mum carapace width, 375 mm; midline plastron length, 439 mm; maximum plastron width, 261 mm; maximum shell depth, 217 mm. Both plastron and carapace are extremely worn and deeply pitted, annuli are no longer discernible, and plastral scute seams barely so. The turtle was reportedly collected on 10 February 2001 as it crawled across a sandbar in the upper Dokhtawady River. The turtle was later killed and eaten, but said to contain no oviductal eggs or noticeably enlarged follicles. The fisherman, a lifelong resident of the area, stated this was the only specimen of *Kachuga* that he had ever captured.

The shell had characteristics of both *K. trivittata* and *K. dhongoka*. According to Ernst and Barbour (1989), both sexes of *K. dhongoka* exhibit a median vertebral stripe and two poorly defined lateral stripes on the carapace, while in *K. trivittata* these stripes are present in males only; females have a uniformly brown carapace. Our specimen appears to have both a median vertebral stripe and lateral stripes, and is larger than the carapace length reported for male *K. trivittata* (46 cm). Moreover, the posterior border of the second vertebral is pointed posteriorly in *K. dhongoka*, a characteristic obvious in our specimen (Table 3), but not reported for *K. trivittata* (Ernst and Barbour, 1989). Also, the length of the second vertebral is greater than the width, and the third vertebral is wider than long in *K. dhongoka*, but these measurements are approximately equal or the scute is slightly wider than long in *K. trivittata* (Ernst and Barbour, 1989). Interestingly, the second vertebral of the specimen is longer than wide, and the third vertebral is wider than long (Table 3), a description consistent with *K. dhongoka*. However, the specimen has an obvious median keel with prominent projections on the second and third vertebrals and a reduced projection on the fourth vertebral (Table 3) as reported for *K. trivittata* (Ernst and Barbour, 1989). *Kachuga dhongoka* has a median keel, but this is reduced to a posterior projection on the second and third vertebral scutes of adults (Ernst and Barbour, 1989). Finally, the plastral formula of the specimen (abd > fem > hum > pect > an > gul) agrees with that reported for *K. trivittata*, rather than *K. dhongoka* (abd > fem > pect > hum > an >< gul) (Smith, 1931; Ernst and Barbour, 1989).

Despite the inconsistent morphological characteristics, the specimen is most likely *K. trivittata*, the only species of *Kachuga* confirmed from Myanmar (Iverson, 1992). *Kachuga dhongoka* occurs only in the Ganges and Brahmaputra drainage of Nepal, Bangladesh, and northeastern India (Ernst and Barbour, 1989; Iverson, 1992) and is unlikely to be found in Myanmar. Myint Maung (1976) reportedly obtained a single specimen of *K. dhongoka* in the early 1970s near Mandalay; however, this specimen has since been lost (Myint Maung, *pers. comm.*) and may have been misidentified.

Table 3. Measurements and description of vertebral scutes from a *Kachuga* shell (possibly *K. trivittata*) obtained at Yee Village along the Dokthawady River, Myanmar, on 18 March 2001.

Vertebral	Midline length (mm)	Maximum width (mm)	Vertebral projection
1	70.0	82.0	Absent
2	99.1	88.6	Prominent
3	61.1	80.4	Prominent
4	110.6	76.5	Projection present, but considerably worn
5	85.0	113.5	Absent

Results of the current and previous investigations (Thorbjarnarson et al., 2000; van Dijk, in press) indicate that viable populations of *K. trivittata* no longer occur in much of the Ayeyarwady River. Likewise, *K. trivittata* is probably extirpated from the lower Chindwin River. A remnant population may occur in the upper Dokhtawady River, and the situation in the headwaters warrants investigation. The possible occurrence of *K. trivittata* in the upper Chindwin, Sittang, and Salween rivers has yet to be investigated. However, with the exception of the latter, these rivers have been extensively degraded by a variety of ecological insults including gold mining, deforestation, agriculture, over-fishing, and siltation (Scott, 1989; Saw Tun Khaing, *pers. comm.*), and are unlikely to support significant numbers of *K. trivittata*. Consequently, we regard *K. trivittata* as Critically Endangered in Myanmar.

Melanochelys trijuga edeniana. — The distribution of this endemic subspecies is poorly known. Locality records are available from lower Myanmar, including Rakhine and Karen States, and Bago and Magwe Divisions (Theobald, 1868; Iverson, 1992; Platt et al., 2001a). We examined shells of locally collected turtles at Hti Chiang Town, Kathar, and Shwegu during March 2001.

Morenia ocellata. — This endemic species is generally thought to be restricted to the Ayeyarwady Delta, lower Sittang River, and coastal regions of the country (Ernst and Barbour, 1989; Iverson, 1992). However, Kuchling (1995) noted market specimens in southern China that appeared to have been collected nearby and speculated that *M. ocellata* may occur much farther north than suggested by previous records. On 7 March 2001 we examined a *M. ocellata* shell in Singkaing Village, approximately 20 km upstream from Mandalay. According to villagers, the turtle was captured in late December 2000 or early January 2001 in floodplain grassland near the village and deposited two eggs shortly thereafter. Villagers regarded *M. ocellata* as rare, and long-term residents stated they had encountered only one other specimen. This record extends the distribution of *M. ocellata* approximately 700 km upstream from previously reported populations in the Ayeyarwady Delta. Furthermore, fishermen at Wacheck Village and Pakokku claimed to occasionally catch *M. ocellata* in the Ayeyarwady River, but specimens were unavailable for our examination.

In November 2000 we also examined a large (800+) group of *M. ocellata* at Yadanabon Zoological Garden in Mandalay that had recently been confiscated from illegal wildlife traders. We selected several of the largest turtles for measurement; the midline carapace length (CL) of four females (CL = 222, 226, 235, 239 mm) exceeded the previously reported size maxima of 220 mm (Ernst and Barbour, 1989). The age of these individuals could not be estimated as *M. ocellata* lack conspicuous annuli.

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Occurrence of Diamondback Terrapins, *Malaclemys terrapin*, on Bermuda: Native or Introduced?

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ABSTRACT. – A breeding population of the American diamondback terrapin, *Malaclemys terrapin*, occurs on the oceanic island of Bermuda; most of the population lives in two brackish lakes surrounded by mangrove vegetation. The question of whether the species reached Bermuda from the USA naturally or by deliberate or inadvertent introduction is considered.

The emydid diamondback terrapin, *Malaclemys terrapin*, is widely distributed in estuaries and salt marshes on the east coast of the USA from Texas to Massachusetts. During the past decade it has been discovered that there is a breeding population of *M. terrapin* on the isolated island of Bermuda (32°18'N, 64°46'W), some 960 km from the US coast (Fig. 1). The recent colonization of many bodies of water in Bermuda by released pet specimens of the American red-eared slider (*Trachemys scripta elegans*) has resulted in closer scrutiny of Bermudian pools, so greater knowledge of the distribution of diamondback terrapins on Bermuda is now available. This paper presents preliminary distributional information, and also considers the question of whether diamondback terrapins have reached Bermuda by natural means or by human intervention.

The currently accepted native Bermudian herpetofauna is limited to the endemic skink, *Eumeces longirostris* (the

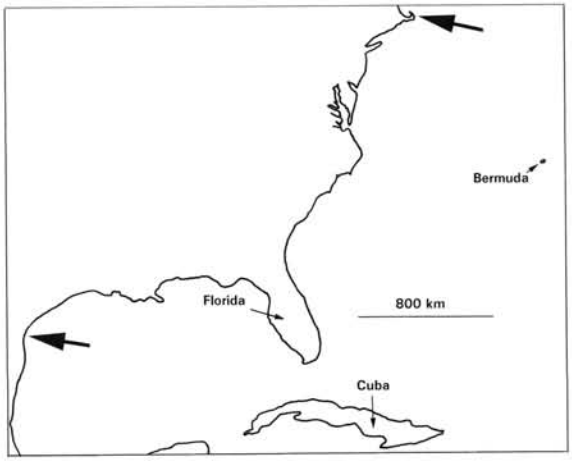

Figure 1. Map to show position of Bermuda in relation to the USA. Large arrows indicate southern (Corpus Christi, Texas) and northern (Cape Cod, Massachusetts) distributional limits of *Malaclemys terrapin*.

only endemic terrestrial tetrapod), and four species of marine turtles. However, there have been numerous well-documented and dated introductions of amphibians and reptiles (several small lizard species of the genus *Anolis*, the cane toad, *Bufo marinus*, and two species of tree frog, as well as the red-eared slider). No such documentation exists for *M. terrapin*. Although present-day Bermuda is now an essentially suburban country (Sterrer, 1998) with a resident population of about 60,000 people and numerous tourists (0.5 million/yr), there is therefore the possibility that the island has harbored an extra, but unrecognized, native reptile for a considerable period of time.

Results. — Diamondback terrapins were first reported in the mid-1990s to the Bermuda Aquarium, Natural History Museum and Zoo (BAMZ) by staff of a local golf course, the Mid Ocean Club, who found eggs in sand bunkers. The eggs were incubated at BAMZ and hatchlings released at the golf course in two small brackish man-made ponds that clearly contained numerous (between 10 to 100) mature male and female diamondback terrapins, as well as specimens of *T. s. elegans*.

Further investigation by BAMZ staff revealed that terrapins were also present in nearby Mangrove Lake, a relatively large natural brackish water body. They have been reported from all parts of the lake, which is completely surrounded by thick mangrove vegetation and separated from the sea by a narrow strip of land. However, the numbers present are currently unknown and an effective mark-recapture census would be a substantial undertaking and logistically difficult. Terrapins are also known from neighboring Trott Pond, another natural brackish pond. Local residents report that terrapins have been present in Mangrove Lake at least for several decades. It seems probable that the artificial golf course ponds were colonized by terrapins from one or other of the much larger natural ponds.

We recently collected three adult female diamondback terrapins from the pools at Mid Ocean Club (carapace lengths 197, 213, 215 mm) (Fig. 2). Their sizes were quite close to maximum recorded lengths for female diamondback terrapins (ca. 225 mm). All had extremely smooth carapaces with negligible scute grooves and rather indistinct markings. The dorsal keel was of negligible height. Carapace color was variable. One animal (215 mm) had a light brown shell, with the most recent scute growth being ivory in color. Its carapace was essentially elliptical and the marginal scutes showed only limited upcurling posteriorly. The skin was pale gray with dark gray spots. There was no moustache stripe. The other two had oval olive green shells, with recent scute growth being light green. Both had finely spotted light green to gray skin and no moustache. Their

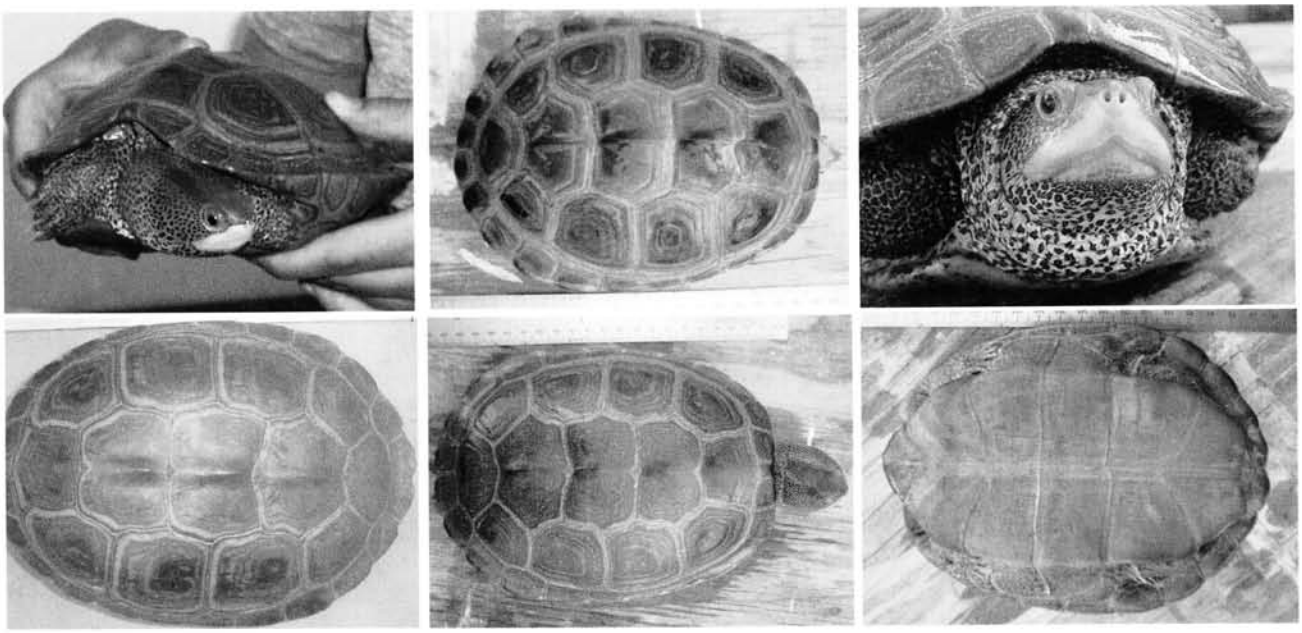

Figure 2. Photographs of diamondback terrapins, *Malaclemys terrapin,* collected recently on Bermuda.

shells showed slightly more marginal upcurling than the brown animal.

Discussion. — Bermuda and its surrounding archipelago is one of the most remote island systems in the world. However, it is known that the Gulf Stream, which runs close to the North American coast between Florida and Cape Hatteras, spins off eddies that pass regularly through Bermudian waters. These eddies have been implicated in the transport of postlarval reef fish from Florida waters to Bermuda (Glasspool, 1994) and also in the transport (probably from Florida) of the extinct Bermudian tortoise *Hesperotestudo bermudae* to the islands, where it occurred some 300,000 years ago (Meylan and Sterrer, 2000). These authors estimated that the tortoise would have floated more than 2000 km to reach Bermuda, possibly achieving the passage in as little time as a week or two.

Among emydid turtles, diamondback terrapins are almost uniquely suited to long-distance travel at sea. Their estuarine natural habitats are often highly saline for weeks at a time (Bentley et al., 1967; Gilles-Baillien, 1970; Dunson, 1970, 1976, 1985). They are capable of living for long periods in sea water because they have low skin permeability to salts and water, excrete salts from orbital salt glands, accumulate urea in the blood plasma (thus minimizing osmotic water loss), and have behavioral responses that prevent drinking and minimize eating when in sea water for long periods (Schmidt Nielsen and Fange, 1958; Bentley et al., 1967; Gilles-Baillien, 1970; Dunson, 1970, 1976, 1985; Davenport and Macedo, 1990; Davenport and Ward, 1993). Most freshwater emydids would succumb to osmotic dehydration and hyperchloremia within a few days in sea water.

Diamondback terrapins are well-suited to the conditions in which they live in Bermuda today. There are no surface streams on the island and the rock formations are highly permeable to sea water. In consequence, most pools are brackish rather than fresh, with the precise salinity depending to a large extent on recent rainfall. It is known that *Malaclemys* is capable of exploiting transient sources of rainwater (Davenport and Macedo, 1990) and is probably the best-adapted brackish-water turtle so far studied. There is little doubt that diamonback terrapins *could* have reached Bermuda naturally.

However, *did* diamondback terrapins reach Bermuda naturally? This is a much more difficult question to answer. *A priori*, diamondback terrapins could a) have been imported as pets and subsequently released, b) been imported as food animals, perhaps during the terrapin culture 'craze' of the early 20th century, or c) have arrived without human intervention as described above.

There is no evidence that diamondback terrapins have ever been imported as pets to Bermuda. Outside the USA they have never been a conspicuous part of the herpetofauna pet trade.

From the 1880s through to the 1920s in the USA, there was great demand for diamondback terrapins as gourmet food items. Initially satisfied by capture of wild terrapins, by 1900 demand, plus declining stocks, had triggered the establishment of ranches and farms, particularly at Beaulieu, Georgia, and Beaufort, North Carolina (Gadow, 1901; Coker, 1906; Hildebrand and Hatsel, 1926; Hildebrand, 1932). Terrapins were not only eaten in the USA, but were exported to Europe and Brazil. The terrapin trade largely collapsed with the 1930s recession in the USA, though cook books published terrapin recipes well into the 1950s. There is no oral or written record of any attempt to farm terrapins in Bermuda, though it is conceivable that someone might have imported a few animals for consumption, but released them instead.

Given the scenario for possible natural colonization outlined above, it would seem likely that a possible natural source population for Bermudian terrapins would have to be in the southern part of the species' range, perhaps in Florida (the apparent source of the endemic skink *Eumeces longirostris* and the extinct fossil *Hesperotestudo bermudae* according to Meylan and Sterrer, 2000). There is no fossil evidence of long-term Bermudian residence for *Malaclemys*. A skeleton (with some scutes intact) was found in a dry cave near Harrington Sound (close to the two natural ponds in which terrapins are currently found). Carbon dating of such recent material would probably be of limited use unless it was medieval or older. Genetic analysis of Bermudian terrapins has not been carried out, and would in any case have to be related to the genetic makeup of diamondback terrapins from the populations living along the eastern coast of the USA. The species' wide geographical distribution, perhaps coupled with limited gene flow between populations living in brackish water habitats separated by open coast, has led to an unusual degree of diversity, with seven subspecies currently recognized (Carr, 1952; Pritchard, 1979).

If Bermudian *M. terrapin* proved to be genetically identical with *M. terrapin terrapin* (the northern diamondback) a natural origin for the terrapins would be virtually ruled out because their distribution is too far north to permit sea transport by the Gulf Stream to Bermuda. A more credible candidate, *M. t. centrata* (the Carolina diamondback) is difficult to separate from *M. t. terrapin* on morphological grounds as there are "all sorts of variations and intergradations" (Carr, 1952). To complicate matters further, farmed terrapins were a mixture of the two subspecies (Carr, 1952) and were released when farms closed. The features of the three terrapins we collected (Fig. 2) are not compatible with published descriptions (Pritchard, 1979) of *M. t. macrospilota*, *M. t. pileata*, or *M. t. littoralis*, all of which have deeply sculpted shells and high dorsal keels. The absence of a moustache and the presence of concentric shell markings exclude *M. t. tequesta*. Of the remaining three subspecies, the smooth, marbled carapace seems more compatible with descriptions of *M. t. centrata* than *M. t. terrapin*. However, it is difficult to rule out *M. t. rhizophorarum*, as that subspecies is relatively poorly studied, also has a smooth carapace with

slight dorsal keel, and occurs in extreme southern Florida where the Gulf Stream sweeps by close to shore.

Conclusions and Recommendations. — The Bermudian population of *M. terrapin* appears to be the only breeding population outside the USA. It is apparently thriving, though a full population estimate would be desirable to establish a benchmark for future study. Whether the species is native to Bermuda or introduced is of conservation and management significance. If native, then full legislative protection and appropriate conservation measures would be appropriate. If introduced, then study of the impact of terrapins upon the brackish-water fauna of Bermuda would be sensible.

The present investigation does not provide conclusive support for either hypothesis, and it is probable that a natural introduction could only be firmly proved if skeletal remains of pre-colonial age emerge at some time in the future. However, a natural introduction could be disproved if the Bermudian specimens can be shown to have closer affinities with *M. t. terrapin* than either *M. t. centrata* or *M. t. rhizophorarum*. There appears not to be an adequate genetic library presently available to permit this to be achieved by DNA analysis. Hopefully this situation will be clarified in the future.

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