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THREATS TO BURDUR LAKE ECOSYSTEM, TURKEY AND ITS WATERBIRDS, PARTICULARLY THE WHITE-HEADED DUCK *Oxyura leucocephala*

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Abstract

Burdur Lake, a closed-basin saline lake in south-west Anatolia, Turkey, is internationally important for its wintering waterbirds. It is the most important wintering site in the world for the white-headed duck Oxyura leucocephala, *a globally threatened species. It has also held internationally important numbers of 10 other waterbird species. The lake is threatened by the construction of an industrial complex and airport on the northern shore. Falling water levels (from construction of upstream dams), sedimentation (from catchment erosion), organic pollution (from food processing and sewage) and inorganic effluent (from a sulphur mine) represent long-term threats to the lake system. Illegal hunting from the shore has a serious impact upon white-headed ducks, which concentrate close inshore and show little escape response in the presence of hunters. White-headed duck numbers have fluctuated considerably since 1967 with a peak (incomplete) count of 10,927 in February 1991. By January 1995, numbers had declined to 2805. Numbers of black-necked grebe* Podiceps nigricollis, *white-fronted goose* Anser albifrons *and tufted duck* Aythya fuligula *have declined. Numbers of large gulls of the* Larus argentatus *group which prey upon white-headed duck have increased, possibly due to pollution. For 10 of 16 waterbird species regularly observed at the site, highest numbers were recorded before 1974. Recommendations for the conservation of the lake are presented. Copyright © 1996 Elsevier Science Limited.*

Keywords: white-headed duck, waterbird, pollution, hunting, sedimentation.

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INTRODUCTION

Burdur Lake (Gölü) in Turkey supports a unique aquatic fauna, including an endemic fish *Aphanius burduricus* and an endemic copepod *Arctodioptomus*

burduricus. It has held up to 335,000 wintering waterbirds and most of the known world population of the white-headed duck *Oxyura leucocephala* (Anstey, 1989; Green & Anstey, 1992). It is an Important Bird Area (Grimmett & Jones, 1989) and was one of five Turkish wetlands listed as Ramsar Sites when Turkey became the 83rd party to the Ramsar Convention (Convention on Wetlands of International Importance, especially as Waterfowl Habitat) in 1994.

The white-headed duck is one of the rarest Palearctic waterbird species and is globally threatened, qualifying as Vulnerable according to IUCN criteria (Collar *et al.*, 1994; Green, in press). It is the only stiff-tail (Oxyurini) naturally occurring in this region, with a patchy distribution from the western Mediterranean eastwards to central Asia (Green & Anstey, 1992). Burdur Lake has consistently held more than half of all the white-headed ducks counted across the species' range during the mid-winter International Waterfowl Census since counts began in 1967 (Anstey, 1989). Up to 11,000 have been counted on the lake out of an estimated world population of 19,000 (Green & Anstey, 1992).

Concern about the status of the white-headed duck led The Wildfowl & Wetlands Trust and International Wetlands and Waterfowl Research Bureau (IWRB) to prepare an international conservation plan for the species in 1989, which stressed the importance of effective conservation measures at Burdur Lake (Anstey, 1989). At that time, white-headed ducks were regularly hunted at Burdur Lake from speedboats and from the shore, even though the species has been protected from hunting in Turkey by national legislation since 1984. The Turkish Society for the Protection of Nature (DHKD) used a booklet summarising the international conservation plan in Turkish to lobby regional and local authorities, leading to a total ban of waterbird hunting at Burdur Lake from December 1990 onwards. This was a temporary ban which was renewed each year.

An international symposium on the conservation of Burdur Lake and the white-headed duck was organised by the Burdur Municipality and DHKD and held at Burdur in December 1991 (DHKD & Burdur Municipality, 1993). As a consequence, an initial review of conservation issues affecting the site was drawn up in February 1992 (Salathé & Yarar, 1992), identifying the need for a detailed study of the ecology of the white-headed duck at Burdur Lake. In response, a research project was conducted in February and March 1993 by The Wildfowl & Wetlands Trust in official partnership with DHKD and the Burdur Municipality (Green *et al.*, 1993). Counts and behavioural studies of the white-headed ducks on the lake were conducted and the impacts of hunting, pollution, habitat change and other threats on the ducks and their food supply were assessed.

Following the ban on hunting of waterbirds at Burdur Lake introduced in 1990, hunting from speedboats stopped completely, but the hunting of white-headed ducks from the shore was regularly observed during the 1993 study. These findings led the National Parks, Game and Wildlife Directorate of the Turkish Ministry of Forestry to declare Burdur Lake a Waterfowl Conservation and Breeding Area, with a permanent ban on the hunting of all waterbirds, prior to the start of the 1993–94 hunting season. Financial support was provided by the British Association for Shooting and Conservation (BASC) and the Ankara-based Game and Wildlife Foundation for the effective implementation of the ban.

We review here all information collected on the nature conservation interest of the lake, assessing the size of and changes in waterbird populations and the significance of various threats. Special attention is paid to the importance of the site for white-headed ducks, and to the impact of hunting. We also make recommendations for future management and research at the site.

METHODS

Site description

Published and unpublished information on the lake, its catchment area and the conservation problems affecting the region were collected from representatives of a range of Turkish institutions during the Burdur symposium in 1991 (DHKD & Burdur Municipality, 1993) and during visits to the area in 1992 (Salathé & Yarar, 1992) and 1993 (Green *et al.*, 1993).

Burdur Lake is a closed-basin (endorreic), alkaline, saline lake of *c.*140 km^2 at 845 m above sea level in south-west Anatolia, Turkey (37° 43'N, 30° 15'E, Fig. 1) divided between the provinces of Burdur to the south and Isparta to the north. It is 30 km long by up to 7 km wide and lies on a geological fault in an earthquake zone (the last major tremor was in 1971). The water has a high salt and soda content and never freezes. In February–March 1993, the average pH was 9·54 and the average conductivity was 17·1 mS (Green *et al.*, 1993).

The lake has a catchment area of 6150 km^2 and is fed by several rivers, many with erratic water flow. The lake bottom was uplifted by an earthquake in 1971, and conflicting reports suggest that while the maximum depth was 110 m, it is now either 42 m or 85 m (Salathé & Yarar, 1992). Burdur city has *c.* 60,000 inhabitants and lies on the eastern shore (Fig. 1). There are numerous small towns in the catchment, which has a total of 150,000 inhabitants. Sugar beet and cereals are grown in flat alluvial plains at both ends of the lake. Vines, roses (for perfume production) and fruit trees are grown in terraces on gentle slopes above the lake. Local tourists use the lake shores for swimming and other leisure activities during the summer.

The lake benthos has a low diversity with only 12 macroinvertebrate taxa recorded in 1993, but is rich in chironomid larvae, which make up over 95% of inverte-

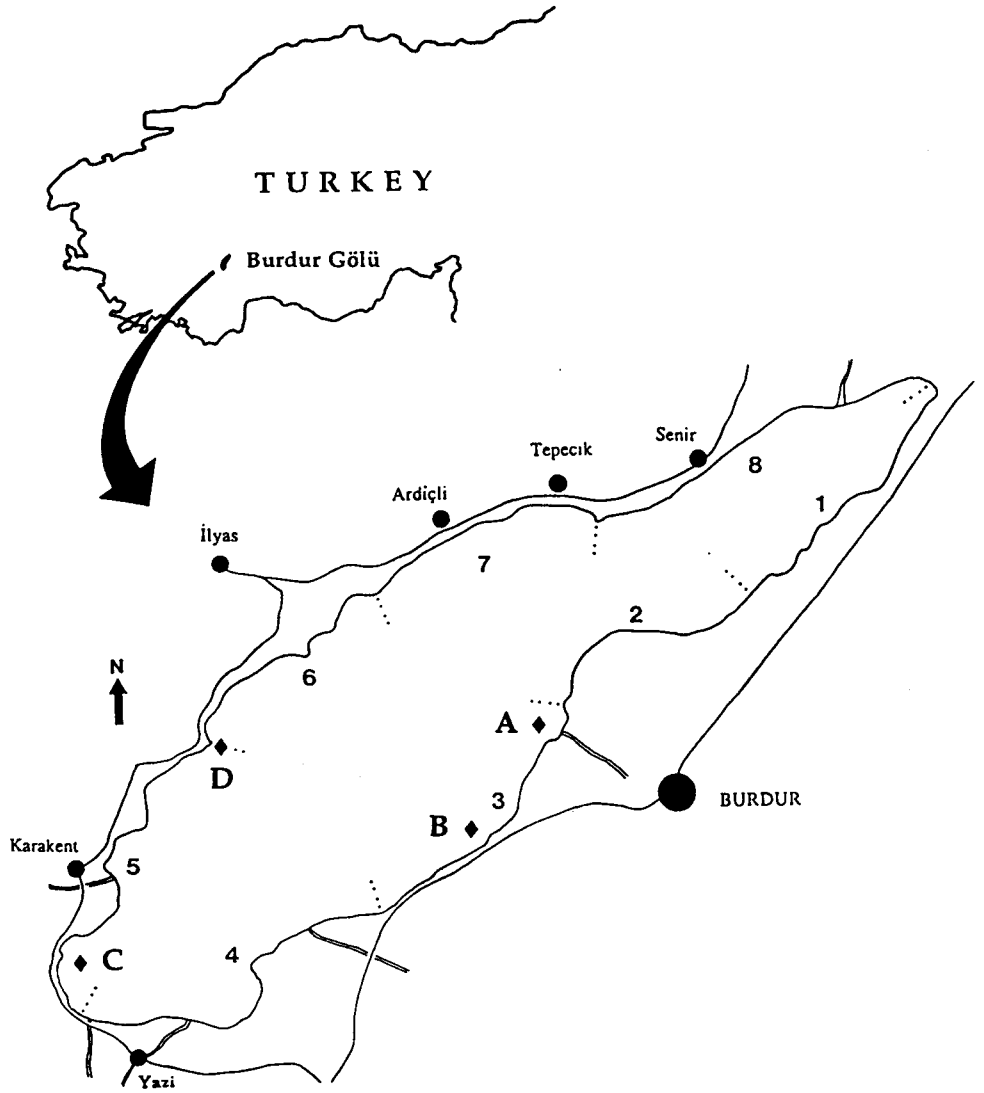

Fig. 1. Location and map of Burdur Lake showing positions of major inflow streams, towns, villages and roads as well as the eight sectors used in the text. Diamonds show sites where hunting impacts were studied. A, sugar factory outflow; B, milk factory outflow; C, south-west bay; D, holiday beach.

brate biomass (Green *et al.*, 1993). Chironomids are the major food of the white-headed ducks and their abundance is likely to be one reason why the white-headed ducks winter at Burdur Lake in such numbers (Green *et al.*, 1993). Brief surveys of plankton have recorded three genera of copepods (including the endemic *Arctodioptomus burduricus*), three genera of rotifers, 17 genera of diatoms, 11 genera of green algae, five genera of blue–green algae and one genus of brown algae (Merter *et al.*, 1986; Timur *et al.*, 1988). Other plants recorded are unidentified filamentous algae and small amounts of *Potamogeton pectinatus* and charophytes such as *Nitella* sp. (Green *et al.*, 1993). Two fish species have been recorded, the endemic *Aphanius burduricus* and *Anatolicthys* sp. (Timur *et al.*, 1988).

Recording birds and hunting

Sizes of and changes in wintering waterbird populations at the lake were considered using data from the IWRB International Waterfowl Census (IWC, see Monval & Pirot, 1989). Burdur Lake has been counted regularly in January or February during the IWC since 1967. Waterbirds are concentrated around the margins of the lake, within telescope range. In most years, one team of observers in a vehicle censused the lake in a single day. These counts are incomplete since some sections of the lake are inaccessible by vehicle, and poor weather conditions have often reduced visibility. In February 1993 and January–February 1995, white-headed ducks were counted on days with calm water and excellent visibility by three teams of observers, two of them walking, to obtain a complete and accurate count of all shores of the lake. A preliminary assessment of the importance of Burdur Lake for waterbirds outside the winter period was also made, using a series of counts conducted in 1994 and 1995 by DHKD and J. Petit (pers. comm.).

There are two forms of large gulls present at the

lake, yellow-legged gulls *Larus cachinnans* (formerly known as *Larus argentatus cachinnans*) and Armenian gulls *Larus armenicus* (formerly *Larus argentatus armenicus*) (Sibley & Monroe, 1990). During the IWC, the identification of these forms has been inconsistent, so for the purposes of the analyses they were lumped together as birds of the *Larus argentatus* group.

Observations of white-headed duck behaviour in relation to hunting activity were carried out during daylight observations between 10 February and 4 March 1993 at four study sites around the lake (Fig. 1). Time budget data were collected within 3-h observation sessions alternated between sites so that the full daylight period was covered twice at each site. The distance of ducks from the shore was recorded at the beginning of each observation session. Flocks were scanned every 15 min, recording behaviour of all individuals (using the categories feeding, resting, preening, movement, alert and social interaction).

The nature of hunting activity was also recorded. The behaviour of white-headed ducks in the presence and absence of hunting activity was compared. For each of the five observation sessions with hunting activity, the mean percentage time spent in different behaviours was calculated from all flock scans when shots were fired during the 15 min before the end of the scan, and for all scans when shots were not fired during the 15 min before the end of the scan. Comparisons were made between paired means using a one-tailed Wilcoxon Matched-Pairs Signed-Ranks test to test the hypothesis that shooting increased alert and locomotion activities and decreased other behaviours.

In February–March 1993, studies of lake chemistry and benthic invertebrate communities were also conducted (Green *et al.*, 1993), and reference is made here to those results which have implications for the conservation of the lake and its fauna.

RESULTS

Waterbird numbers at Burdur Lake

Eighteen IWC census counts were made of Burdur Lake between 1967 and 1995 inclusive (Table 1). A wetland is identified as being of international importance if it meets at least one of the Ramsar criteria (Ramsar, 1990). Burdur Lake meets several criteria, most notably because it has two endemic species and because of the size of its waterbird populations. The waterbird criteria are satisfied in several ways, since the lake regularly supports over 20,000 waterbirds and because it regularly supports 1% of the individuals in the regional populations of several waterbird species. Using the mean IWC counts, this 1% criterion is satisfied for white-headed duck, common coot *Fulica atra*, black-necked grebe *Podiceps nigricollis* and common pochard *Aythya ferina* (Table 1). However, using the mean of the five most recent counts (a common method for assessing international importance, Rose & Scott, 1994) up to and including 1995, the 1% criterion is only satisfied by the white-headed duck. The 1% limit

Table 1. Summary of mid-winter (January or February) IWC counts at Burdur Lake from 1967 to 1995 (regularly recorded species) Population trends are analysed with Spearman rank correlations (r_s: $^{*}p<0.05$; $^{***}p<0.001$)

Species	r_s	Mean	Peak & Year	1% Level[a]
Great-crested grebe *Podiceps cristatus*	–0·400	21	135 1970	250–10,000[c]
Black-necked grebe *Podiceps nigricollis*	–0·887***	2679	11,900 1973	1000
White-fronted goose *Anser albifrons*	–0·829***	800	3000 1967	2500
Ruddy shelduck *Tadorna ferruginea*	0·222	117	550 1993	200
Common teal *Anas crecca*	–0·493	475	1784 1971	10,000
Mallard *Anas platyrhynchos*	–0·227	442	1203 1973	40,000
Northern pintail *Anas acuta*	0·174	126	700 1970	3000
Eurasian wigeon *Anas penelope*	–0·495	419	2000 1967	6000
Northern shoveler *Anas clypeata*	0·312	264	2000 1994	2200
All *Anas* species combined	–0·186	1836	4176 1994	—
Red-crested pochard *Netta rufina*	0·004	464	2604 1973	500
Common pochard *Aythya ferina*	–0·293	14,352	54,250 1986	12,500
Tufted duck *Aythya fuligula*	–0·863***	1145	11,210 1973	6000
White-headed duck *Oxyura leucocephala*	0·218	5017	10,927 1991	170
Common coot *Fulica atra*	–0·371	53,116	263,000 1969	25,000
Gulls of *Larus argentatus* group[b]	0·704*	30	170 1995	250–10,000[c]
Black-headed gull *Larus ridibundus*	0·343	326	900 1988	1000–10,000[c]
Total number of waterbirds	–0·036	78,295	334,872 1969	—

[a]1% of the estimated regional population of that species (Rose & Scott, 1994), the figure that has to be regularly exceeded to satisfy the Ramsar criterion for international importance. Regional populations are those subsets of the world population that are demographically isolated from each other without regular exchange of individuals.
[b]Includes all birds described as herring gull *Larus argentatus*, yellow-legged gull *L. cachinnans* or Armenian gull *L. armenicus*.
[c]Regional population size unclear and precise 1% levels are unknown.

has been exceeded in at least one winter for white-fronted goose *Anser albifrons*, ruddy shelduck *Tadorna ferruginea*, red-crested pochard *Netta rufina* and tufted duck *Aythya fuligula* (Table 1).

Surveys conducted on 27–28 July, 27 October and 24 December 1994 suggest that Burdur Lake is internationally important for a number of species outside January and February, the usual winter count period. Species recorded in higher numbers than in mid-winter and with counts exceeding the 1% thresholds (Table 1) are ruddy shelduck (over 1000 in July), black-necked grebe (15,110 in October), great-crested grebe *Podiceps cristatus* (1735 in October), black-headed gull *Larus ridibundus* (2000 in December) and yellow-legged gull (1430 in December). For the last three species, precise 1% thresholds are unknown and only the minimum estimate is exceeded by these counts (Table 1). In October, counts of coot (67,915) and common pochard (27,530) were much higher than those of January 1995.

Population trends for midwinter populations of 16 species at Burdur Lake over 29 years showed highly significant negative trends for black-necked grebe, tufted duck and white-fronted goose (Table 1, Fig. 2(a),(b)). The only significant positive trend was recorded for large gulls of the *Larus argentatus* group (Fig. 2(b)). Trends for other Anatidae species, great-crested grebe, common coot and black-headed gull were not significant. There are indications from other analyses that the number of waterbirds wintering at Burdur Lake are declining. For 10 of the 16 waterbird species regularly recorded at the site, the highest numbers were recorded in 1973 or earlier (Table 1), even though only seven of the 18 censuses were conducted over this period. There has been a consistent decline in the peak numbers of waterbirds counted in each decade, with 334,872 in the 1960s (1969), 214,366 in the 1970s (1973), 141,856 in the 1980s (1986) and 58,185 in the 1990s (1995), partly as a result of the decline in the numbers of common coot, the most abundant species, with 263,000 in 1969, 120,690 in 1973, 85,700 in 1989 and 50,600 in 1995.

White-headed duck numbers counted in mid-winter have varied considerably, with a peak of 10,927 on 4 February 1991 (Fig. 2(c)), even though most of sectors 1 and 2 of the lake and the northernmost tip of sector 3 (see Fig. 1) were not counted (Berrevoets & Erkman, 1991). Over 20% of the birds counted in 1993 and over 50% of those counted in 1995 occurred in these areas (Table 2), suggesting that the peak numbers of white-headed ducks may have been well in excess of 11,000. The counts prior to 1971 were extremely low, probably as a consequence of incomplete counts. The population trend of white-headed ducks from 1971 onwards is negative but not statistically significant (r_s = –0·445, p >0·1). Counting of this species from 1992 onwards has been particularly accurate, suggesting that the apparent drop in numbers since 1991 (Fig. 2(c)) is real. The 1995 count of 2805 (Table 2) represents a 74% decline since 1991, despite improved coverage.

There has been no detailed study of the timing of migration of white-headed ducks, and considerable numbers appear to be present at the lake all year round, although it is unsuitable for breeding due to the lack of nesting habitat. About 500 birds were seen on 27–28 July 1994 (J. Petit, pers. comm.) and 342 were recorded on 23 July 1995. Over 2000 white-headed ducks have been recorded as early as 17 October (1982) and as late as 3 April (1991) (I. Green, N. Moorhouse and G. Magnin, unpublished data).

Four counts (three complete and one partial) of white-headed ducks were carried out in February 1993. Some 3010 ducks were present in the first half of February, falling to 2162 birds by the end of the month as birds left on spring migration (Table 2). All four counts were lower than all previous IWC counts since 1970 (Fig. 2(c)). The overall proportion of adult males recorded was 49·3%. The bird distribution between lake sectors varied considerably between counts, but the western side (sectors 5–8; Fig. 1) was consistently more important (Table 2), holding 70% of birds on average. Birds regularly moved between different sites, and bays that held flocks of several hundred during some counts held none during others. White-headed ducks were concentrated around the margins of the lake, close to the shoreline. Numbers peaked within 11–20 m of the water's edge (Fig. 3), well within shotgun range. Over 50% of all observations occurred within 40 m of the shore.

More recent midwinter surveys have counted similar numbers of white-headed ducks. On 7 February 1994, 3337 were counted, probably an underestimate since bad weather reduced visibility and sectors 1 and 2 of the lake (Fig. 1) were not covered at all. On 29 January 1995, 2805 were counted in a complete census under ideal weather conditions. A further complete count of 1655 was made on 25 February 1995 under reasonable weather conditions. In contrast to 1993, in 1995 most birds were recorded together in a single bay on the eastern side of the lake (Table 2). The effluent from a sugar factory enters this bay, which was a study site in 1993 (Fig. 1).

Impact of hunting on white-headed ducks

Hunting intensity

A high level of illegal hunting of white-headed ducks was recorded during 96 h of daylight observations on the lake in 1993 (Table 3). No hunting was seen at the milk factory inflow which is in a military zone with restricted access. The hunting pressure at the other three sites was probably similar to that found on the rest of the lake. The areas over·which hunting activity was monitored around these four sites represent 15% of the lake perimeter (excluding the northern portion of the lake not used by white-headed ducks at the time), and held a total of about 25% of the white-headed ducks present on the lake.

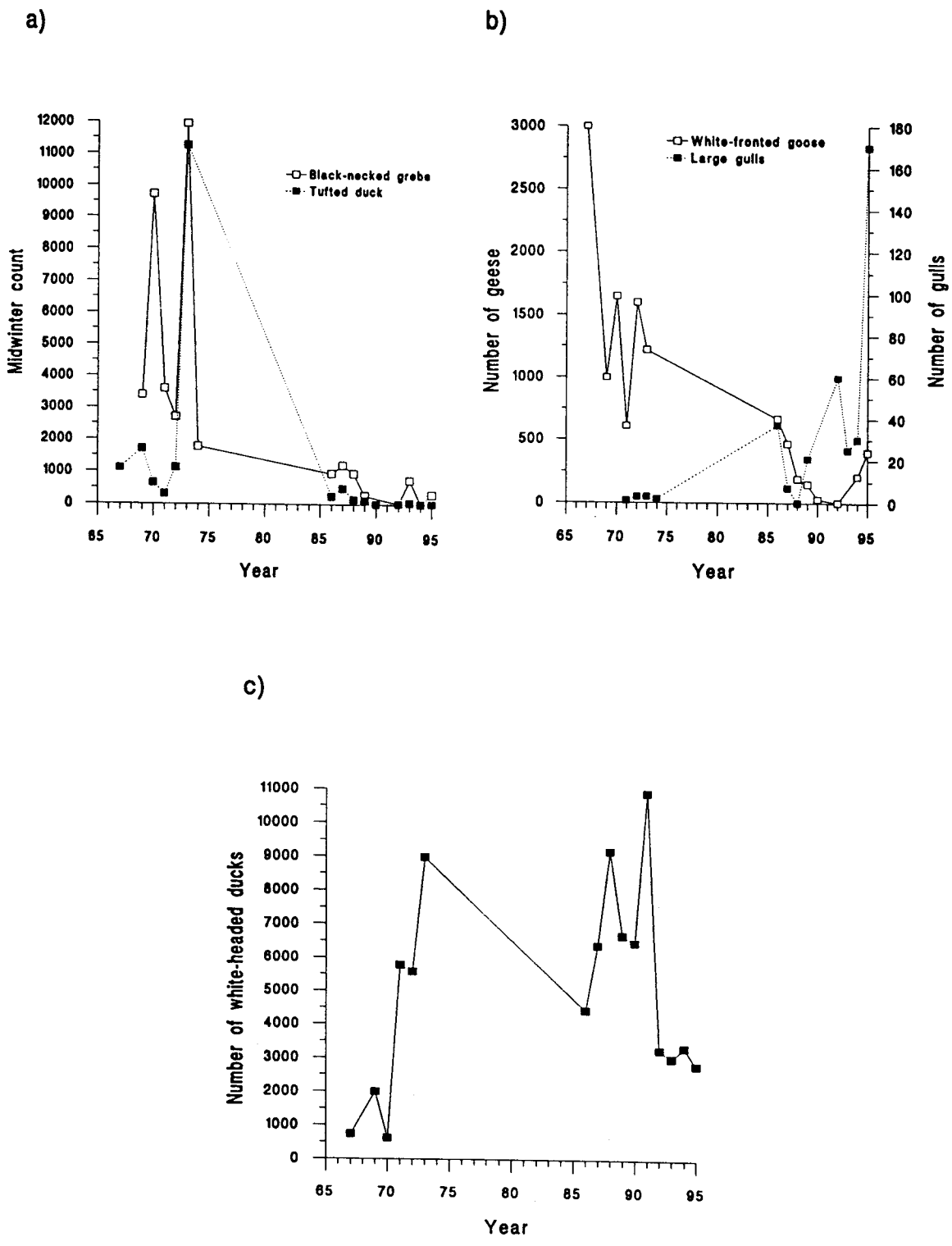

Fig. 2. Mid-winter counts of (a) black-necked grebe and tufted duck; (b) white-fronted goose and large gulls; and (c) white-headed ducks at Burdur Lake. Large gulls are those identified as *Larus argentatus, L. cachinnans* or *L. armenicus*. Gulls were not counted during the IWC in the 1960s. Data courtesy of IWRB.

In addition to the seven birds killed at these sites (Table 3), five other shot white-headed ducks were observed, three carried by a hunter walking south past the south-west bay and two shot *c.* 2 km south of the milk factory inflow. Hunters were frequently encountered in other locations and were often seen shooting at white-headed ducks. Hunters' shooting butts constructed from rocks, reeds and corrugated iron were abundant on the lake, especially in sectors 1–3 (Fig. 1) where a total of 35 was counted.

Table 2. The numbers and distribution of wintering white-headed ducks at Burdur Lake in 1993 and 1995
See Fig. 1 for the position of lake sectors. Only part of the lake was counted on 6 February 1993. On 7 February 1993, a large group of birds moved in an unknown direction shortly after being counted; 2687 is a minimum figure for the whole lake made under the assumption that these birds were later recounted; the total of 3148 assumes that none of these birds was recounted.

	Lake sector										
Date	1	2	3	4	5	6	7	8	Number sexed	% males	Total count
6/2/93	—	—	158	—	607	1112	148	—	507	45·0	2025
7/2/93	1	509	123	174	370	1510	300	161	902	49·6	2687–3148
14/2/93	0	717	269	102	471	831	288	332	1537	51·1	3010
28/2/93	1	129	392	18	244	311	630	437	1069	48·6	2162
29/1/95	0	0	1560	0	470	0	64	711	—	—	2805
25/2/95	0	0	1655	0	0	0	0	0	—	—	1655

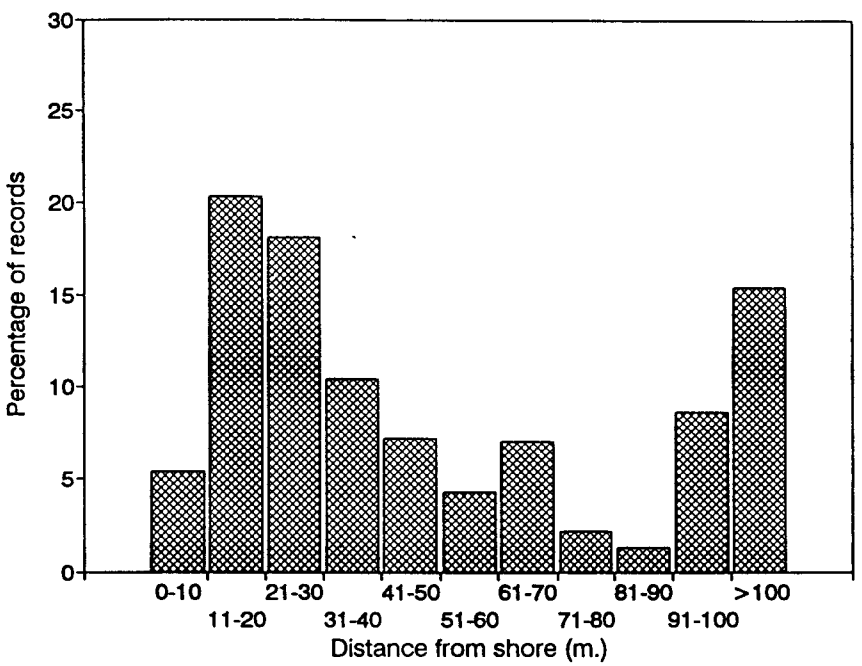

Fig. 3. Distance of white-headed ducks from the shore at Burdur Lake during daytime. Data from four sites amalgamated, n = 2 743.

Table 3. Hunting statistics from four study sites at Burdur Lake (A–D in Fig. 1), 10 February–4 March 1993

	Sugar factory	Milk factory	South-west bay	Holiday beach	Total
Observation time[a]	24	24	24	24	96
Hunters seen	5	0	8	1	14
Total shots heard	26	0	55	15	96
Shots at w-h duck[b]	25	0	2	4	31
W-h duck killed	5	0	0	2	7
W-h duck crippled	1	0	0	1	2
W-h ducks killed or crippled per day[c]	3	0	0	1·5	4·5
Other birds killed	1	0	1	0	2[d]

[a]Number of daylight hours spent at the site.
[b]Number of shots seen to be directed at the white-headed ducks that were under observation. The target of most other shots heard was unknown and many may also have been directed at white-headed ducks.
[c]Calculated by dividing the total killed or crippled by two, since there were 12 h of daylight per day.
[d]Both common pochard.

The majority of hunters' shots observed were fired at white-headed ducks, largely because it was much more difficult to get within range of other species. In contrast to white-headed ducks, coot, pochard and other ducks rapidly swam or flew well out of range when hunters approached the shore or began shooting. During the 1992–1993 winter, it is very likely that more white-headed ducks were shot than any other species at Burdur Lake, and 78% of the waterbirds shot during observations were white-headed ducks (Table 3). However, the sites selected for observations may have supported relatively fewer individuals of other species than other sites used by hunters.

There were an estimated 4·5 white-headed ducks killed or crippled per day in the four study sites combined, with an unknown number of extra birds suffering injuries (Table 3). Since the study area only covered a small proportion of the lake, this suggests very substantial hunting mortality during the 1992–1993 winter, especially since shooting occurred throughout the 135-day national hunting season (which was generally respected even though the local ban was not). White-headed ducks that were crippled came onto land and undertook constant preening, and probably died shortly afterwards. Hunters often shot at white-headed duck flocks that were too far away for any individuals to be killed outright, so it is likely that many more individuals received hunting injuries that were not obvious to the observer, and may have died later or experienced reduced reproductive success.

Our data may underestimate the hunting pressure on white-headed ducks at Burdur Lake during the 1992–1993 winter prior to our arrival. The observed level of hunting may have been reduced during the study period by our activities, as efforts were made to inform hunters that the species is legally protected. Our physical presence by the lake may also have deterred hunters who already knew the legal position. In addition, 18 h of our observations in Table 3 were made after the hunting season ended on 28 February, after which only one hunter was seen.

Effects of hunting on bird behaviour

Hunters shot at white-headed ducks during five of the 32 daylight observation sessions in 1993. Casual observation showed that white-headed ducks demonstrated very little reaction when shot at, typically swimming away (often remaining in a sleeping posture) from the hunter, then returning to their original position and activity within 10 min. No birds flew off in response to shooting, and none showed the head-up-tail-up alert posture adopted in the presence of predatory gulls (Fox *et al.*, 1994). Some birds feeding close to hunters showed no visible reaction to shooting, making them extremely easy targets. In contrast to white-headed ducks, coot and other duck species disappeared from the study site as soon as the first shot was fired.

An observed decrease in resting and increase in movement of white-headed ducks after shots were fired approached statistical significance, whilst feeding and alert behaviour were unaffected (Table 4). The presence of predatory gulls, analysed in an identical way, caused significant increases in the amount of alert and locomotory behaviour and a significant decrease in feeding behaviour (Fox *et al.*, 1994).

OTHER THREATS TO THE LAKE ECOLOGY

Pollution

In 1993, three state-owned factories and a state-owned mine were releasing untreated waste into the lake. A milk factory and a sugar factory close to Burdur city (Fig. 1) continually release organic waste. In 1993, the inputs increased nitrate and phosphate concentrations in lake water, even 100–200 m from the shore (Green *et al.*, 1993). Milk factory waste entering the lake contained 5·94 mg/l of dissolved nitrate N and 5·98 mg/l of dissolved phosphate P, while sugar factory waste contained 1·23 mg/l N and 0·94 mg/l P. Flow rates were not measured in 1993, but in 1982 milk waste entered the lake at a rate of 2 l/s and sugar waste entered at 174 l/s (Gölge *et al.*, 1986). A meat and fish factory near Burdur also discharges organic wastes which, during three visits between 1991 and 1993, penetrated into the soil before reaching the lake. Domestic sewage from Burdur city currently filters into the soil or is used to irrigate agricultural land between the town and the lake, but is due to enter the lake directly upon completion of a central sewage system which is currently under construction (80% completed at the end of 1993). Owing to the costs of a treatment plant, it is unlikely that the sewage will be treated before entering the lake

Table 4. Effects of hunting on white-headed duck behaviour at Burdur Lake

Analyses are conducted on paired means for scans with and without hunting using a one tailed Wilcoxon Matched-Pairs Signed-Ranks test. SD, Standard Deviation; N_t, number of matched pairs in which there is a difference; T, Wilcoxon Statistic.

	With hunting		Without hunting				
Behaviour	Mean	SD	Mean	SD	N_t	T	p
Alert	0·0	0·0	0·06	0·14	1	0	0·50
Movement	29·1	34·7	7·4	5·9	5	13	0·089
Feeding	20·3	10·5	23·8	20·7	5	8	0·50
Resting	44·0	28·7	65·4	25·9	5	14	0·053

(DHKD, unpublished data). Recreational and other housing developments outside the city already discharge their sewage directly into the lake. During recent summers, some lake beaches have been declared unsuitable for swimming due to sewage pollution. There are proposals for the treatment of waste from the milk, sugar, meat and fish factories, but it remains unclear if they will be implemented.

Studies in winter 1993 found no clear evidence of negative effects of organic pollution from the sugar and milk factories upon chironomid populations. The biomass of chironomids around the factory outlets was compared to that found at other parts of the lake, whilst controlling for depth and substrate which are strong predictors of biomass. The biomass around the sugar factory outlet was lower than expected, but that around the milk factory outlet was higher than expected (Green *et al.*, 1993).

The Etibank sulphur mine at Keçiborlu, 15 km north of the lake, released inorganic mining wastes into the lake via the River Adalar. In 1993, the River Adalar was heavily polluted by metal ions, particularly iron (14 mg/l), and was highly acidic (pH 4·4–5·3) (Green *et al.*, 1993). Although the Adalar seeped into the ground about 1 km from the lake shore, the pH in the nearest part of the lake was reduced from its normal range of 9·54–9·66 to 9·30 (Green *et al.*, 1993). The Adalar has also been found to contain high concentrations of cadmium, chromium, copper, magnesium, manganese, nickel, zinc, cobalt and selenium that are likely to accumulate at the top of the lake food chain with toxic effects (Gölge *et al.*, 1986). The chironomids in this area are significantly smaller than elsewhere in the lake (Green *et al.*, 1993). The sulphur mine is currently working with minimum capacity and is expected to close down soon for economic reasons. It is unknown if seepage of pollutants from mine workings into the lake will continue once the mine is closed.

A new threat to Burdur Lake comes from the construction of a major industrial complex of 200 ha (with 114 industrial units, mainly textiles) and an airport at the north end of the lake starting in 1993. Planes from the airport will fly in and out directly over the north end of the lake, which often holds most of the waterbirds.

No quantitative information is available on the use of agrochemicals in the lake catchment, although pesticides and fertilizers are in use and are a potential threat to the lake ecosystem. It is not known if spent lead shot left in the lake sediments by hunting activity causes significant levels of lead poisoning of waterbirds.

Siltation

The lake catchment area suffers severe erosion as a result of deforestation and overgrazing of vulnerable vegetation which overlies geologically young calcareous slopes with little or no organic topsoil to support vegetation. Extensive re-afforestation programmes to restore vegetation and top-soil to the bare hillsides around the lake have had limited success due to insufficient funding and low precipitation in recent years (mean 347 mm/year in the eight years prior to 1992, compared with 436 mm/year in the previous 60 years, Salathé & Yarar, 1992).

Erratic water flows in inflow rivers carry very heavy sediment loads into the lake. This is illustrated by the large quantities of sediments (over 300 mg/l in 1993) carried by two streams flowing into the lake at Karakent and Suludere (Green *et al.*, 1993). In the late 1960s, the annual input of sediment to the lake was estimated at 480,000 m^3 (X. Cengiz, pers. comm.).

Reducing water levels

Drought and increased water abstraction for irrigation in the catchment have caused a marked reduction in the volume of water reaching the lake from river inflow and direct precipitation in recent years. Between February 1992 and February 1993, water levels dropped by an estimated 20 cm (Green *et al.*, 1993). A further marked drop was noted by January 1994. Four dams have recently been built upstream on the river Bozçay, formerly the largest source of freshwater input to the lake. A fifth dam is under construction and a sixth is planned. Completion of the first four reservoirs reduced inflow to the lake from the river from 12,500 m^3/year to 6500 m^3/year, resulting in an estimated decrease in lake depths of 25 cm. The completion of the fifth and sixth dams is forecast to cause a further reduction in river inflow to 3000 m^3/year and an additional decrease in lake depth of 15 cm (Salathé & Yarar, 1992). Since evaporation exceeds inflow, the lake has reduced in recent years from 246 km^2 as shown on past maps to *c.* 140 km^2 currently, exposing extensive salt and mudflats at the flat northern end and gravel beaches along other lake shores. These declines follow a long period of rises in lake levels, including a marked rise following the earthquake in 1971 (Salathé & Yarar, 1992).

DISCUSSION

Changes in waterbird numbers

Owing to the lack of other forms of long-term monitoring, the annual IWC counts provide the best indicator of ecological changes that have occurred at Burdur Lake. There is strong evidence that declines have occurred in the numbers of tufted duck, black-necked grebe and white-fronted goose wintering at the lake over the past 29 years. It seems likely that these declines have been caused by factors operating at Burdur Lake, since the regional populations of the first two species are actually increasing whilst that of the third is stable (Rose & Scott, 1994). The first two species may have been affected by deteriorating water quality, whilst the geese are more likely to have been affected by changes to areas immediately surrounding

the lake (e.g. in land use) or by hunting pressure. The decline in grebe numbers suggests there may have been a similar decline in the abundance of fish. However, trends in the size of wintering waterbird populations may result from factors operating elsewhere during their life cycle (Kushlan, 1993).

It is possible that the lack of significant trends in other species is largely a reflection of the inaccuracy of the IWC counts, given that the extent of coverage and the weather conditions varied between years and that the number of birds present may have been severely underestimated on some occasions. Changes in peak counts per decade suggest that long-term declines have occurred in the total numbers of waterbirds. Likewise there is evidence that the numbers of the two most abundant species wintering at Burdur Lake (common coot and common pochard) have declined, since the means of the last five midwinter counts have fallen below the 1% threshold for international importance, despite particularly accurate counting in the 1990s. Counts of coot over this period have not exceeded 19% of the numbers recorded in 1969. The abundance of submerged plants on which coot feed is likely to have declined due to sedimentation and eutrophication, and such plants were extremely scarce by 1993 (Green *et al.*, 1993). Although counts in 1994 suggest that Burdur Lake is still internationally important for a series of species in autumn and early winter, including black-necked grebe, common pochard and common coot, low mid-winter counts suggest that available food resources may now not be sufficient to support these populations throughout the winter.

These declines suggest that the value of Burdur Lake to waterbirds has decreased as a result of the various threats described above. In contrast, there is evidence of an increase in numbers of *Larus argentatus*-type gulls, perhaps as a result of increasing pollution of the lake, since in 1993 the major gull flocks were roosting and feeding at the milk factory inflow. Such an increase may affect the white-headed ducks by increased disturbance and predation, since these large gulls regularly attack white-headed ducks at Burdur Lake (Fox *et al.*, 1994).

Although the long-term trend for white-headed ducks is not significant, there has been a real decline since 1991. Annual mid-winter counts from 1992 to 1995 inclusive were particularly accurate yet were all lower than each of the previous nine counts. It is possible that this recent decline has been partly due to a change in the distribution of wintering white-headed ducks. However, there is no evidence that more birds are wintering elsewhere in Turkey as only 1189 birds were recorded on other Turkish wetlands during the 1992 IWC and only 566 during the 1993 IWC (DHKD Bird Section reports). There is no evidence that atypical weather has caused a redistribution of birds. However, the distribution of white-headed ducks in the former Soviet Union remains poorly known (Green & Anstey, 1992) and there may conceivably have been a major relocation of wintering birds to this region. Low breeding success in recent summers could partly explain the decline in the number of birds at Burdur. This is supported by the sex ratio of 40% adult males in 1991 (Berrevoets & Erkman, 1991) compared with 49% in 1993, which may suggest a decrease in unsexed first-year birds.

Impact of hunting on white-headed ducks

It is possible that the high level of mortality of white-headed ducks caused by hunting in the 1992–1993 winter exceeds any sustainable harvest and is additive rather than compensatory (*sensu* Owen & Black, 1990). Hunting represents a continuing threat to this population and may have been a partial cause of its recent reduction in size. However, it seems likely that the decline in numbers of white-headed ducks since 1991 has coincided with a reduction in hunting intensity rather than an increase. Local hunting organisations and DHKD conducted education campaigns from 1990 to 1992 to deter hunters from shooting white-headed ducks, although these were clearly insufficient to eliminate the problem. Those questioned when hunting white-headed ducks at the lake within Burdur Province in 1993 were a combination of licence-holders from Burdur, unlicensed hunters from Burdur and those visiting from other provinces (e.g. Bursa). The majority were either unable to identify white-headed ducks or claimed to be unaware that they were a protected species. Limited observations during surveys in 1994 and 1995 suggested that hunting activity had been reduced since 1993, but not eliminated. However, with the support of BASC, the wardening system has been improved and in the 1995–1996 season a very tight control over poaching is expected.

Increased hunting pressure or habitat loss on their breeding grounds in Russia and Kazakhstan (Green & Anstey, 1992) could conceivably play an important role in explaining the reduced numbers of white-headed ducks at Burdur Lake, since the political changes in the former Soviet Union are often reported to have led to increased hunting of wildlife.

Other threats to the lake and its fauna

The ecological character and conservation value of Burdur Lake is significantly threatened by a range of factors, as is typical of wetlands of importance for waterbirds in Turkey (Grimmett & Jones, 1989) and throughout the Mediterranean region (Hollis, 1992). Many current changes could have a negative impact on the white-headed ducks even if the problems of illegal hunting are solved. The distribution and abundance of their food supply is likely to be affected by man-induced changes. Enhanced sediment, organic and inorganic inputs to the closed lake system may have already changed its ecological character. The lake is undergoing eutrophication, which generally leads to a loss of biodiversity in wetlands, although it increases

the numbers of certain species (Nilsson, 1978). Although there is no evidence that pollution from the sugar and milk factories has affected chironomids, local and overall organic enrichment of the closed basin lake system is very likely to have negative impacts on other species of fauna and flora. The effects of these discharges are likely to be far more dramatic in summer when much higher temperatures and reduced wave action may lead to significant oxygen depletion around the inflows.

A similar situation exists at Albuferas de Adra, Almería, a major breeding site for white-headed duck in Spain. Leaching of fertilisers from surrounding market gardens is causing rapid eutrophication, characterised by a loss of submerged vegetation and a blooming of phytoplankton. The numbers of coot at the site have reduced drastically, while white-headed duck numbers have so far (1994) shown no evidence of decline (M. Paracuellos Rodríguez, pers. comm.).

Rapid sediment deposition at Burdur Lake is likely to increase substrate instability and turbidity, and is thus likely to reduce chironomid biomass (Moss, 1988; Green *et al.*, 1993). As water levels drop and the lake recedes, the decrease in the area of habitat may itself limit the number of white-headed ducks and other waterbirds that the lake can support. Çorak Lake (1150 ha), another closed basin lake in Burdur Province and formerly an important wintering site for white-headed ducks (Anstey, 1989), has been totally dry since 1987. The reason for this is unclear but may be sedimentation and/or drought.

The intensity of threats to Burdur Lake is accelerating as a series of developments is proposed and realised within its catchment. In the long term, the input of acidic effluents from the industrial complex could cause major ecological change by exhausting the buffering capacity of the lake. Textile industry effluent is very acidic (Mason, 1981), and could markedly reduce lake pH. It has been suggested that a significant lowering of the pH of the lake would result in the release of hydrogen sulphide in toxic quantities, owing to the naturally high levels of sulphur compounds in the lake (Timur *et al.*, 1988). The bird-strike problem has not been considered during planning of the airport, and there is a possibility of hydrocarbon and other pollution entering the lake.

Conclusions for conservation of the lake

It is very important that the threats facing the lake are addressed, particularly to conserve its endemic species and population of white-headed ducks. Measures required to solve these problems need not conflict with the needs and activities of the local human population around the lake. Since the lake is an important leisure area in the summer, and thousands of people live on the lake shores all year round, there is a common interest that further degradation of the lake should be prevented. Furthermore, the proximity of the major tourist centre of Antalya means that a well-conserved lake could potentially be developed for birdwatching and other kinds of benign foreign tourism. The extraction of water within the lake catchment area for irrigation purposes is a clear case where a threat to the lake may not be solved without marked restriction of human activities.

The current proposals for an industrial complex and airport at the northern end of the lake should be subjected to a full Environmental Impact Assessment and EIAs of the various existing pollution problems should also be carried out. Improved measures are required for sedimentation control, accelerating current afforestation and soil erosion control programmes. Treatment plants should be fitted to the sugar factory, milk factory and Burdur sewage system to minimise the quantity of pollutants entering the lake. Remedial action is required at the sulphur mine to minimise the leaching of inorganic pollutants into the lake from old mine workings. There is a need to establish an adequate programme of site wardening to eliminate waterbird hunting at Burdur Lake.

Effective action to conserve the lake requires appropriate research to allow formulation of policy. It is vital that the relative contribution of various factors to the reduction in water levels in Burdur Lake is clarified by detailed study of the hydrology of the watershed, and that a strategy to stop further reductions is formulated. The rate of sediment input to the lake should also be measured.

Regular waterbird counts carried out by DHKD should continue to clarify the importance of the site outside winter and to allow improved assessment of population trends. Ecological studies of other major components of the lake ecosystem (plankton, vegetation and fish) are required. Long-term monitoring of water chemistry should be carried out to assess the impact of pollution discharge and the effects of future treatment techniques. A socio-economic and cultural study is required in the lake catchment to clarify the extent of human dependence on the lake's resources. A plan for the integrated management of Burdur Lake should be prepared, using the results of the above studies.

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