

## Appendices

### Appendix 3.1. A summary of genomic investigations of the Afrotheria pertinent to the Sirenia

Extensive genomic analysis provides support for the unification of the diverse assemblage of mammals placed under the Afrotheria. The Superorder Afrotheria was named by Stanhope *et al.* (1998a,b) based on a major analysis involving complete sequences of four mitochondrial genes and additional sequences from four nuclear genes, sampled from many species of mammals. The genetic database was used to construct phylogenetic trees subjected to sophisticated analyses including neighbour-joining, maximum likelihood and maximum parsimony statistical methods. Springer *et al.* (1999) conducted additional statistical analyses with mitochondrial and nuclear genes from representatives of 11 different orders of mammals and obtained very high support for the grouping of the five orders within Afrotheria and the three orders within the Paenungulata. Nishihara *et al.* (2005) confirmed the monophyly of the Afrotheria using morphological cladistics, and 19 nuclear gene sequences in analysing retroposons (short interspersed element or SINE insertions) that are very unlikely to be inserted at the same locus independently in the evolution of different lineages. Multiple additional analyses of molecular data that pertain to the Sirenia but that use different numbers of genes or different statistical approaches have been conducted by several different laboratories (e.g. Amrine and Springer 1999; Amrine-Madsen *et al.* 2003; Arnason *et al.* 2008; Kjer and Honeycutt 2007; Liu and Miyamoto 1999; Murata *et al.* 2003; Murphy *et al.* 2001a, 2001b; Nikaido *et al.* 2003). These and studies noted below should be consulted for more detailed considerations. In general, all affirm the Afrotherian lineage, a paenungulate grouping within the Afrotheria, and the placement of the Sirenia within the paenungulates. The greatest area of disagreement, as in the morphological research, involves the alignment of the hyraxes with other paenungulates.

Asher *et al.* (2003) combined morphological, fossil and molecular data in an intricate analysis run by supercomputer. Their findings affirmed the relationships of the paenungulates, supported the monophyly of the Tethytheria and some of the other afrotherian relationships, but called into question some of the

conclusions about the early origins of the Afrotheria. Springer *et al.* (2007) also compared results of a series of statistically complex phylogenetic analyses based on morphological, fossil and molecular data. This work included a pseudoextinction analysis in which living orders were treated as if they were extinct to assess the predictive power of morphological versus molecular traits. They concluded that the molecular data were far superior to the morphological and fossil data in defining the Afrotheria and Paenungulata. The distinctiveness of the Afrotheria and close relationships among the sirenians, hyraxes and elephants were confirmed by parsimony, Bayesian, and partition analyses, built on an expanded data set of 14 326 base pairs from 20 different nuclear genes drawn from four marsupial outgroups and 53 placental taxa (Springer *et al.* 2007). The genetic analysis joined sirenians with hyraxes as closer to each other than either is to the elephants, but these within-paenungulate affinities varied with the application of the pseudoextinction method and the statistical analysis used. Similarly, Seiffert (2007) conducted another analysis of afrotherian phylogeny combining both morphology and genomic information, based on over 4590 characters including 400 morphological characters and both extant and fossil taxa. The analyses of extant mammals confirmed the Sirenia and Proboscidea as grouping together under the Tethytheria, and the tethytheres joining with the Hyracoidea to form the Paenungulata. Inclusion of extinct taxa repeated this pattern but with less strong statistical support, and joined the paenungulates with the tubulidentates at the next higher level. This work also defined some morphological synapomorphies for the Afrotheria, but left open questions of the strength of the potential monophyly of various pairs of relationships among the Sirenia, Proboscidea and Hyracoidea. Asher (2007) also analysed combined morphological and genomic data and found support for the Afrotheria, but also saw varying interpretations of the strength of relationships between pairs of the three paenungulate groups. In most of the analyses by Asher (2007) the Tethytheria were joined using combined morphological and genomic data sets, but stronger support linking the Sirenia with the Hyracoidea was derived from genomic data of Recent taxa alone.

As Murphy *et al.* (2004) noted, the placements of the Sirenia, Proboscidea and Hyracoidea relative to each other continues to pose a major ambiguity in the molecular classification of the Afrotheria, as was true for earlier morphological studies. In one analytical approach using sequences of mitochondrial DNA genes, the Sirenia and Proboscidea were indeed most closely aligned to one another and then were joined with the Hyracoidea at a somewhat greater distance; based on two other separate analyses, however, the sirenians and hyraxes were closer to one another than either was to the elephants (Stanhope *et al.* 1998a). A close association between sirenians and proboscideans was also suggested by later analyses of segments of mitochondrial DNA (mtDNA) genes (Murata *et al.* 2003) and combined mtDNA and nuclear genes using maximum likelihood and parsimony analyses (Murphy *et al.* 2001a), whereas a closer affinity between the hyraxes and elephants was suggested by combined nuclear and mtDNA genes using Bayesian and other analytical techniques (Murphy *et al.* 2001b; Waddell *et al.* 2001). Nishihara *et al.* (2005) confirmed the extant paenungulates as monophyletic within Afrotheria, with a likely closer pairing of Sirenia with Proboscidea. Yet additional analyses including more genes and Bayesian statistical techniques

place the sirenians closer to the hyracooids than to proboscideans (Springer *et al.* 2007), whereas other new studies using extensive mitochondrial DNA with both maximum likelihood and Bayesian analyses agree with the grouping of the Sirenia with Proboscidea as tethytheres apart from the hyraxes (Arnason *et al.* 2008). The relationships and degree of divergence of the hyraxes with other paenungulate orders based on molecular data thus remain enigmatic, as they have on various levels based on morphological analyses.

Chromosome painting (also known as Zoo-fluorescence *in situ* hybridisation or Zoo-FISH), which hybridises human chromosomes with those of other mammals and then maps loci in common, also shows strong support for the Afrotheria (Kellogg *et al.* 2007; Pardini *et al.* 2007). Recent results of such cytogenetic analyses have also entered the evidence for affinities among the extant paenungulates, and seem to offer more direct conclusions regarding these relationships. Kellogg *et al.* (2007) used chromosome painting to hybridise human chromosomes with Florida manatee metaphase chromosomes, and mapped 44 homologous segments; many of these associations were found in common with other species in the Afrotheria, and the greatest commonality was between manatees and elephants. However, comparisons with hyraxes were not available. Subsequently, more extensive, reciprocal, cross-species chromosome painting studies were carried out on representatives of all three groups: Florida manatees, the Cape rock hyrax (*Procapra capensis*) and the African elephant (*Loxodonta africana*), using the armadillo and humans as outgroups in the analysis (Pardini *et al.* 2007). Additional insights were allowed with this reciprocal multi-species analysis, including the reconstruction of an ancestral paenungulate karyotype based on chromosomal homologies and patterns of chromosomal rearrangements (fusions or fissions), i.e. rare genomic changes. Based on these comparisons, Pardini *et al.* (2007) were able to reconstruct in part the 29 chromosome pairs of the suggested ancestral paenungulate karyotype ( $2n = 58$ ) prior to the divergence of the three orders. The subsequent chromosomal rates of evolution estimated for the three orders were lower than estimates for other mammals, and lower than the rate of change of the ancestral paenungulate lineage between its origin in the early Afrotheria and its splitting into the Sirenia, Proboscidea and Hyracoidea. A number of fissions and fusions were syntenic (loci on the same chromosome) with the other Afrotheria, and at least 10 shared chromosomal changes were synapomorphic for the three paenungulate orders. There were no synapomorphic changes specific to any combination of pairs within the paenungulates. This observation led to the conclusion that, within the limits of the Zoo-FISH technique, the Paenungulates are monophyletic (Pardini *et al.* 2007).

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**Appendix 3.2.** Summaries of representative fossil species of sirenians, their temporal presence in the fossil record, geographical distributions and descriptive aspects of their morphology, ecology and relationships.

**Table 3.2.1.** Representative fossil taxa in the sirenian families Prorastomidae and Protosirenidae. According to Domning (2001a) the Prorastomidae is paraphyletic. A number of other, unnamed species are known from the Protosirenidae (e.g. Domning *et al.* 1982). References listed emphasise more recent literature and reviews. Domning (1996) should be consulted for a more comprehensive listing of additional sources.

Representative	Time	Distribution	Comments	References
<b>Family</b>				
<b>Prorastomidae</b>				
<i>Prorastomus sirenooides</i>	late Early or early Middle Eocene	Jamaica	Four-legged, capable of terrestrial locomotion; pachyosteosclerotic bones; undeflected, laterally compressed rostrum suggests selective browsing on submerged and emergent plants other than seagrasses	Domning (2001c); Gheerbrant <i>et al.</i> (2005); Savage <i>et al.</i> (1994)
<i>Pezosiren portelli</i>	early Middle Eocene	Jamaica	Four-legged, capable of terrestrial locomotion, but amphibious and likely spending most time feeding in the water	Domning (2001a,c); Gheerbrant <i>et al.</i> (2005)

**Table 3.2.1.** (cont.)

Representative	Time	Distribution	Comments	References
<b>Family</b>				
<b>Protosirenidae</b>				
<i>Ashokia antiqua</i>	early Middle Eocene	India	Known from cranium; phylogenetic relationships with other protosirenids unclear	Bajpai <i>et al.</i> (2009)
<i>Protosiren eothena</i>	early Middle Eocene	Pakistan	Known only from postcranial elements	Zalmout <i>et al.</i> (2003)
<i>Protosiren fraasi</i>	early Middle Eocene	Egypt	Quadrupedal; down-turned rostrum	Gingerich <i>et al.</i> (1994); Gheerbrant <i>et al.</i> (2005)
<i>Protosiren sattaensis</i>	Middle Eocene	Pakistan	Known only from postcranial elements	Gingerich <i>et al.</i> (1995)
<i>Protosiren smithae</i>	late Middle Eocene	Egypt	Quadrupedal; down-turned rostrum	Domning and Gingerich (1994)

**Table 3.2.2.** Representative fossil taxa of the Subfamily Halitheriinae in the Family Dugongidae. See Domning (1994, 1996, 2001c) and references noted below for details on arrangements, original authorities and synonymies, and more detailed paleontological information. Named forms based on limited or dubious paleontological evidence or of uncertain placement are omitted, but can be found in Domning (1996).

Representative	Time	Distribution	Comments	Selected References
<b>Subfamily</b>				
<b>Halitheriinae</b>				
<i>Eotheroides aegyptiacum</i>	Middle Eocene	Egypt	Cladistically stable as the most primitive dugongid; represents a sister group to all other dugongids; pachyosteosclerotic bones in anterior thorax	Domning (1994, 2001c); Domning and de Buffrénil (1991)

Table 3.2.2. (cont.)

Representative	Time	Distribution	Comments	Selected References
<i>Eotheroides lambondrano</i>	Middle Eocene	Madagascar	Skull length ca. 270 mm; three upper incisors; longer and wider molars than <i>E. aegyptiacum</i> ; pachyosteosclerotic ribs	Samonds <i>et al.</i> (2009)
<i>Eotheroides babiae</i>	Middle Eocene	India	Smaller than <i>E. aegyptiacum</i>	Bajpai <i>et al.</i> (2006)
<i>Eosiren abeli</i>	Middle Eocene	Egypt	Named based on minor amounts of fossil material; holotype skull destroyed in World War II	Sickenberg (1934); Domning (1994, 2001c); Domning <i>et al.</i> (1994)
<i>Eosiren libyca</i>	Late Eocene	Egypt	May have given rise to <i>E. imenti</i>	Andrews (1906); Domning (2001c); Domning <i>et al.</i> (1994)
<i>Eosiren stromeri</i>	Late Eocene	Egypt	Like <i>E. libyca</i> , had pachyosteosclerotic bones throughout the thorax	Sickenberg (1934); Domning (2001c); Domning and de Buffrénil (1991)
<i>Prototherium intermedium</i>	Late Eocene	Italy	Probably should be raised to a separate genus	Domning (1994, 2001c)
<i>Prototherium veronense</i>	Late Eocene	Italy	Some primitive morphological features considered evolutionary reversals	Sickenberg (1934); Domning (2001c)
<i>Eosiren imenti</i>	Early Oligocene	Egypt	Rostral deflection 45–55°; likely was euryhaline and fed on both seagrasses and freshwater plants	Domning <i>et al.</i> (1994)

Table 3.2.2. (cont.)

Representative	Time	Distribution	Comments	Selected References
<i>Halitherium taulannense</i>	Late Eocene	France	Possibly represents the earliest species of <i>Halitherium</i>	Sagne (2001)
<i>Halitherium schinzii</i>	Early Oligocene	Europe	2.1 to 3.0 m long; probably gave rise to <i>H. christolii</i> and its subsequent <i>Metaxytherium</i> lineage	Domning and Thomas (1987)
<i>Halitherium christolii</i>	Late Oligocene	Europe	Increased rostral deflection from <i>H. schinzii</i> ; may have been present in eastern North America; 2–3 m long	Aranda-Manteca <i>et al.</i> (1994); Domning and Thomas (1987); Gheerbrant <i>et al.</i> (2005)
<i>Caribosiren turneri</i>	Oligocene	Puerto Rico	Small; extreme snout deflection (>75°) but no tusks; probably a specialist on leaves, perhaps some small rhizomes	Domning (2001b); Reinhart (1959)
<i>Metaxytherium krahuletzii</i>	Early Miocene	Europe	The most primitive known <i>Metaxytherium</i> ; fed on benthic seagrasses	Domning and Pervesler (2001); Domning and Thomas (1987)
<i>Metaxytherium medium</i>	Middle to Late Miocene	Europe	Over 2.8 m long; fed on benthic seagrasses	Domning and Thomas (1987)
<i>Metaxytherium crataegense</i>	Early to Middle Miocene	South-eastern North America, Eastern Pacific (Peru)	Rostral deflection ≤ 60°; probably gave rise to slightly larger <i>M. floridanum</i>	Aranda-Manteca <i>et al.</i> (1994); Domning (2001b); Muizon and Domning (1985)



**Table 3.2.2.** (cont.)

Representative	Time	Distribution	Comments	Selected References
<i>Metaxytherium floridanum</i>	Middle Miocene	Florida	Strongly down-turned snout for bottom feeding; about 3.2 m long	Domning (1988)
<i>Metaxytherium arctodites</i>	Middle Miocene	Eastern North Pacific (California, Mexico)	Small but functional tusks; 71° rostral deflection, indicating bottom feeding on seagrass leaves and smaller rhizomes; about 3 m long; may have given rise to the hydrodamaline <i>Dusisiren</i> , or possibly a sister taxon	Aranda-Manteca <i>et al.</i> (1994)
<i>Metaxytherium serresii</i>	Late Miocene to Early Pliocene	Europe, Libya	A 'dwarf' sirenian at 2.4 m long; fed on benthic seagrasses	Domning and Thomas (1987); Bianucci <i>et al.</i> (2008)
<i>Metaxytherium subapenninum</i>	Late Pliocene	Europe	Nearly 4 m long; fed on benthic seagrasses	Domning and Thomas (1987)

**Table 3.2.3.** Representative fossil and Recent taxa of the subfamilies *Dugonginae* and *Hydrodamalinae* in the Family *Dugongidae*. See Domning (1994, 1996, 2001c) and references noted below for details on arrangements, original authorities and synonymies, and more detailed paleontological information. Named forms based on limited or dubious paleontological evidence or of uncertain placement are omitted but can be found in Domning (1996).

Representative	Time	Distribution	Comments	References
<b>Dugonginae</b>				
<i>Crenatosiren olseni</i>	Late Oligocene	South-eastern US	Small-bodied with small to moderate-sized tusks; the most primitive known dugongine, it was a sister group to all other members of the subfamily	Domning (1991, 1997, 2001b)

**Table 3.2.3.** (cont.)

Representative	Time	Distribution	Comments	References
<i>Bharatisiren indica</i>	Late Oligocene	India	Distinct from <i>B. kachchhensis</i> based on flat frontal roof and caudal boss on premaxillary symphysis	Bajpai <i>et al.</i> (2006)
<i>Domningia sodhae</i>	Early Miocene	India	Large dugongine with deflected rostrum and flattened tusk-like upper incisors	Thewissen and Bajpai (2009)
<i>Dioplotherium manigaulti</i>	Oligocene–Early Miocene	South-eastern US	Rostral deflection of 50–55° or more; enlarged tusks with enamel on both sides	Domning (1989a)
<i>Dioplotherium allisoni</i>	Early–Middle Miocene	Eastern Pacific (California, Baja California) and western Atlantic (Brazil)	Mandibular deflection greater than rostral deflection, perhaps indicating pulling tusks down and back for excavating rhizomes; extinction in North Pacific due to changing environment, possible competition with desmostylians	Domning (1978a, 2001c); Toledo and Domning (1991)
<i>Bharatisiren kachchhensis</i>	Early Miocene	India	Genus represents first dugongine from east of the Mediterranean; moderate rostral deflection; large tusks	Bajpai and Domning (1997)

Table 3.2.3. (cont.)

Representative	Time	Distribution	Comments	References
<i>Rytiodus capgrandi</i>	Early Miocene	France; a later species present in Libya, possibly Brazil	Broad bladelike, self-sharpening tusks; perhaps a synapomorphy with <i>Corystosiren</i> ; strongly deflected snout; large (perhaps up to 5 m)	Domning (1978b, 1990, 2001b); Toledo and Domning (1991)
<i>Nanosiren sanchezi</i>	Late Miocene	Venezuela	<i>N. sanchezi</i> and <i>N. garciae</i> were the smallest post-Eocene sirenians, body mass about 150 kg	Domning and Aguilera (2008)
<i>Xenosiren yucateca</i>	Late Miocene–Early Pliocene	Yucatan area of Caribbean	Possible descendant of <i>D. allisoni</i> ; large, self-sharpening tusks (mediolaterally compressed with enamel only on medial sides) and modified zygomatic arch likely used for forceful uprooting of rhizomes in a backward and downward motion	Domning (1989b, 2001b)
<i>Nanosiren garciae</i>	Early Pliocene	Florida	<i>N. garciae</i> and <i>N. sanchezi</i> were the smallest post-Eocene sirenians, body mass about 150 kg	Domning and Aguilera (2008)

**Table 3.2.3.** (cont.)

Representative	Time	Distribution	Comments	References
<i>Corystosiren varguezii</i>	Early Pliocene (genus known from ?Early Miocene)	Yucatan area of Caribbean, Florida	Bladelike, self-sharpening tusks; massive skull roof	Domning (1990, 2001b,c)
<i>Dugong dugon</i>	Recent	Indo-Pacific Oceans	Poor fossil record, but with closely related Late Pliocene form known from Florida implying late dispersal to the Pacific	Domning (2001b,c); Domning and Furusawa (1994)
<b>Hydrodamalinae</b>				
<i>Dusisiren reinharti</i>	Early Miocene	Baja California	Likely capable of feeding on plants higher in water column (small or no tusks and ?no strongly deflected rostrum); ca. 3.5 m long?	Domning (1978a, 2001b); Domning and Furusawa (1994)
<i>Dusisiren jordani</i>	Middle to Late Miocene	California	Reduction in size and number of adult teeth; ca. 4.5 m long	Domning (1978a); Domning and Furusawa (1994)
<i>Dusisiren dewana</i>	Late Miocene	Japan, California	Weak rostral deflection; reduced dentition; reduced claw-like forelimb; ca. 4.3 m long	Domning and Furusawa (1994); Gheerbrant <i>et al.</i> (2005); Takahashi <i>et al.</i> (1986)

**Table 3.2.3.** (cont.)

Representative	Time	Distribution	Comments	References
<i>Dusisiren takasatensis</i>	Late Miocene	Japan	Likely more derived than (or referable to) <i>D. dewana</i> ; dentition present but reduced; about 3.7 m long	Kobayashi <i>et al.</i> (1995)
<i>Hydrodamalis spissa</i>	Early Pliocene	Japan	Status unclear, perhaps referable to <i>H. cuestae</i>	Domning and Furusawa (1994)
<i>Hydrodamalis cuestae</i>	Late Miocene–Late Pliocene	California, Baja California	Low rostral deflection; no teeth in adults; no phalanges; ca. 9–10 m long	Domning (1978a); Domning and Furusawa (1994)
<i>Hydrodamalis gigas</i>	Pleistocene–Recent (extinct)	California, Aleutian and Commander Islands, Japan	Adapted for cold water and feeding on kelps; ca. 9–10 m long; no teeth; no phalanges; see Chapter 00.	Domning (1978a); Domning and Furusawa (1994); Gheerbrant <i>et al.</i> (2005); Steller (1751; see Chapter 2)

**Table 3.2.4.** Representative fossil and Recent taxa in the sirenian Family Trichechidae. References listed emphasise more recent literature and reviews. See Domning (1994, 1996, 2001c) and references noted below for details on arrangements, original authorities and synonymies, and more detailed paleontological information. Named forms based on limited or dubious paleontological evidence or of uncertain placement are omitted but can be found in Domning (1996).

Representatives	Time and Distribution	Comments	References
<b>Subfamily Miosireninae</b>			
<i>Anomotherium langewieschei</i>	Late Oligocene, Europe	Possibly molluscivorous	Domning (1994); Gheerbrant <i>et al.</i> (2005); Diedrich (2008)

Table 3.2.4. (cont.)

Representatives	Time and Distribution	Comments	References
<i>Miosiren kocki</i>	Early Miocene, Europe	Possibly molluscivorous	Clementz <i>et al.</i> (2009); Domning (1994); Gheerbrant <i>et al.</i> (2005); Sickenberg (1934)
<b>Subfamily</b>			
<b>Trichechinae</b>			
<i>Potamosiren magdalenensis</i>	Middle Miocene, Colombia	Thick molar enamel, similar cusp pattern to <i>Ribodon</i> ; incomplete fossil material	Domning (1982, 1997b); Gheerbrant <i>et al.</i> (2005)
<i>Ribodon limbatus</i>	Late Miocene–Early Pliocene, Argentina; ?Pliocene, south-eastern US	First appearance of continuously erupting supernumerary cheek teeth	Domning (1982, 1994)
<i>Trichechus manatus</i>	Early Pleistocene to Recent, Florida	Episodic changes in North American distribution with changing environmental conditions; molecular genetics reveals possible patterns in geographic evolution not yet seen in fossil record	Cantanhede <i>et al.</i> (2005); Domning (1982, 2001b, 2005); Garcia-Rodriguez <i>et al.</i> (1998)
<i>Trichechus senegalensis</i>	Recent, West Africa; no fossil record	Likely Late Pliocene or Pleistocene dispersal to Africa from western Atlantic	Domning (1978c, 1982, 2001c); Domning and Hayek (1986); Vianna <i>et al.</i> (2006)
<i>Trichechus inunguis</i>	Recent, Amazon Basin; no fossil record	More derived morphological traits (teeth, nails, external morphology) than other <i>Trichechus</i> , but molecular genetics suggest possible earlier origin	Domning (1982, 1996); Domning and Hayek (1986); Vianna <i>et al.</i> (2006)

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## Appendix 4. A series of tables listing the foods eaten by the dugong, the Amazonian manatee, the West Indian manatee, and the West African manatee

**Table 4.1.** *Dugongs consume a wide variety of seagrasses, several species of algae and some species of invertebrates as revealed by studies using a range of techniques<sup>1</sup>.*

	Pacific Islands	Australian region including Torres Strait	East and South-East Asia	Indian sub-continent	East Africa	Arabian region
<b>Seagrasses</b>						
<i>Amphibolis</i>		S				
<i>Cymodocea</i>	D	D	D,S	B,D	B	D
<i>Enhalus</i>	D	D	B,D,S	B,D	B	
<i>Halodule</i>	D	B,D,S	D,S	B,D	B	D,S
<i>Halophila</i>	D	B,D,S	B,D,S	B,D	B	D,S
<i>Posidonia</i> <sup>2</sup>						
<i>Syringodium</i>	D	D,S	D,S	B	B	D
<i>Thalassodendron</i>	D	D				D
<i>Thalassia</i>	D	D	D,S			D
<i>Zostera</i>		B,D,S	D	B	B	
<b>Marine Algae</b>						
<i>Caulerpa</i>		B	D			D
<i>Chaetomorpha</i>						D
<i>Ceramium</i>		D				
<i>Dictyota</i>		B				
<i>Gelidiella</i>		B				
<i>Gracilaria</i>		B				
<i>Hypnea</i>		D				
<i>Laurencia</i>		B,d				
<i>Padina</i>		B				
<i>Sargassum</i>		B,D	D			D
<i>Spyridia</i>		D				
<i>Styopodium</i>						D
<i>Turbinaria</i>		B				
<i>Udotea</i>		D				D
<i>Ulva</i>		B				
Algae n/i	D	D	D,d	D		
<b>Mangroves</b>						
<i>Avicennia</i>		D				
Mangrove n/i		d				
<b>Marine Invertebrates</b>						
Ascidean:		D				
<i>Polycarpa</i> (solitary)						

Table 4.1. (cont.)

	Pacific Islands	Australian region including Torres Strait	East and South- East Asia	Indian sub-continent	East Africa	Arabian region
Ascidean: <i>Sycozoa</i> (colonial)		D,S				
Ascidean: solitary n/i		D,d				
Brachiopod: n/i			B			
Crabs: n/i			D			
Holothurian: n/i		d				D
Hydroids: colonial n/i		d				
Hydrozoan: n/i						D
Mollusca: <i>Botula</i> <i>vagina</i>		B				
Mollusca: n/i		d				
Polychaetes: Chaetopterid n/i		D				
Polychaetes: n/i			D			D
Sea pen: <i>Virgularia</i>		B				
Sipunculid: n/i			B			
Sponge: n/i		d				D

<sup>1</sup> B inferred from observations of wild dugongs; D recorded in dugong digesta including feces; S inferred from dugong feeding signs. Foods which appear to be consumed incidentally are in lower case; those targeted deliberately are in upper case. No distinction can be made between targeted and incidental feeding for foods inferred from the behaviour of wild dugongs.

<sup>2</sup> Best (1981) reported that Australian dugongs fed on *Posidonia australis* presumably based on Gohar (1957); observations by Anderson (1986) suggest this is unlikely to be correct. n/i = not identified.

**Sources:** Adulyanukosol *et al.* 2001, 2004; Aketa *et al.* 2001; Anderson 1982, 1986, 1989, 1994, 1998; Anderson and Birtles 1978; André *et al.* 2005; Annandale 1905; Aragonés 1994; Community Centred Conservation 2003; de Jong 1996; den Hartog 1970; Dexler and Freund 1906; Erftemeijer *et al.* 1993; Gohar 1957; Hanafy *et al.* 2006; Heinsohn and Birch 1972; Heinsohn *et al.* 1977; Hirasaka 1934; Ikeda and Mukai (2011); Jarman 1966; Johnstone and Hudson 1981; Jones 1959, 1967, 1976, 1980; Jonklaas 1961; Kingdon 1971; Lipkin 1975; Mahmud 2010; Marlow 1961; Marsh *et al.* 1982, 1999; Mukai *et al.* 2000; Nair *et al.* 1975; Nakanishi *et al.* 2008; Nakaoka and Aioi 1999; Nakaoka *et al.* 2002; Petit 1924, 1955; Preen 1992, 1995 a and b; Shirakihara *et al.* 2007; Spain and Heinsohn 1973; Thomas 1966; Tsutsumi *et al.* 2006; Wake 1975; Whiting 2002; World Wildlife Fund Eastern African Marine Ecoregion 2004.

**Appendix Table 4.2.** Genera of freshwater food plants eaten by the Amazonian manatee. The percentages are based on the proportion of slides of digesta<sup>1</sup> in which the genus was detected by Colares and Colares (2002) and thus represent incidence in the diet rather than relative volume. The genera without percentages were reported by Vosseler (1924–25), Husar (1977), Domning (1981), Best (1981), Pereira (1944), Timm et al. (1986), Rosas (1994) and Guterres et al. (2008). Unless indicated, the authors did not report the techniques used. Guterres et al. (2008) based their records on reports from locals and observations of feeding signs on aquatic plants growing in várzea ecosystems (white water). Some genera grow in more than one habitat.

Genus	% <sup>1</sup>	Basis for record <sup>2</sup>	Genus	%	Basis for record <sup>2</sup>
<b>Submerged</b>			<b>Emergent (terrestrial) continued</b>		
<i>Cabomba</i>	2	D	<i>Cyperus</i>		S/B
<i>Ceratophyllum</i>			<i>Dichromena</i>		
<i>Myriophyllum</i>			<i>Duroia</i>		S/B
<i>Najas</i>		S/B	<i>Echinochloa</i>	14	D,S/B
<i>Pontederia</i>		S/B	<i>Elaeoloma</i>		S/B
<i>Vallisneria</i>			<i>Eleocharis</i>		S/B
<b>Floating (natant)</b>			<i>Eugenia</i>		S/B
<i>Azolla</i>		S/B	<i>Eupatorium</i>		S/B
<i>Ceratopteris</i>		S/B	<i>Ficus</i>		S/B
<i>Eichhornia</i>	11	D,S/B	<i>Fimbristylis</i>		S/B
<i>Hydrocotyle</i>		S/B	<i>Genipa</i>		S/B
<i>Hymenachne</i>	3	D,S/B	<i>Ipomoea</i>	2	D,S/B
<i>Leersia</i>		S/B	<i>Justica</i>		S/B
<i>Limnobium</i>		S/B	<i>Limnocharis</i>		S/B
<i>Luziola</i>	7	D,S/B	<i>Ludwigia</i>	3	D,S/B
<i>Ludwigia</i>		S/B	<i>Mabea</i>		S/B
<i>Najas</i>			<i>Macrolobium</i>		S/B
<i>Phyllanthus</i>		S/B	<i>Mikania</i>		S/B
<i>Pistia</i>	6	D,S/B	<i>Montrichardia</i>		
<i>Potamogeton</i>			<i>Neptunia</i>	1	D,S/B
<i>Salvinia</i>	8	D,S/B	<i>Nymphaea</i>		S/B
<i>Utricularia</i>	2	D,S/B	<i>Oldenlandia</i>		S/B
<b>Emergent (terrestrial)</b>			<i>Operculina</i>		
<i>Aeschynomene</i>		S/B	<i>Oryza</i>	3	D,S/B
<i>Alternanthera</i>		S/B	<i>Oxandra</i>		S/B
<i>Borreria</i>		S/B	<i>Panicum</i>	8	D,S/B
<i>Brachiaria</i>		S/B	<i>Paspalum</i>	23	D,S/B
<i>Brosimum</i>		S/B	<i>Pennisetum</i>		S/B
<i>Byrsonima</i>		S/B	<i>Phaseolus</i>	6	D,S/B
<i>Calathea</i>		S/B	<i>Polygonum</i>	1	D,S/B
<i>Calladium</i>			<i>Rhabdadenia</i>		S/B
<i>Campsiandra</i>		S/B	<i>Sagittaria</i>		S/B
<i>Caperonia</i>		S/B	<i>Scleria</i>		S/B
<i>Casoria</i>			<i>Symmeria</i>		S/B
<i>Cayaponia</i>		S/B	<i>Tassadia</i>		S/B
<i>Cercropia</i>		S/B	<i>Torulinium</i>		S/B

**Appendix Table 4.2.** (cont.)

Genus	% <sup>1</sup>	Basis for record <sup>2</sup>	Genus	%	Basis for record <sup>2</sup>
<i>Commelina</i>		S/B	<i>Utricularia</i>		S/B
<i>Cymbosema</i>		S/B			

<sup>1</sup> 5 slides from each of 50 stomach and 50 fecal samples;

<sup>2</sup> B inferred from observations of wild manatees; D recorded in digesta including feces; S inferred from manatee feeding signs; S/B inferred from feeding signs or reports of locals.

**Appendix Table 4.3.** *West Indian manatees consume a wide variety of freshwater and marine vascular plants, algae, invertebrates and even fish as revealed by studies using a range of techniques<sup>1</sup> in various parts of their range. Some authors have classified the growth forms of the freshwater plants eaten by manatees slightly differently from the classification used here. Epiphytes and invertebrate periphyton have not been included but are listed by Hartman (1979).*

	Florida	Central America <sup>2</sup>	Antilles <sup>3</sup>	South America <sup>4</sup>
<b>Seagrass</b>				
<i>Halodule</i>	B,D,O,S	D,O	D,O	
<i>Halophila</i>	D,S	B,D,S		
<i>Syringodium</i>	B,D,O,S	D,O	B,D,O	+
<i>Thalassia</i>	B,D,O,S	D,O	B,D,O	+
<b>Marine Algae</b>				
<i>Acanthophora</i>	b			
<i>Agardhiella</i>	b			
<i>Anadyomene</i>		D		
<i>Bryothamnion</i>		D		
<i>Caulerpa</i>	B,D	D	d	
<i>Chaetomorpha</i>	B,D			
<i>Champia</i>	b			
<i>Chara</i>		D		
<i>Cladophora</i>	o	D		
<i>Chondria</i>	b			
<i>Cryptonemia</i>		D		
<i>Dasya</i>	B			
<i>Dictyopteris</i>		D		
<i>Dictyota</i>		D		
<i>Ectocarpus</i>	+			
<i>Enteromorpha</i>	b,D,O			
<i>Gelidiella</i>		D		
<i>Gelidium</i>		D		
<i>Gracilaria</i>	B,b,D,O	D		
<i>Halimeda</i>	B		B	
<i>Hypnea</i>	B			

Appendix Table 4-3. (cont.)

	Florida	Central America <sup>2</sup>	Antilles <sup>3</sup>	South America <sup>4</sup>
<i>Laurencia</i>	B			
<i>Lyngbya</i>	B,b			
<i>Navicula</i>	O			
<i>Oscillatoria</i>	O			
<i>Osmundaria</i>		D		
<i>Padina</i>		D		
<i>Polysiphonia</i>	B			
<i>Sargassum</i>	B	D		
<i>Spyridia</i>	B			
<i>Spirogyra</i>	b,O			+
<i>Ulva</i>	B,b,D,O	D	D,d	O
<i>Vaucheria</i>	B			
<i>Wranglia</i>	B			
unidentified	D		D	B
<b>Mangroves</b>				
<i>Avicennia</i>				B*
<i>Rhizophora</i>	O,D	D		B*,S
unidentified	B,D	B	D	
<b>Animals</b>				
Hydroids	D		D	
Jellyfish: <i>Stomolophus</i>	O			
Unidentified sponges	d			
Bryozoan: <i>Bugula</i>	D			
Polychaete: <i>Chaetopterus</i>	d			
Unidentified holothurians	d			
Sea hare: <i>Bursatella</i>	d			
Ascidean: <i>Molgula</i>	D			
Ascidean: <i>Styela</i>	D			
Unidentified tunicates	D		d	
Fish (dead and alive)	O		O	
Rat (dead)	O			
<b>Submerged Freshwater Vegetation</b>				
<i>Cabomba</i>	D			O
<i>Ceratophyllum</i>	B,D,O		B,D	O
<i>Egeria</i>	D			
<i>Elodea</i>	B,O			O
<i>Hydrilla</i>	O,D			+
<i>Myriophyllum</i>	D,O			O
<i>Najas</i>	B,D,O	D		+
<i>Nitella</i>	+			+
<i>Ruppia</i>	B,D,O	D		O <sup>5</sup>
<i>Utricularia</i>	B			O
<i>Vallisneria</i>	B,D,O			O

Appendix Table 4.3. (cont.)

	Florida	Central America <sup>2</sup>	Antilles <sup>3</sup>	South America <sup>4</sup>
<b>Natant (Floating) Freshwater Plants</b>				
<i>Azolla</i>	+			O
<i>Eichhornia</i>	B,D,O	B		B,O
<i>Hymenachne</i>	+			O
<i>Lemna</i>	O			+
<i>Nelumbo</i>	+			O
<i>Neptunia</i>	+			+
<i>Nuphar</i>	B			
<i>Nymphaea</i>	B			O
<i>Pistia</i>	D,O,B	B		O
<i>Salvinia</i>	O			O
<i>Sagittaria</i>	D			O
<i>Victoria</i>	+			O
Unidentified		B		
<b>Emergent/Terrestrial Plants</b>				
<i>Alternanthera</i>	O			O
<i>Casuarina</i>	D			
<i>Chara</i>	B			O
<i>Cocos</i>	O			
<i>Colocasia</i>	O			
<i>Cyperus</i>		B		B
<i>Distichlis</i>	B			
<i>Eleocharis</i>	B	B		B
<i>Eragrostis</i>		B,S		
<i>Ficus</i>	D			
<i>Fimbristylis</i>				B
<i>Genipa</i> (fruit)				B
<i>Hydrocotyle</i>	O			
<i>Ipomoea</i>	+			O
<i>Juncus</i>	D			
<i>Laguncularia</i>				B
<i>Luziola</i>	+			O
<i>Machaerium</i>				B
<i>Mimosa</i>	+			O
<i>Montrichardia</i>	+,S			B,O,S
<i>Panicum</i>	B,D,O	B		B,O
<i>Paspalum</i>	B,O,D,d	D		O
<i>Phragmites</i>	D,O		B,D	
<i>Pontederia</i>	B,O	B		
<i>Potamogeton</i>	D			
<i>Portulaca</i>	B			
<i>Quercus</i>	O			
<i>Rhabdadenia</i>				B
<i>Rhynchospora</i> <sup>6</sup>				B
<i>Sabal</i>	O			

Appendix Table 4.3. (cont.)

	Florida	Central America <sup>2</sup>	Antilles <sup>3</sup>	South America <sup>4</sup>
<i>Sagittaria</i>	B,d	B		O
<i>Sambucus</i>	O			
<i>Scirpus</i>	O	B		
<i>Scleria</i>	S			S
<i>Serenoa</i>	O			
<i>Spartina</i>	B,D,O,S			B
<i>Typha</i>	B,D,O	B		O
<i>Urochloa</i>	O			
<i>Vigna</i>	B			
<i>Zizaniopsis</i>	B/S			
n/i	D	B,S		
<b>Freshwater Algae</b>				
<i>Anabaena</i>	O			
<i>Mougeteria</i>	O			O
<i>Nitella</i>	B			O
<i>Pithophora</i>	B			
<i>Spirogyra</i>	O			

<sup>1</sup> B inferred from observations of wild manatees or reports of fishers or Indigenous people; D recorded in digesta including feces; O confirmed from observations of wild manatees; S inferred from manatee feeding signs; + reported by Ronald *et al.* (1978) basis for report unknown and sometimes uncertain as to whether recorded in Florida, Guyana or both; foods consumed incidentally (< 2% by volume) are in lower case; those targeted deliberately in upper case; n/i = not identified;

<sup>2</sup> Belize, Mexico, Nicaragua, Panama;

<sup>3</sup> Bahamas, Cuba, Jamaica, Puerto Rico;

<sup>4</sup> Brazil, French Guiana, Guyana, Surinam;

<sup>5</sup> Allsopp (1969) states that most of these foods were also observed in the stomach contents of manatees killed incidentally in Guyana;

<sup>6</sup> formerly *Dichromena*

**Sources:** Allsopp 1960, 1969; Barrett 1935; Baugh *et al.* 1989; C Beck personal communication 2009; Bengtson 1981, 1983; Bertram and Bertram 1964; Best 1981; Best and Teixeira 1982; Borges *et al.* 2008; Castelblanco-Martínez *et al.* 2009; Dekker 1974; Domning 1981; Duplaix and Reichart 1978; Estrada and Ferrer 1987; Etheridge *et al.* 1985; Hardisky 1979; Hartman 1979; Hurst 1987; Husson 1978; Ledder 1986; Lefebvre and Powell 1990; Lefebvre *et al.* 2000; Lewis *et al.* 1984; Lluch 1965; Marsh *et al.* 1999; Maynard 1872; Mignucci-Giannoni and Beck 1998; Moore 1951; Mou Sue *et al.* 1990; Odell *et al.* 1978; O'Shea 1986; O'Shea and Rathbun 1982; Packard 1981 (as primary source); Packard 1984; Paludo and Langguth 2002; Powell 1978; Powell and Rathbun 1984; Powell and Waldron 1978; Rathbun *et al.* 1990; Reynolds 1977; Ronald *et al.* 1978; C Self-Sullivan personal communication 2008; Sgueros 1966; Shaul and Haynes 1986; Silverberg 1988; Spiegelberger and Ganslosser 2005; Tiedemann 1980; Zoodsma 1991.



**Appendix Table 4.4.** Genera of confirmed foods of wild West African manatees obtained using various techniques<sup>1</sup>. The foods eaten by *Trichechus senegalensis* are almost certainly much more diverse than suggested by this list.

Genus	Basis for record	Genus	Basis for record
<b>Seagrasses</b>		<b>Emergent (Terrestrial) Plants</b>	
<i>Cymodocea</i>	B	<i>Alternanthera</i>	+
<i>Halodule</i>	O	<i>Crinum</i>	B
<b>Mangroves</b>		<i>Cyperus</i>	O,B
<i>Avicennia</i>	+	<i>Crytospermia</i>	+
<i>Rhizophora</i>	O,B	<i>Drepanocarpus</i>	+
<b>Freshwater Animals</b>		<i>Echinochloa</i>	+
Molluscs	O,B	<i>Justica</i>	+
Fish	B	<i>Manihot</i>	O,B
<b>Submerged Freshwater Plants</b>		<i>Mimosa</i>	B
<i>Ceratophyllum</i>	+	<i>Oryza</i>	+
<i>Crinum</i>	B	<i>Paspalidium</i>	+
<i>Myriophyllum</i>	+	<i>Paspalum</i>	+
<i>Najas</i>	S	<i>Pennisetum</i>	+
<i>Ruppia</i>	+	<i>Phragmites</i>	B
<b>Natant (Floating) Freshwater Plants</b>		<i>Polygonum</i>	B
<i>Azolla</i>	+	<i>Pterocarpus</i>	+
<i>Eichhornia</i>	B	<i>Rhynchospora</i>	+
<i>Leersia</i>	+	<i>Typha</i>	+
<i>Lemna</i>	B	<i>Vossia</i>	B,S
<i>Nymphaea</i>	B	Grasses n/i	+
<i>Nymphoides</i>	B	<i>Hybiscus (tiliaceus)</i>	B
<i>Pistia</i>	B		
<i>Salvinia</i>	+		
<i>Neptunia</i>	B		

<sup>1</sup> B inferred from observations of wild manatees or reports of fishers or Indigenous people; O confirmed from observations of wild manatees by scientists; S inferred from manatee feeding signs; + basis for report unknown; n/i = not identified.

**Sources:** Beal 1939; Bessac and Villiers 1948; Best 1981; Cadenat 1957; Dekeyser 1955; Dodman *et al.* 2008; Dorst and Dandelot 1970; L Keith personal communication 2008; Kienta 1982 in Powell 1996; P Ofori-Dansen personal communication to L Keith 2009; Perkins 1848; Powell 1996 and unpublished field notes; Powell and Kouadio 2008; Reeves *et al.* 1988, 2002; Roth and Waitkuwait 1986 in Powell 1996; Shaw 1856.

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## Appendix 6.1. Reproductive Anatomy

### REPRODUCTIVE ORGANS

The reproductive anatomy of male and female sirenians reflects both their paenungulate origins (Chapter 3) and their fusiform body shape. The testes occur immediately posterior to the kidneys. This position is characteristic of all paenungulates and is apparently not a secondary adaptation to the aquatic environment in sirenians, even though it is a characteristic shared with cetaceans. However, the gross morphology of the testes and excurrent ducts of dugongs and manatees resemble those of cetaceans much more closely than those of elephants and hyraxes (Marsh *et al.* 1984a). As in cetaceans, the anatomy of the venous structures associated with the reproductive tissues exhibits structural adaptations to the challenges of maintaining them at appropriate temperatures (Rommel *et al.* 2001). Preventing sperm from becoming too hot is a particular challenge for mammals without external testes. These resemblances reflect the similarities of the abdominal cavities of sirenians and cetaceans, which are dictated by the morphological adaptations of both groups to their aquatic environments (e.g. reduced pelvic girdle, streamlined shape and absence of hind limbs; see Chapters 1 and 2). The penis generally remains internal but is extruded when the animal becomes stimulated (or bloats after death).

As explained in Chapter 5, Florida manatees (and probably dugongs) are promiscuous, with multiple males mating with individual females during a single estrus. This mating behaviour suggests that manatees may engage in sperm competition, wherein sperm from more than one male within the reproductive tract of a female compete with one another to fertilise the ovum. Species of mammals that are sperm competitors tend to have testes which are exceptionally large relative to their body size. Manatees have a tendency towards larger testes



than typical for mammals of their size but not exceptionally so (about twice the mass predicted by body size in mature males in breeding months; Reynolds *et al.* 2004). However, the body mass may be inflated by the size of the gut and density of the integument, making the relative mass of the testes 'artificially' low. Additionally, the large seminal vesicles which are a feature of the sirenian male reproductive tract might partially compensate for the size of the testes in sperm competition (Reynolds *et al.* 2004).

In both dugongs and manatees, each ovary lies in a complete peritoneal pouch hidden in the dorsal abdominal wall immediately posterior to the kidney and lateral to the ureter. The ovarian tissue (Figure 6.5) is suspended from the abdominal wall by a ligament called the mesovarium which is continuous with the peritoneum and heavily embedded with fat, especially in pregnant females (Marmontel 1988; Kwan 2002). Each ovary is attached to the extremity of the corresponding cornua (horn) of the bicornuate uterus. Marsh *et al.* (1984b) and Marmontel (1988, 1995) describe the reproductive anatomy of female dugongs and Florida manatees in detail.

There are striking similarities between the female reproductive anatomies of sirenians and elephants (see Marsh *et al.* 1984b; Larkin 2000). These similarities include: (1) the large number and form of the ovarian corpora lutea (endocrine structures that prepare the body for gestation and parturition) and their scars which are known as corpora albicantia (Figure 6.5); (2) the zonary placenta (Carter *et al.* 2008), which leaves conspicuous scars (Figure 6.6) in the uterus at former attachment sites in elephants and dugongs (but not always in manatees); (3) the bicornuate uterus which has one cervix and a small uterine body; (4) the cycle of histological changes in the uterine endometrium; and (5) the axillary mammary glands.

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## Appendix 6.2. History of Manatee Population Modelling

The first effort to model manatee populations was undertaken in the early 1980s when the database on Florida manatee reproduction was rudimentary and no reliable estimates of survival had been made. Packard (1985) developed a deterministic age-structured Leslie matrix model with 10 age classes and life history parameter estimates somewhat different from those that have emerged in subsequent years with more intensive data collection. This analysis also chose the simplified option of bracketing several scenarios of possible survival rates per age class to deal with uncertainty in parameter estimates. Although inputs were necessarily crude, modelling results suggested low population growth rates and that adult survival was the most important life history parameter affecting these growth rates. Adult survival had a greater influence on potential population growth rates than did calf or subadult survival or proportions of adults breeding.

The next phase in modelling Florida manatee populations took advantage of a larger life history database than that available to Packard and was also deterministic (Eberhardt and O’Shea 1995). This analysis applied the classic Lotka-Leslie model and followed an analytical approach generalised later by Eberhardt (2002). The model utilised survival probabilities and reproduction rates based on longitudinal observations of multiple individuals recognisable by scar patterns as described in Chapter 6 and applied them separately to estimating population growth rates at three study areas: Crystal River, Blue Spring and the Atlantic Coast. The model considered two age classes: adults and calves. The Leslie matrix model with constant adult survival was truncated at age 50, and the delta method and bootstrapping were applied to estimate the variances of population growth rate and the relative importance of the main variance components (adult survival, early age survival and rate of reproduction). Changes in adult survival had the greatest effect on population growth rate, with a change of 1% in survival causing about the same degree of change in growth rate. Estimated annual growth rates ranged from 1% at the Atlantic Coast to 7% at Crystal River. These positive growth rates were consistent with trends in count indices at winter aggregation sites (e.g. Garrott *et al.* 1994, 1995; Ackerman *et al.* 1995).

Marmontel *et al.* (1997) used a very different approach. They calculated age-specific survival using a traditional life table analysis based on ages at death of 1212

Florida manatees obtained from the carcass salvage program and also assessed reproductive parameters based on anatomical evidence from female carcasses from this program (Marmontel 1995; see Chapter 6). Unlike the more geographically constrained longitudinal re-sighting studies done up until that point, this approach allowed estimation of vital parameters in a large sample from throughout Florida over a 16-year time frame. Estimation of survival using this method is *ad hoc* and suffers from the analytical drawbacks noted in Chapter 6 (see the section on survival estimation) but at the time was the only method available that provided estimates covering the entire geographic distribution of the Florida subspecies. The data were analysed in the stochastic framework of a population viability analysis program that varied timing and impact of catastrophic mortality (hurricanes, disease and severe cold) as well as demographic traits. However, uncertainty in parameter estimates could only be accommodated by bracketing ranges of values in separate analyses. Marmontel *et al.* (1997) noted that the life table assumptions in the analysis produce stable estimates of population growth and that sampling and process variation of parameters could not be separated (see Runge *et al.* 2004), but the results can be considered a sensitivity analysis. Findings were consistent with the Packard (1985) and Eberhardt and O'Shea (1995) models in that adult survival was the key parameter influencing population growth or decline. Forecasts suggested long-term persistence of the population if adult mortality could be lowered by management actions such as reducing deaths from collisions with boats.

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## **Appendix 7. Helminth parasites of sirenians**

Knowledge of the systematics, and geographic and host ranges of the helminth parasites have advanced greatly since the review by Beck and Forrester (1988). Below we tabulate this more recent information and provide an updated list of references on the topic.

**Appendix Table 7.1.** *Helminth parasites of sirenians, after Beck and Forrester (1988) with updates. For details on past records see ibid. Comments focus primarily on nomenclature. Recent records are those that have appeared since 1988.*

Host	Class and Family	Species	Location in host	Comments	Noteworthy recent records
<i>Dugong dugon</i>	TREMATODA				
	Paramphistomidae	<i>Solenorthis travassosi</i>	Caecum	Jones (2005) considered this the only species in the genus, and supported synonymising the following taxa with it: <i>Solenorthis baeri</i> , <i>S. gohari</i> , <i>S. ngqubimalofouzi</i> and <i>Indosolenorthis hirudinaceus</i> .	
	Opisthotrematidae	<i>Opisthotrema dijonis</i>	Eustachian tubes, middle ear, esophagus	See Blair (2005a) for review of the family	
		<i>Opisthotrema australe</i>	Eustachian tubes, middle ear		
		<i>Pulmonicola pulmonalis</i>	Nares, lungs		Blair (2005a) recognises this taxon as including <i>Cochleotrema indicum</i> and <i>Paracochleotrema indicum</i> as synonyms
		<i>Lankatrema mannarensis</i>	Wall of stomach, duodenum and small intestine		Nomenclature supported by Blair (2005a)
		<i>L. minutum</i>	Wall of cardiac gland		
		<i>L. microcotyle</i>	Wall of ileum		

Appendix Table 7.1. (cont.)

Host	Class and Family	Species	Location in host	Comments	Noteworthy recent records
		<i>L. macrocotyle</i>	Wall of ileum	Nomenclature supported by Blair (2005a)	
		<i>Lankatrematoides gardneri</i>	Pancreatic ducts	Nomenclature supported by Blair (2005a)	Helminth age structure in hosts from Papua New Guinea <sup>1</sup>
		<i>Folitrema jecoris</i>	Gall bladder and bile ducts within liver	Nomenclature supported by Blair (2005a)	
Labicolidae		<i>Labicola elongata</i>	Abscesses in upper lip	Nomenclature supported by Blair (2005b). See <i>ibid</i> for review of the family.	
Rhabdiopoeidae		<i>Rhabdiopoeus taylori</i>	Lumen of intestines	Nomenclature supported by Blair (2005c). See <i>ibid</i> for review of the family.	
		<i>Taprobanella bicaudata</i>	Stomach, duodenum, pyloric caeca	Nomenclature supported by Blair (2005c)	
		<i>Haerator caperatus</i>	Lumen of ileum	Nomenclature supported by Blair (2005c)	
		<i>Faredifex clavata</i>	Large abscesses in wall of ileum	Nomenclature supported by Blair (2005c)	
Spirorchidiidae (?)		Eggs of unknown species	Ovaries, myometrial blood vessels	Observations in Marsh <i>et al.</i> (1984)	
NEMATODA					
Toxocaridae		<i>Paradujardinia halicoris</i>	Lumen of stomach, cardiac gland		

Appendix Table 7.1. (cont.)

Host	Class and Family	Species	Location in host	Comments	Noteworthy recent records
<i>Trichechus manatus latirostris</i>	TREMATODA				
	Paramphistomidae	<i>Chiorchis fabaceus</i>	Lumen of caecum and colon	See Jones (2005) for review of the family	
		<i>Chiorchis groschaffi</i>	Lumen of small intestine	Described by Coy-Otero (1989)	Southern Florida <sup>2</sup>
	Opisthotrematidae	<i>Pulmonicola cochleotrema</i>	Nares, lungs	Nomenclature supported by Blair (2005a). See <i>ibid</i> for review of the family.	
		<i>Moniligerum blairi</i>	Mucosa and submucosa of small intestine	Nomenclature supported by Blair (2005a)	
	Nudacotylidae	<i>Nudacotyle undicola</i>	Lumen of small intestine	Family reviewed and supported by Barton and Blair (2005)	
	NEMATODA				
	Heterocheilidae	<i>Heterocheilus tunicatus</i>	Lumen and mucosa of stomach and small intestine		
	Rhabditidae	<i>Rhabditoides</i> sp.	Skin	Likely accidental (Forrester 1992)	
	CESTODA				
	Anoplocephalidae	<i>Anoplocephala</i> sp.	Lumen of small intestine	Likely accidental (Beck and Forrester 1988)	

Appendix Table 7.1. (cont.)

Host	Class and Family	Species	Location in host	Comments	Noteworthy recent records
<i>Trichechus manatus manatus</i>	TREMATODA				
	Paramphistomidae	<i>Chiorchis fabaceus</i>	Lumen of caecum and colon	Nomenclature supported by Jones (2005); see <i>ibid</i> for review of family.	Puerto Rico <sup>2,3,4</sup> ; Dominican Republic <sup>5</sup>
		<i>Chiorchis groschaffi</i>	Lumen of small intestine	Described by Coy-Otero (1989)	Puerto Rico; Mexico; Dominican Republic;
	Opisthotrematidae	<i>Pulmonicola cochleotrema</i>	Nares, lungs	Nomenclature supported by Blair (2005a); see <i>ibid</i> for review of the family.	Cuba <sup>2,4,6</sup> Puerto Rico <sup>2,3,4</sup> ; Dominican Republic <sup>5</sup>
		<i>Moniligerum blairi</i>		Supported by Blair (2005a)	Puerto Rico <sup>4</sup>
	Nudacotylidae	<i>Nudacotyle undicola</i>	Lumen of small intestine	Family reviewed and supported by Barton and Blair (2005)	Puerto Rico <sup>4</sup>
	NEMATODA				
	Heterocheilidae	<i>Heterocheilus tunicatus</i>	Lumen and mucosa of stomach and small intestine		Puerto Rico <sup>3,4</sup> ; Dominican Republic <sup>5</sup>
<i>Trichechus inunguis</i>	TREMATODA				
	Paramphistomidae	<i>Chiorchis fabaceus</i>	Lumen of caecum and colon	Nomenclature supported by Jones (2005); see <i>ibid</i> for review of family.	



**Appendix Table 7.1.** (cont.)

Host	Class and Family	Species	Location in host	Comments	Noteworthy recent records
	NEMATODA				
	Heterocheilidae	<i>Heterocheilus tunicatus</i>	Lumen and mucosa of stomach and small intestine		
<i>Trichocheilus senegalensis</i>	TREMATODA				
	Paramphistomidae	<i>Chiorchis fabaceus</i>	Lumen of caecum and colon	Nomenclature supported by Jones (2005); see <i>ibid</i> for review of family.	
	NEMATODA				
	Heterocheilidae	<i>Heterocheilus domingi</i>	Unspecified		

<sup>1</sup> Blair and Hudson (1992);

<sup>2</sup> Mora-Pinto (2000);

<sup>3</sup> Mignucci-Giannoni *et al.* (1999a);

<sup>4</sup> Colon-Llavina *et al.* (2009);

<sup>5</sup> Mignucci-Giannoni *et al.* (1999b);

<sup>6</sup> Coy-Otero (1989).

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