

Diet of the Freshwater Turtle *Chelodina longicollis* (Testudines : Chelidae) from the Coastal Dune Lakes of the Jervis Bay Territory

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Abstract

Chelodina longicollis is an opportunistic carnivore that obtains its food from a wide variety of sources—plankton, nekton, benthic macro-organisms, carrion, and terrestrial organisms that fall upon the water. Although there are some quantitative differences between the littoral components of the diet and the composition of the littoral fauna, these can be attributed to differences in accessibility or 'noticeability' among prey species. There is no evidence to suggest that *C. longicollis* is selective in what it eats, within the confines of carnivory. Comparison of the diet of *C. longicollis* with those of other sympatric chelids reveals considerable overlap; the relevance of this to geographic variation in abundance of the species is discussed.

Introduction

Recent studies have done much to increase knowledge of the diets of Australian chelid turtles. Species of the genus *Emydura* are typically omnivorous (Legler 1976; Chessman 1978; Georges 1982a), although they may be carnivorous when young with increasing tendencies towards omnivory as they age (Georges 1982a). *Chelodina expansa*, *C. longicollis*, *Pseudemydura umbrina* and *Rheodytes leukops* are carnivorous (Parmenter 1976; Legler and Cann 1980; Burbidge 1981; Chessman 1983, 1984), though the latter two species lack the specialized morphological adaptations of *Chelodina* and other long-necked chelids (Parmenter 1976; Legler 1978; Pritchard 1984) necessary for securing fast-moving prey. Within the confines of carnivory, *Chelodina expansa* is a selective and specialized predator feeding upon highly motile prey such as decapod crustaceans, aquatic bugs and small fish (Legler 1978; Chessman 1983), whereas *C. longicollis* is reported to have a diverse and opportunistic diet (Parmenter 1976; Chessman 1984).

Chelodina longicollis is widely distributed in eastern Australia (Cogger 1983) and its diet has been described for populations from Gippsland in Victoria (Chessman 1978), the Murray Valley of Victoria and New South Wales (Chessman 1984), and from farm dams of the New England Tableland, N.S.W., where the species is very abundant (Parmenter 1976). The species is also very abundant in Lakes Windermere and McKenzie, two permanent closed freshwater dune lakes of the Commonwealth Territory of Jervis Bay, on the coast of New South Wales. The hydrology, geology and water chemistry of these lakes have been described (Jacobson and Schuett 1984), but their biological characteristics have received very little attention. However, studies of dune lakes elsewhere have shown them to be deficient in nutrients, of low productivity and of low biotic diversity when compared to other types of Australian waterbodies (Bayly 1964; Timms 1973; Bayly *et al.*, 1975; Bensink and Burton 1975). In this paper the diet of *C. longicollis* in the two dune lakes is described and, for the first time, quantitatively compared to the available littoral, profundal and planktonic fauna, to determine if the turtles are selective in what they eat. *C. longicollis* is the only species of turtle to inhabit the dune lakes at Jervis Bay but can be found together with *C. expansa* in dune lakes on Moreton I., Qld (personal observation)

and with *C. expansa* and *Emydura krefftii* on Fraser I., Qld (Georges 1982b). The diets of the three species are compared to provide insight into geographic variation in abundance of *C. longicollis*.

Materials and Methods

Specimens of *C. longicollis* were caught by muddling, by diving, and in hoop traps (Legler 1960) baited with liver and sardines enclosed in wire mesh. Traps were cleared of turtles at intervals ranging from 75 to 150 min. Each turtle was furnished with a unique combination of notches in the marginal scutes and underlying bone. Carapace lengths (straight-line maximum) were recorded, but sex could not be determined. Stomach contents of a total of 109 turtles from L. McKenzie and 100 turtles from L. Windermere were removed in October and December of 1983 and October of 1984, by stomach flushing: a 12-V submersible pump (L.V. Motors model 105) was used to supply a steady flow of water, which was passed into the stomach through a flexible plastic tube (after Legler 1977). The water then passed back up the oesophagus carrying with it the items of food. Water flow was adjusted for turtles of different sizes by interchanging tubes of different diameters. Twenty-three turtles, in addition to those mentioned above, yielded little or no material: either their stomachs were empty, or their stomach contents were only partly dislodged. Data from these individuals were not included in the analysis. All turtles were flushed as soon as possible, and never more than 2 h, after capture or removal from the traps. Stomach contents were preserved in 70% alcohol and were later examined under a stereo-microscope. Sand and fragments of litter were assumed to have been accidentally ingested and were not included in the analysis of food items. On occasion, turtles did gain access to the bait, but the liver and sardines could be easily distinguished from other items of the diet (including kangaroo flesh eaten as carrion). Such items of bait, if present, were removed before the sample was preserved.

Percentage composition by number and percentage occurrence (Windel and Bowen 1978) were used to evaluate the relative importance of different foods eaten by *C. longicollis*. The numerical method involved counting the number of items belonging to each taxonomic group. Aquatic insects and small crustaceans usually remained intact and were easy to count. The numbers of terrestrial arthropods, when fragmented, were determined from the numbers of hindwings or other identifiable parts. Items that did not occur as discrete units (such as filamentous algae and carrion) could not be counted and were omitted from the numerical analysis. Frogs' eggs, which occurred in large numbers in some stomachs, but which were probably eaten from a single egg mass by each turtle, were counted as one item so as not to bias the numerical estimates. The occurrence method involved counting the number of turtles that had eaten one or more items of a particular food, and expressing the count as a percentage of the number of turtles examined. The relative merits of these two methods, among others, have been discussed by Windel and Bowen (1978).

Differential rates of digestion and passage through the gut for different types of food inject an element of bias into estimates of the relative importance of food types calculated from stomach contents. The importance of foods with a relatively slow rate of passage will be overestimated. This source of bias was held to a minimum by excluding from the analysis partly digested invertebrates found in the mucous plug which, before it is dislodged by the flushing process, resides in the pyloric stomach before passing to the intestine.

Relative abundances of various taxa from the littoral zone, profundal zone and the water column were estimated for comparison with those in the diet of *C. longicollis*. Littoral zone organisms were collected with a vertical column sampler (cross-sectional area 0.07 m²) placed on the bottom at a depth ranging from 0.50 to 0.75 m. Macrophytes were removed and retained for identification. The substratum was agitated to a depth of 20 mm by hand, and a small hand-net (500 µm mesh) was moved through the water inside the column until no further animals were collected with successive dips. Five replicates from each compass quarter (north, south, east, west) were taken from each lake on each day that turtle diets were sampled, so that valid comparisons could be drawn. Specimens were returned to the laboratory alive, and sorted under low magnification within 6 h of collection. They were preserved in 70% alcohol and later identified and counted.

Benthic organisms from the profundal zone of each lake were collected in December 1984, with a 150-by-150-mm Eckman grab. The contents of each grab were thoroughly washed through a 500-µm-mesh net, and the remaining debris and live organisms were returned unpreserved to the laboratory for sorting and identification. Five replicates from each of four sites in each lake were used to estimate the summer standing crop of profundal organisms. Sampling of the littoral zone was repeated in 1984, to enable valid comparisons of the summer standing crop of benthic invertebrates from the littoral and profundal zones of each lake.

Zooplankton were collected by drawing a net (200 mm diameter circular aperture, 100 μm mesh size) from the lower limit of the euphotic zone to the surface. The lower limit of the euphotic zone was the depth at which only 1% of light present at the surface had penetrated, as determined by a Licor underwater quantum sensor (LI 192SB) and a Licor quantum light meter (185B). Netted zooplankton were washed into the collecting bottle, preserved in 10% formalin, dyed with Rose Bengal and stored for later sorting and identification. One sample from each of four sites in each lake was collected on four occasions (October and December 1983; October and December 1984).

The Peterson method, as modified by Bailey (1951, 1952), was used to estimate the size of the turtle populations in the two lakes. However, in studies of freshwater turtles Peterson estimates are known to regress strongly with sampling effort (Georges 1982b), and they should be regarded only as indicating the relative abundances of turtles in the two lakes, and not as measuring the absolute numbers present. Turtle density was calculated as the number of turtles per hectare of water, and as the number per 10 m of shoreline. Lake Windermere was determined by a plane-table survey to have an area of 42.4 ha and a perimeter of 8246 m. Lake McKenzie was much smaller, with an area of 8.9 ha and a perimeter of 1475 m. Lake Windermere is also much deeper (maximum c. 13 m) than Lake McKenzie (maximum c. 5 m).

Throughout this paper, estimates are presented with their standard errors and not with sample standard deviations.

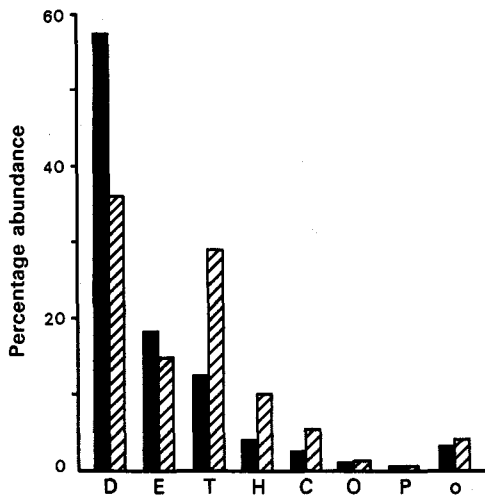


Fig. 1. Relative abundance of invertebrates (by Order) in the littoral zone of L. McKenzie, compared to estimates of their numerical importance to the diet of *C. longicollis* in the lake. Solid columns, littoral zone; hatched columns, diet. D, Diptera; E, Ephemeroptera; T, Trichoptera; H, Hemiptera; C, Coleoptera; O, Odonata; P, Plecoptera; o, others.

Results

The food of *C. longicollis* is listed in Tables 1 and 2, together with an indication of the relative importance of each major food type. *C. longicollis* is clearly a carnivore, because small quantities of living or freshly dead plant material were obtained from only five of the 209 turtles, and probably had been accidentally ingested, given the ready availability of plant material. Dipteran larvae and pupae (Culicidae: Chaoborinae, Chironomidae, Ceratopogonidae) and caddisfly larvae (primarily Leptoceridae) were numerically the most important foods of turtles from L. McKenzie, the lake with the most diverse invertebrate fauna (Table 1). With the exception of the Plecoptera, all of the orders of aquatic insect found in the lake were among the stomach contents of a substantial proportion of turtles examined (21.1–59.6% by occurrence). Terrestrial invertebrates, presumably taken after they fell into the water, and amphibian eggs and larvae were also important, each occurring in about 30% of stomachs.

Zooplankton identified from the water column of L. McKenzie were ostracods (Cytheromatidae), calanoid copepods (*Calamoecia tasmanica*) and pelagic forms of phantom midge larvae (Culicidae: *Chaoborus* sp.). Apparently, only the latter were large enough to be detected and eaten by *C. longicollis*. The average density of phantom midges in the euphotic zone was 219.9 ± 29.8 individuals per cubic metre ($n = 12$). They were eaten by 24.8% of

Table 1. Stomach contents of *C. longicollis* from L. McKenzie, with an indication of the relative importance of each food type in the diet and in the littoral zone

Percentage occurrence gives the number of stomachs that contained one or more items of a particular food type, expressed as a percentage of the total number of stomachs examined. Abundance, percentage of items examined. A, adults; E, eggs; L, larvae; N, nymphs; P, pupae; +, contribution of <0.1%

Taxon	Diet		Littoral fauna (%)
	Occurrence (%)	Abundance (%)	
Aquatic insects			
Coleoptera	33.0	2.3	2.4
Carabidae (L)	0.9	+	0.0
Dytiscidae (L, A)	32.1	2.2	2.3
Gyrinidae (L)	0.0	0.0	0.1
Noteridae (L)	0.9	+	0.0
Diptera	39.5	70.7	58.9
Ceratopogonidae (L)	0.9	+	9.5
Chironomidae (L)	27.5	15.1	48.6
Culicidae: <i>Chaoborus</i> (L, P)	24.8	55.6	0.8
Ephemeroptera	28.4	6.2	18.1
Baetidae: <i>Baetis</i> (N)	0.9	+	0.0
Leptophlebiidae:			
<i>Ulmerophlebia</i> (N)	28.4	6.2	18.1
Hemiptera	53.2	4.3	3.9
Corixidae (L, A)	34.9	3.0	2.1
Notonectidae (A)	24.8	1.1	1.8
Odonata	21.1	0.5	0.7
Anisoptera			
Aeschnidae (N)	3.7	0.1	0.0
Corduliidae (N)	6.4	0.2	0.6
Gomphidae (N)	2.8	0.1	0.1
Zygoptera			
Lestidae (N)	4.6	0.1	+
Plecoptera			
Gripopterygidae (N)	6.4	0.2	0.3
Trichoptera	59.6	12.3	12.4
Atriplectididae (L)	9.2	0.7	0.3
Leptoceridae: 4 spp. (L, P)	52.3	10.8	11.1
Odontoceridae (L, P)	16.5	0.5	1.0
Crustacea			
Atyidae: <i>Caridina</i>	9.2	0.5	0.5
Terrestrial Arthropoda	31.2	2.2	—
Oligochaeta			
Tubificidae	0.0	0.0	1.0
Platyhelminthes			
Tricladida	0.0	0.0	0.5
Vertebrata			
Amphibia (A, L, E)	30.3	0.9	0.2
Carrion	1.8	—	—
Algae	4.6	—	—
Miscellaneous	—	0.4	1.1
Raw totals	109 turtles	5188 items	2189 items

turtles examined and contributed 55.6% of items to their diets. One turtle was found to contain 1577 phantom midge larvae. No macro-organisms were found in the profundal zone of L. McKenzie, so, with the exception of wind-blown insects and carrion, the remainder of the turtles' diets consisted of organisms from the littoral zone (Table 1). The littoral zone had a summer standing crop of 1653.6 ± 183.4 organisms per square metre ($n = 20$). The contribution of a particular taxon to the diet was significantly correlated with its relative abundance in the littoral zone ($r_s = 0.65$, $P < 0.01$, $n = 16$ families). However, of those invertebrates that contributed 5% or more of the littoral items eaten, dipterans (Chironomidae, Ceratopogonidae)

Table 2. Stomach contents of *C. longicollis* from L. Windermere with an indication of the relative importance of each food type in the diet and in the littoral zone

Conventions as in Table 1

Taxon	Diet		Littoral fauna (%)
	Occurrence (%)	Abundance (%)	
Aquatic insects			
Coleoptera			
Dytiscidae (A)	5.0	+	4.8
Diptera	1.0	+	17.4
Chironomidae (L)	1.0	+	17.1
Culicidae: <i>Chaoborus</i> (L)	0.0	0.0	0.3
Ephemeroptera			
Leptophlebiidae:			
<i>Ulmerophlebia</i> (N)	0.0	0.0	1.1
Hemiptera			
Corixidae (L, A)	0.0	0.0	0.9
Megaloptera			
Corydalidae (L)	1.0	+	0.0
Odonata	5.0	0.1	0.4
Anisoptera			
Gomphidae (N)	5.0	0.1	0.4
Libellulidae (N)	1.0	+	0.0
Trichoptera	97.0	99.8	73.9
Atriplectididae (L)	13.0	0.1	1.3
Leptoceridae: 4 spp. (L, P)	85.0	95.1	70.7
Odontoceridae (L, P)	54.0	4.8	1.9
Crustacea			
Atyidae: <i>Caridina</i>	2.0	+	0.4
Terrestrial Arthropoda	7.0	+	—
Mollusca			
Planorbidae: <i>Physastra</i>	3.0	+	0.1
Vertebrata	9.0	+	0.1
Pisces	7.0	+	0.0
Amphibia (A)	2.0	+	0.1
Carrion	1.0	+	—
Miscellaneous	1.0	+	0.1
Raw totals	100 turtles	18673 items	1036 items

and mayfly larvae (Leptophlebiidae: *Ulmerophlebia* sp.) were better represented in the littoral zone than in the diet, whereas caddis-fly larvae, hemipterans (Corixidae, Notonectidae) and coleopterans (Dytiscidae) were proportionally better represented in the diet than in the littoral zone (Fig. 1).

There were no obvious relationships between composition of the diet and turtle body size, nor between the sizes of prey item and turtle body, such as have been found for some *Emydura* spp. (Chessman 1978; Georges 1982a).

In L. Windermere, littoral macro-invertebrates were much less abundant (summer standing crop of 231.4 ± 35.6 organisms per square metre, $n = 20$) and less diverse (Table 2) than in L. McKenzie. Very few planktonic organisms large enough to be eaten by *C. longicollis* were present in the water column (about 3.5 organisms per cubic metre), though, unlike that of L. McKenzie, the profundal zone was inhabited (85.9 ± 23.9 organisms per square metre). Caddis-fly larvae numerically dominated all other foods (Table 2), both in the environment (73.9%) and in the stomachs of the turtles (99.8%), though fish (found in 9.8% of samples) and odonates (found in 5% of samples) must also be considered important, by virtue of their size. Valid comparisons between the diet of *C. longicollis* and the composition of the littoral fauna in L. Windermere were not possible, because almost all of the turtles were caught in two small inflows, whereas the littoral samples were collected from throughout the littoral zone.

C. longicollis was much more abundant in L. McKenzie (163.8 ± 34.2 turtles per hectare; 9.9 ± 2.1 per 10 m of shoreline) than in L. Windermere (26.1 ± 8.3 turtles per hectare; 1.3 ± 0.4 per 10 m of shoreline).

Discussion

The results confirm the findings of Parmenter (1976) and Chessman (1984) that *C. longicollis* is a carnivore that obtains its food from a wide variety of sources, chiefly plankton, nekton, benthic macro-invertebrates, carrion, and terrestrial organisms that fall upon the water. The turtles' catholic diets give them much scope for opportunism in feeding, and the geographic variation in diet, evident from this study and the two mentioned above, probably results from differences in the local abundance of prey items. However, in none of the populations studied extensively does this opportunism extend to plant material, so the carnivory of *C. longicollis* is probably obligatory.

Littoral prey of *C. longicollis* corresponded reasonably well with the composition of macro-organisms in the littoral zone (Fig. 1), though dipterans and mayfly larvae were proportionally less well represented in the diet than in the littoral samples, whereas caddis-fly larvae, hemipterans, and coleopterans were better represented. These subtle differences between the diets of the turtles and the composition of the littoral fauna are best explained in terms of differences in accessibility or 'noticeability' among prey species. Of the invertebrates less well represented in the diet than in the littoral samples, the chironomids consisted primarily of species in the subfamily Chironominae, tribe Chironomini (*Cryptochironomus*, *Pseudochironomus* and *Chironomus* made up 93% of chironomids in the October 1983 sample), the larvae of which almost all build stationary cases on or within the substratum and many burrow in soft sediment (Simpson and Bode 1980). Ceratopogonid larvae mainly live in mud or debris (Colless and McAlpine 1970) and larvae of the mayfly *Ulmerophlebia* sp. were observed to be burrowers. The organisms that were better represented in the diet were either nektonic (corixids, notonectids, dytiscids), or conspicuous benthic forms such as the Trichoptera that rely on movable cases for protection. Hence, there is no evidence that *C. longicollis* is selective in the animals (of suitable size) that it eats.

The Peterson method of assessing turtle abundance is likely to yield underestimates (Georges 1982b), so it is clear that the dune lakes of the Jervis Bay Territory contain large populations of *C. longicollis*. The lower abundance of turtles in L. Windermere compared to that in L. McKenzie is to be expected, because the invertebrate fauna of L. Windermere is less diverse and much less abundant, possibly reflecting lower rates of production (though these rates were not measured). Furthermore, turtles in L. Windermere must compete for food with the fishes *Galaxius maculata* and *Philypnodon* sp. (aff. *grandiceps*), whereas fish are absent from L. McKenzie. Lower densities of the planktonic *Chaoborus* sp. and nektonic hemipterans in L. Windermere can be attributed to the presence of these fish (Bayly *et al.* 1975; Chessman 1984); both of these taxa are major foods for *C. longicollis*.

The abundance of *C. longicollis* in the dune lakes of the Jervis Bay Territory is somewhat puzzling, given that studies of turtles in dune lakes elsewhere suggest that such permanent lentic habitats are not favoured by the species. For example, in L. Coomboo (8.8 ha) on Fraser I.,

Qld, an intensive 2-year study yielded 683 *Emydura krefftii*, 11 *Chelodina expansa* and two *C. longicollis* (Georges 1982b). In ephemeral water-bodies on the island, not containing *E. krefftii* or *C. expansa*, *C. longicollis* does better. A small ephemeral waterbody to the east of L. Coomboo contained only *C. longicollis*, and the species is reasonably common in the many coastal swamps on the island (personal observations), though accurate estimates of their abundance were not made. The diet of the omnivorous *E. krefftii* overlaps substantially that of *C. longicollis*, because it feeds upon a wide variety of benthic macro-organisms, carrion and terrestrial insects that fall onto the water (Georges 1982a). However, it is a short-necked species and is unable to secure the small fishes which are common in the dune lakes of Fraser I., and few adult aquatic coleopterans and hemipterans are eaten. These nekton are the food of *C. expansa*, a wholly carnivorous turtle specialized for feeding on highly motile prey (Chessman 1983). Perhaps the combination of *E. krefftii* and *C. expansa*, both inhabitants of permanent water-bodies, is sufficient to virtually exclude *C. longicollis* from the permanent dune lakes of Fraser I., a habitat which, judging from the abundance of *C. longicollis* in the permanent dune lakes of the Jervis Bay Territory, appears to be otherwise most suitable.

Acknowledgments

We are grateful to Neil Taylor and Fred Howe for providing us with access to the lakes, and to Guy Chester, Luiz Ribero, Ken Thomas, Roger Thompson and Antony Van Papenrecht for assistance with field work and sorting samples before identification. Bill Maher coordinated the collection of the October 1984 littoral samples, and Frank Krikowa collected the data on lake morphometrics. Peter Liston and Chris Bentley counted and identified the zooplankton, and Shirley Robinson identified the fishes. We are also grateful to Jim Hone and David Williams for their valuable comments on a draft of this paper. The Canberra C.A.E. provided laboratory space and material support.

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