallower water, which reduces water costs but also productivity of potential heron prey. More recently, dry-ground rice farming is expanding. Although it is less productive, costs of water management are significantly reduced. Transition to dry land farming will put at risk heron populations now depending on flooded fields. In northern Italy, where the heron populations have come to require rice wetlands, one-third of the fields have already been converted and further losses could affect up to half of the breeding population (Fasola and Ruiz 1996). Other changes in farming practice can also affect herons. For example, in Japan changing water delivery from canals to pipes decreased food availability for herons because of reduced recruitment of fish to the rice fields (Narusue and Uchida 1993). Changes in winter flooding regimes would affect migrant and wintering birds. Also of concern is the loss of rice fields through changing to other crops that have higher market value or lower costs of production, thereby eliminating flooding. The fundamental threat to many rice fields, immediately or eventually, is the loss of flooded fields to human development.

The regional importance of rice fields to herons can scarcely be overestimated. Heron conservation planning must take into account local human practices and through planning and research influence the institution or continuation of practices beneficial to herons.

Aquaculture

Aquaculture can have important benefits to herons (Chapter 13). Fish farms make ample foraging opportunities available, with optimal prey in near-optimal feeding conditions (angry farmers notwithstanding). Positive population responses have been documented, and the expansion of aquaculture can be expected to increase foraging opportunities for both resident and wintering herons. It is crucial that the true impact of herons on fish farms be understood and that, in the ideal case, heron predation be allowed (although perhaps constrained). A good example is the study of Ashkenazi and Yom-Tov (1996) which argues that heron predation causes little detriment and even some benefit to the farm. Heron use of fish ponds does not necessarily have an economic impact and need not be controversial, as indeed is the case in Hong Kong (Young 1993). But an objective, locally-relevant information base is required to influence aquacultural practice and the opinions available to farmers.

Reservoirs

The control of surface water by reservoirs is common worldwide. Some reservoirs create fringing wetlands in the desert, whereas others feed rice fields. Herons can quickly come to depend on these water sources. Lakes, ponds, rivers, and even large wetlands are similarly under specific water management regulations. The well-known example of the Florida Everglades is essentially the effect of water management in large shallow reservoirs. Where water is managed and herons are present, heron conservation planning needs to understand the positive and negative effects of water management practices and attempt to influence them for the benefit of the herons.

Regional Management

We need to understand the feeding habitat conservation needs of local heron populations, continental populations and entire species. We also need to understand how management practices are affecting these groups at the local, regional, and national levels. While high-scale (regional, national, or continental) planning is essential to set overarching goals, real conservation action of value to herons happens locally. The most appropriate way to integrate goals on different scales is through regional and local planning, preferably on a watershed basis in concert with national or continental goals.

Flyway management

The success of managing hunted waterfowl on a flyway basis has been well established. Migratory herons must fulfil their habitat requirements not only while nesting, but also while on migration and while wintering (Chapter 11). Flyway management for non-hunted species involves the identification of large habitat areas and of key sites for nesting, migratory, and wintering herons along the flyway, and the coordinated protection and management of these sites. Key sites (or Important Bird Areas) are the important locales used by a significant portion of a population for at least part of the year (see for example Pineau 1992, Mikuska et al. 1998). By linking important areas, the conservation and management of local habitat is placed in the appropriate higher scale context. Heron conservation can establish its own reserve networks, or more realistically partner with flyway-based management schemes for various wetland birds. Examples of flyway programmes that can serve as a template for heron conservation include the North American Waterfowl Management Plan (Streeter et al. 1997), Western Hemisphere Shorebird Reserve Network (Davidson 1997), African–Eurasian Waterfowl Agreement (Boere and

Lenten 1997), and the Asia–Pacific Migratory Waterfowl Conservation Strategy (Mundkur and Matsui 1997).

Watershed management

It is clear that preservation of aquatic habitats suitable for herons is essential for heron conservation worldwide. Parks, refuges, reserves, easements, zoning, wetland protection laws, and private preservation activities are a workable array of methods used for conservation of wetlands. Such actions preserve aquatic habitats from being drained and developed in ways adverse to herons.

However critical as a foundation, habitat preservation alone will be inadequate for conservation of most heron habitats in the long run. Vegetation, water depths and their fluctuations, patch sizes and dispersion are all subject to manipulative action. In the Mediterranean, for example, available freshwater feeding sites are manipulated to increase fish production by controlling water levels (Britton 1982). In larger systems where water discharges are controlled by dikes, water depth fluctuations can be manipulated to create conditions suitable for heron feeding. Wetlands will inevitably be increasingly managed and manipulated.

Heron use of artificial sites poses both opportunities and difficulties for heron conservation. Sites such as rice fields provide feeding habitat that otherwise might not be available, or as productive. In some cases these fields have replaced natural freshwater marshes preferred by herons, but without them the natural habitats might well have been drained. Changes in management practices, such as the extent of flooding and resulting ability to support fish and amphibians, could affect these habitats' usefulness to herons. More drastically, economic pressures may change the value of rice farming in certain areas, leading to abandonment of rice cultivation.

It is the regional mosaic of potential habitat that is used by herons. So it is the regional mosaic that needs to be the geographic basis for conservation planning. This mosaic may encompass combinations of natural wetlands and artificial sites, of colony and feeding sites, or of breeding, post-breeding and wintering sites.

Herons are not the only users of their feeding habitats, and their needs will have to be reconciled with the multiple use of these habitats by other wildlife and humans. The sustainable use of wetlands is a core principle of modern wetland conservation. This principle serves herons well in that they have a degree of flexibility in adapting to sustainable use strategies. It is likely that heron conservation will require some active management or the continuation or enhancement of various activities. Thus it is essential that herons' needs be made part of the wider sustainable use planning at a watershed scale.

Conclusions

Management and conservation of heron feeding habitat should be a conservation priority in areas having large concentrations of herons or supporting rare species. In such areas, the geographic pattern of heron habitat use and the temporal pattern of use within the geographic pattern need to be understood. Conservation and management of heron feeding habitat should be undertaken on a regional basis, and as part of more encompassing strategies of sustainable, multiple use. Habitat conservation requires maintenance of such characteristics as water depths, water fluctuations, vegetation, prey base, and dispersion of patches. Feeding habitat is often not continuous, so its patchiness, including patch size and dispersion, affect heron use. Small patches may not contain sufficient food or shelter to support herons. It is likely that the larger the individual patches within the matrix of available feeding sites, the more herons can be supported. The temporal dispersion of patches is also important in that herons can feed sequentially in patches if they become suitable in an orderly sequence, allowing herons to change patches efficiently. The size and physical and temporal dispersion of patches can determine the length of time a heron can feed in an area.

Certain species require specific vegetative structural characteristics, especially those that feed in dense herbaceous plants and those that feed from bushes and trees overhanging the water. For these species, maintenance of vegetation structure is required for their use of a habitat. If a heron is physically able to access a patch through the feeding repertoire available to it, its presence will be determined primarily by prey availability. Irrespective of other characteristics, insufficient prey availability will cause a heron to avoid a potential feeding patch.

The pattern, timing, and extent of water level changes, as determined by rainfall or overland flows, often determine prey availability, and therefore feeding patch suitability. In dry seasons, falling water conditions concentrate prey, make it available in shallower locations, and present a succession of feeding patches. In wet seasons, flooding allows prey populations to expand, both spatially and numerically. Timing of each is crucial, as the herons' reproductive and migration phenology must be in synchrony with local and regional patterns of food availability. To the extent that the timing of hydrological fluctuations determines patterns of prey abundance and dispersal, maintenance of such fluctuations is critical to heron habitat use.

Heron feeding habitat conservation can be built on an already solid foundation of heron biology and wetland ecology. To be successful it needs to be locally based, regionally compatible, and placed in the appropriate national and flyway perspective. Heron feeding habitat conservation, especially, should be based on herons' being an integral part of sustainable land use, and flyway, national and international water bird management plans.