SHORT PAPER

Diving and Amphibious Behaviour in a Free-living *Crocodylus porosus*

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ABSTRACT

Twelve Estuarine Crocodiles (6-51 kg) were fitted with recording back packs in order to study the longevity, frequency and daily/tidal rhythm of natural dives by crocodiles free-living in their familiar habitat. Despite disinterest shown by captive crocodiles in removing their jackets in tank trials, all but one of the seven crocs recaptured 5-16 days after release had shed their jackets and recorders. Results from this 9.75 kg animal showed that it had a prolonged emergence during each daylight low tide (basking?), that it dived mainly in daylight hours (feeding?) predominantly in the upper half of the tide and that most dives were of very short duration (1-5 minutes). Even the longest dive, 30 minutes, was well within the aerobic capabilities of a crocodile this size. Although these results are from a single animal, and may turn out to be quite atypical, if attachment problems are solved the method has clear potential for revealing much about the daily activity patterns of free-ranging crocodiles, and other animals.

A study of diving behaviour in Estuarine Crocodiles, *Crocodylus porosus,* free-living in their familiar habitat was attempted in the Tomkinson River, northern Australia in October 1981 by fitting each of 12 crocodiles with a recording back pack. Information was collected from only one animal, but the experience gained would allow us to undertake a follow-up study with a much higher success rate. No opportunity exists for a follow-up study in the forseeable future. Accordingly, we report here the data gained from that single animal, acknowledging whatever limitations it may have, in the belief that the results are of interest and may encourage others to employ similar techniques.

Questions, about the longevity, frequency and daily/tidal rhythm of natural dives in *C. porosus,* led us in 1979 to plan this study as background to laboratory studies of diving physiology in *C. porosus.* Meanwhile, the use of recording back-packs in free-ranging animals was applied with considerable success to Weddell seals (Kooyman *et al.* 1980), establishing that they typically dive repetitively and for only short periods when feeding under natural conditions.

Much has been written about terrestrial aquatic behaviour in various species of crocodilian, starting with Pliny who recorded that Nile crocodiles spend the day on shore and the night in the water, a view confirmed by Cott (1961). The importance of daytime shore basking has been drawn attention to by many authors. Little has, however, been recorded about diving patterns under natural conditions in any species, or about tidally correlated behaviour patterns in estuarine species. The main question we particularly wanted to address was whether on not dives too long to be accounted for by aerobic metabolism were common in *C. porosus*.

The recording unit was made by Kinney and Farwell (EnviRecord, Los Angeles). It was a battery-operated recording microprocessor sealed in a teflon casing (7.5 x 6.5 x 2.1 cm), with a spring-loaded insulated and hydrophobic probe attached to the brass lid of the unit. At the top of the probe was a gold-plated electrode. The probe was bent forward to cope with the *penchant* of crocodiles for resting in the water with the body sloping at approximately 45° (Fig. 1). The recorder was mounted on the crocodile in the pocket of a neutrally buoyant neoprene rubber jacket (Fig. 1). Trials with captive crocodiles had shown that this appeared not to prejudice their behaviour and that they did not attempt to remove it. The same trials showed also that all observed dives were recorded successfully. Each minute, the device sampled and recorded whether there was a conductive wet-bridge between the probe-tip and the lid of the casing. Any period of one minute or more was recorded as a dive, whereas

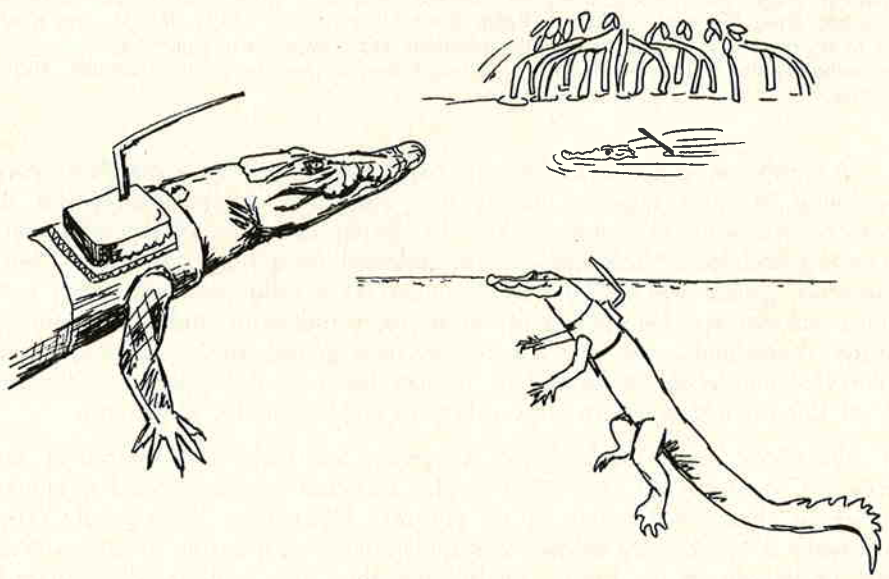


Fig. 1. Sketches of the crocodile and its recording back-pack.

even a brief moment of surfacing during any one minute sampling period was not logged as a dive. Hence, the device was set-up to recognise brief surfacing between dives. While this missed very short dives, it avoided possible confusion from the lapping of waves over the probe tip. The recording unit could retain 8192 samples (thus total sampling time was 5.69 days). Sampling rate could be adjusted; the one minute rate was a compromise that missed very short dives but gave a reasonably long sampling time. Following recovery, the unit was interrogated with a read-out device activating a chart recorder (Figs 2, 3).

Crocodiles in the field study were caught by a non-injurious harpooning technique (Webb and Messel 1977). After being fitted with the recorder, each was released at its capture site in brackish or salt water between 17.2 and 54 km upstream from the open sea. Six of the jackets had a small radio-transmitter incorporated to aid relocation and recapture. A description of the habitat provided by the Tomkinson River (meandering, mangroved-fringed) may be found in Messel et al. (1979) and Grigg (1981). Contemporaneously, tritiated water and ^{22}Na were injected in order to study water and sodium fluxes (reported elsewhere, Grigg *et al.* submitted). Crocodiles were marked by scute-clipping. Seven of twelve crocodiles (65-122 cm SVL, 5.57-51.3 kg) were recaptured within 5-16 days, none more than 1500 m from the capture and release point. Despite the

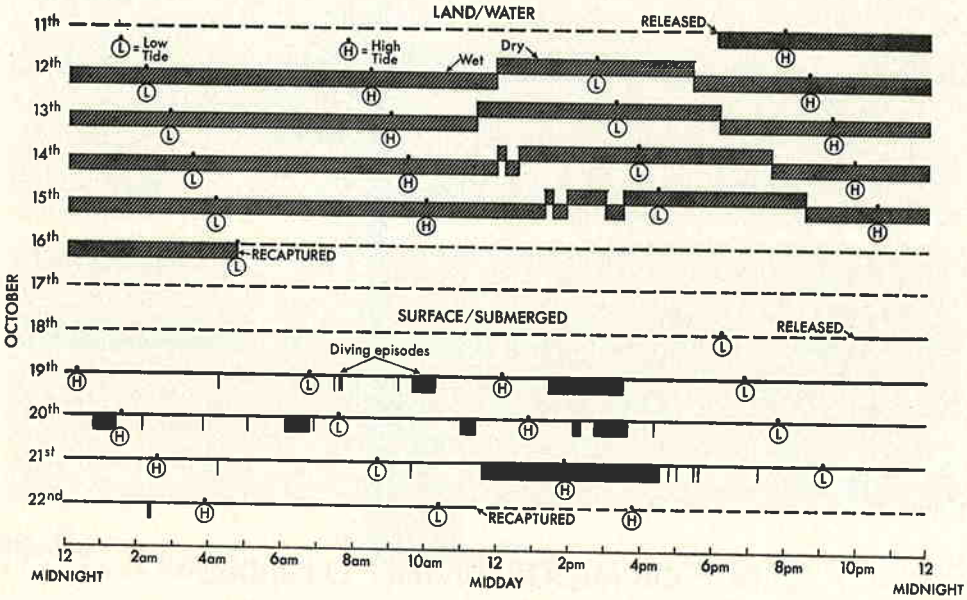
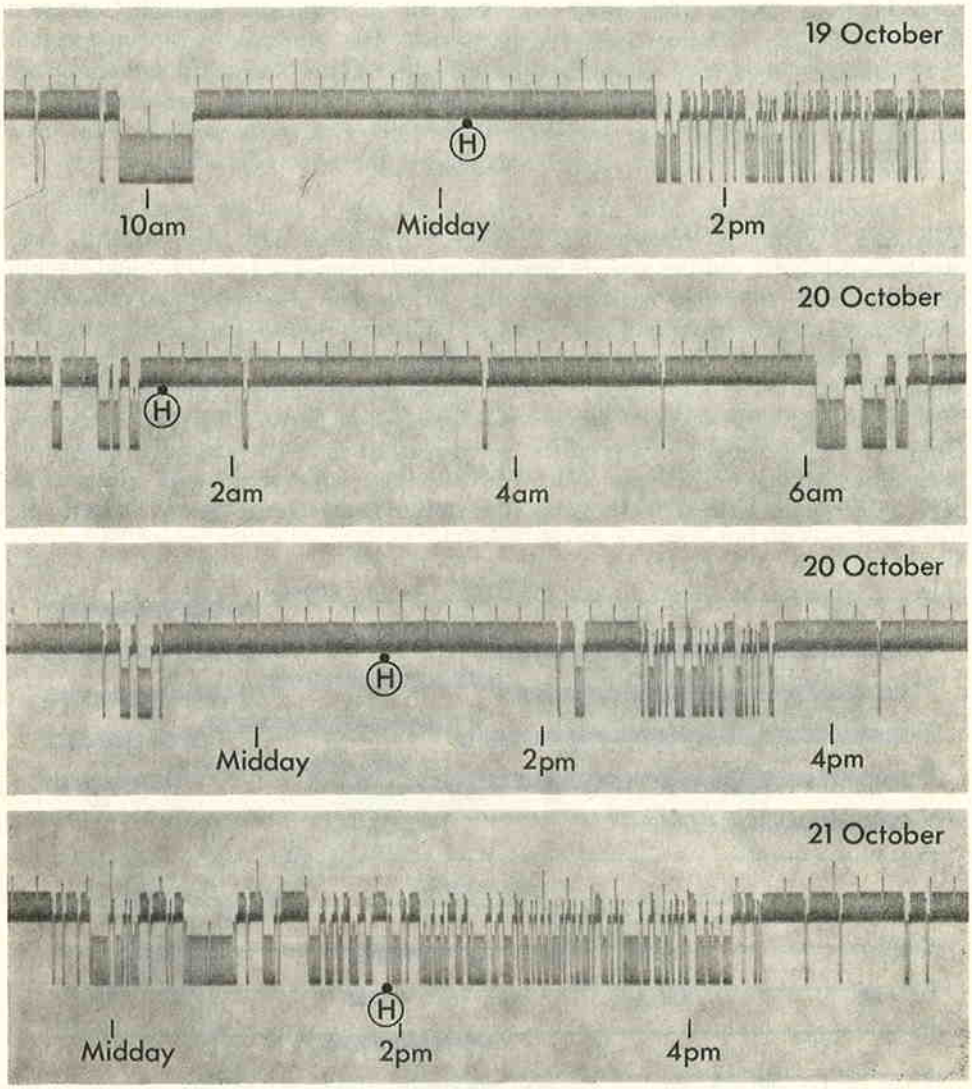


Fig. 2. Time spent by a 9.75kg female *Crocodylus porosus* on land and in the water (upper panel) October 11-14, and diving episodes (lower half) October 18-22, in the Tomkinson River, northern Australia, 1982. Circled H and L points mark times of high and low tide each day.



DETAIL OF MAJOR DIVING EPISODES

Fig. 3. Detail of read-out from the back-pack after recovery, showing a selection of the major diving episodes.

disinterest shown by captive crocodiles in removing the jackets during diving trials, all but one (#2079) of the wild-ranging crocodiles had shed their recorders and back packs. Two abandoned recorders were recovered along the shore by radio-tracking but these yielded no unambiguous data.

The animal from which data were obtained successfully was a 9.7 kg (#2079) female captured 25.5 km upstream against the eastern bank and released at the same point at 1806 hrs Eastern Standard Time, October 11, 1981. She was recaptured at 0445 October 16. Interrogation of the recorder revealed that the probe had gained a thin film of river sediment which, when moist, allowed a conductive path from the probe tip to the metal lid of the recorder. Hence, the record did not show dive patterns, but whether the probe was wet or dry. This fortuitously gave useful information of a different kind (Fig. 2, upper half). The problem was rectified, the animal re-released at 2158 hrs, October 18 and recaptured at 1130 hrs October 22, whereupon it was found that the re-adjusted recorder had operated as planned (Fig. 2 lower half, Fig. 3).

The results show that this crocodile had a prolonged emergence during the daylight low tide (Fig. 2, upper). We interpret this to be time spent ashore.

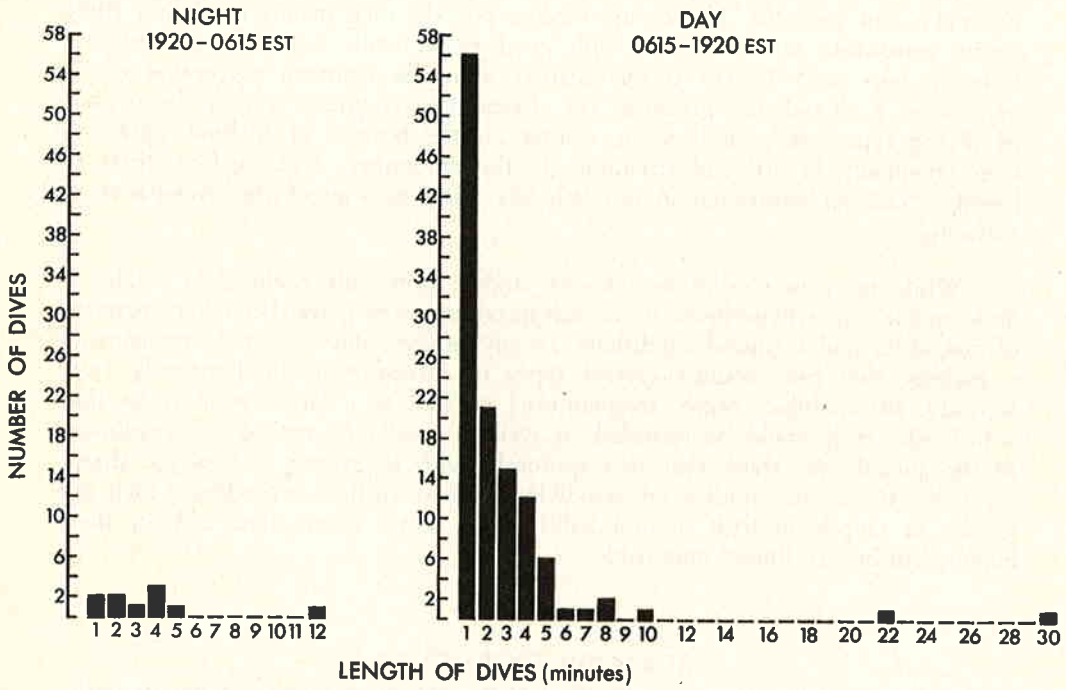


Fig. 4. Length/frequency distribution of dives one minute or longer, by night and by day, October 18-22, 1982.

Its periods of diving were mainly in daylight hours (Fig. 2, lower, Fig. 4), often (not always) associated with the upper half of the tide (Fig. 2, lower). The importance of the height of the tide as a determinant of behaviour is shown by middle-of-the-day time on land (basking?) on October 12, 13 at low tide, and middle-of-the-day diving (feeding?) on October 19, 20, 21. This interpretation predicts that the crocodile would likely be out of the water on the morning daylight low tides of October 20-22, about which we have no information from the dive recorder (except that there were no dives). However, her recapture followed our discovery of her right out of the water and up among the mangroves at about 10.30 a.m. October 22. Lack of up-directed tracks from the water's edge across the soft mud showed that she had been out of the water for some time. It seems likely that both time and tide are major factors influencing crocodile behaviour in tidal systems.

As to the length of dives, they are mostly very short (1-5 minutes) (Figs 3, 4) and have only brief intervals between, with, perhaps, only a single breath at the surface in many instances. The longest dive was 30 minutes, known to be well within the aerobic limit for a crocodile of that size (J. Wright, pers. comm.). Whether or not the periods of diving represent feeding periods is unknown, but probable. If they are feeding periods, then mainly daylight feeding seems reasonable for an animal with good visual skills but their pattern and duration (up to 5 hours) is inconsistent with the common perception of *C. porosus* as a sit-and-wait predator. An alternative hypothesis is that the periods of diving represent periods spent resting on the bottom in shallow water, as seen commonly in stressful situations in the laboratory, with surface visits to breathe. Such an interpretation is much less likely because of the irregularity of surfacing.

While no firm conclusions can be drawn from this preliminary study, it does enable some hypotheses to be advanced concerning the behaviour patterns of crocodiles under natural conditions. In any future study we would recommend a package that can monitor several types of information simultaneously (e.g. wet/dry, surface/dive, depth, temperature) as well as a larger memory so that a full tidal cycle could be recorded, as well as a reliable method of attachment to the animal. We think that this approach, with improving technology, shows a lot of promise for studies for free-living animals such as crocodiles which are so shy or cryptic in their natural habitat that direct observation without their being disturbed is almost impossible.

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