THE DIET AND FEEDING ECOLOGY OF THE GREEN SEA TURTLE (*Chelonia mydas*) IN AN ALGAL-BASED CORAL REEF COMMUNITY

Thesis submitted by

Gregory Allan Forbes
B.Sc., M.Sc. (California Polytechnic University)

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Department of Zoology
and
Department of Tropical Environmental Studies and Geography
James Cook University of North Queensland
Queensland, Australia

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Dedication

This thesis is dedicated to the memory of Darryl Reimer, my dear friend who lost his life while studying the animals that he loved.

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Declaration

I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any university or other institution of tertiary education. Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

Gregory Allan Forbes

20 OCT '97

Date

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Date

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The catching and handling of sea turtles is a labour intensive effort and cannot be adequately accomplished without several people sharing a very small boat for extended periods of time and then working late into the night. During this project I spent many hundreds of hours on board our catch boat with a special breed of people that found pleasure and satisfaction in jumping from a perfectly safe boat at high

speed into the water to catch turtles. In the process, they returned to the boat with coral cuts, broken fingers, broken teeth, bruised bodies and tales of close encounters with sharks. However, in most instances, they also returned with a turtle. It is this devotion and persistence that I so valued and could never hope to explain. However, without such a special group of people, this project would have been impossible. I therefore express my sincere appreciation for the adventure shared and the turtles captured to the following people: Brad Jones for almost never missing a turtle; Peter Eggler for sacrificing his incisors to the cause; Phil Davies for catching so many turtles and for understanding why the boat was on the bottom of the lagoon; Paul Buehler for dislocating his shoulder and not letting the turtle loose; Marc Deacon for always being willing to go after "one more"; Lisa Hellinger for believing that our boat was unsinkable and for going out in 20 knot winds and to Rodd Thorton, Kevin Mitchell, Mark Latter, Jim Buck, John and Shiela Payne and Dawn Bishop for the many turtles that they caught. Above all, I look back upon the times that I spent catching turtles with my dear friend Darryl Reimer as some of the best times of my life. Thank you for your knowledge, wisdom, humour and friendship with me and my family.

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Abstract

Nutrition is considered to have an important influence upon the life history of the green sea turtle including regulation of its growth rate, age at sexual maturity, egg production and remigration intervals amongst other influences. It would therefore be expected that the green turtle would select dietary items that would maximise its nutrient intake and balance its energy budget as predicted by optimal foraging models.

Although the feeding ecology of green turtles in seagrass communities has received attention, no study to date has investigated the feeding ecology of green turtles in an algal community. This was the first study to describe the diet and feeding ecology of green turtles foraging in an algal-based community (Heron Reef, Queensland) where seagrasses were absent.

Algae account for the greatest areal cover of benthic biota on Heron Reef with over four times the areal cover of living corals. Heron Reef supports over 115 species of algae although only seven of these ever exceed more than 2% of the total algal cover. The main component of the algal assemblage is the algal turf which accounts for 56% of the total areal cover of algae. The algal community on Heron Reef is composed of species that are dynamic in distribution and diverse in chemistry. Although no trends or patterns could be detected, there is a significant spatial and temporal variation in the areal cover of algae both within and between reef habitats. The lipid, carbohydrate, ash and energy content of macroalgae species on Heron Reef varied significantly from each other but did not change significantly over time. In contrast, the change in levels of nitrogen was significant over time.

Green sea turtles on Heron Reef include both resident and migrant turtles. The resident green turtles include animals from all age classes ≥35 cm in curved carapace length with immature animals accounting for 74% of the resident population. The sex ratio of the resident turtles is not significantly different than 1:1.

Algae are the most important and almost the exclusive diet item of green turtles of all age classes and both sexes on Heron Island during all seasons. Green turtles on Heron Reef demonstrate diet preference and avoidance of undesirable species. The diet varies significantly both temporally and between age classes although there is no continuity or discernible pattern to these changes. The differences observed between the age classes may disappear when desirable dietary species become available. There are no discernible differences in diet between sexes.

The diet of individual turtles captured on repeat occasions varied over time although there is no apparent pattern or continuity to this change. Some individuals exhibited considerable shifts in diet while others remained rather constant in their dietary choices. Green turtles of all age classes appear to have a base diet of algal turf but they will opportunistically exploit desirable monogeneric stands of algae when they become available.

Optimal foraging models that predict diet based upon a single variable do not serve as useful predictors of diet in green turtles feeding in complex algal communities. Although diet selection does occur, green turtles on Heron Reef do not select dietary items as an exclusive function of their availability, nutrient, ash, energy or secondary compound profiles. The green turtle appears to select dietary items in response to a complex interdependent matrix of variables that influences the nutritive and energy potential of their diet while reducing the effects of algal secondary compounds. Diet selection is most likely a combination of positive and negative (avoidance) diet selection decisions.

When confronted with constantly changing algal chemistry and availability, the green turtle's optimal strategy may be to forage within the heterogenous algal turf. Such a strategy would ensure that at least some superior species were included in the diet while at the same time possibly mitigating the influences of secondary compounds while optimising the benefits of diet mixing. As the composition of the algal turf is dynamic, this strategy would also ensure the inclusion of newly available species in the diet.

Chapter 1

Introduction

The green sea turtle (*Chelonia mydas* Linnaeus, 1758) is the largest member of the Family Cheloniidae which includes five extant genera and six species of sea turtles. Green turtles are known to occupy a series of developmental habitats as they mature (Carr *et al.*, 1978,1980,1986; Limpus, 1978; Balazs, 1980b; Lanyon *et al.*, 1989). Hatchlings and neonates are frequently found along pelagic oceanic convergence zones where food is concentrated (Carr, 1967a,b, 1986, 1987; Carr and Meylan, 1980; Witham, 1980). It has been proposed that green turtles are carnivorous during this pelagic phase (Moorhouse, 1933; Carr, 1980; Hirth, 1971; Balazs, 1980b; Lanyon *et al.*, 1989). Young green turtles remain in the pelagic areas for several years before moving to near-shore, shallow-water, developmental feeding grounds (Carr, 1978; Limpus, 1978,1980; Balazs, 1980b,1987; Limpus *et al.*, 1984; Lanyon *et al.*, 1989; Meylan and Meylan *et al.*, 1994) such as coral reefs, rocky reefs, mangrove stands and seagrass meadows. In these areas, green turtles feed upon seagrasses, algae, mangrove leaves and seeds and, to some extent, invertebrates (Table 2.2). The green turtle is the only herbivorous sea turtle species.

Wild green turtles exhibit slow rates of growth and attain sexual maturity after many decades (Limpus 1980, 1993; Limpus and Walter, 1980; Balazs, 1982; Bjorndal and Bolten, 1988 and others). At sexual maturity, growth rate slows significantly (Carr and Carr, 1970; Carr and Goodman, 1970; Limpus and Walter, 1980; Bjorndal and Bolten, 1988 and others) as energy reserves are directed towards reproduction (Kwan, 1994). When the growth rate and age at sexual maturity of wild turtles and turtles reared in captivity and fed high protein and energy diets are compared, it is apparent that both

growth and age at first breeding are influenced by nutrition. Captive turtles fed diets high in protein and energy grow and mature faster than turtles feeding upon natural diets which contain lower protein (Wood and Wood, 1980).

Both sexes of green turtles migrate from their resident feeding grounds to mating and nesting grounds that may be several hundred to several thousands of kilometres away over open ocean (Balazs, 1980b, 1983a; Limpus 1980; Limpus *et al.*, 1984; Limpus and Nicholls, 1988; Meylan, 1982; Limpus *et al.*, 1992). The energy required for this migration and the associated breeding activities can represent 10-24% of the female's yearly energy budget (Bjorndal, 1982). Limpus (1996) found an inverse relationship between the length of a migration and the number of clutches and eggs laid by loggerhead turtles (*Caretta caretta*). No wild green turtle population is known to have females that remigrate to the nesting grounds on an annual basis. However, captive turtles fed high protein and energy diets regularly nest annually (Wood and Wood, 1980). The annual nesting of captive turtles and the absence of annual nesting in wild turtles suggest that this aspect of the turtle's natural history is also nutritionally regulated.

Green turtles are known to be selective grazers in seagrass communities where they select for young plants with higher nutritive values and lower epiphyte and lignin levels (Bjorndal, 1979,1980; Ogden, *et al.*, 1980; Mortimer, 1981,1982). It has been proposed that diet selection may not be limited to the selection of a particular plant part or growth stage but may include preferences for rare species (Ross, 1985). In contrast, other authors suggest that green turtles select their diet as a function of availability rather than preference (Ogden, 1976; Mortimer, 1981; Garnett *et al.* 1985). On a much broader scale, it has been proposed that green turtles preferentially feed upon

seagrasses rather than algae when both are available (Bjorndal, 1979a,1980; Mendonca, 1983).

Since growth rate, age at sexual maturity and remigration interval appear to be nutritionally regulated, it is expected that the green turtle selects dietary items that maximise its nutrient intake and balance its energy budget as predicted by optimal foraging models.

This study was the first to examine the feeding ecology of a green turtle population that is limited to algal forage. The goal of this study was to determine the diet of green sea turtles feeding in an algal-based coral reef community and to attempt to determine those factors that may influence the selection of an optimal diet. The objectives of this study were as follows:

1. To determine the components of the diet of green sea turtles feeding in an algal-based coral reef community and to ascertain if the pooled or individual diets of these turtles change over time (Chapter 6).
2. To quantify seasonal changes in the diversity and abundance of the algal assemblage (Chapter 5), along with any changes in the nutrient and energy content of selected algae species (Chapter 7).
3. To determine if diet selection occurs and if it does, whether selection is a function of gender, age or reproductive status of the turtles (Chapter 6) or a function of the temporal availability (Chapter 5 & 8) or nutrient and energy content of the forage (Chapters 7 & 8).
4. To determine if the foraging strategy of green sea turtles in an algal-based habitat can be identified and if it can, determine if this strategy fits existing optimal foraging models (Chapter 8).

Chapter 2

Background and Literature Review

2.1 The Green Turtle[1]

2.1.1 Systematics

The green sea turtle (*Chelonia mydas* Linnaeus, 1758) is a member of the Family Cheloniidae, a family that includes five extant genera and six species (loggerhead turtle, *Caretta caretta* ; hawksbill, *Eretmochelys imbricata* ; olive ridley, *Lepidochelys olivacea* ; Kemp's ridley, *L. kempii* ; Australian flatback, *Natator depressus*). A seventh sea turtle species, the leatherback turtle (*Dermochelys coriacea*) belongs to the monospecific Family Dermochelyidae.

Until recently, the Genus Chelonia was believed to be polyspecific with 2-3 species; the green sea turtle (*C. mydas*), the flatback turtle (*C. depressa* Garman, 1880) and the black turtle (*C. agassizii* Bocourt, 1868). More recent work on the systematics of *C. depressa* using osteological and electrophoretic data have resulted in a proposed reclassification of this turtle from *Chelonia* to *Natator* (Limpus *et al.*, 1988; Zangerl *et al.*, 1988). Based upon its original description (Bocourt, 1868), the black turtle (*C. agassizi*) of the eastern Pacific is still commonly assigned full species status in the literature (Carr, 1981; Balazs, 1985; Figueroa, 1989; Figueroa and Alvarado, 1990; Dutton and McDonald, 1990). However, investigations using mitochondrial DNA restriction site analysis suggest that *C. agassizi* should be considered conspecific with *C. mydas* (Bowen *et al.*, 1992).

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[1] To avoid repeatedly referring the reader to comprehensive literature reviews of particular topics, Table 2.1 provides a listing of these reviews. Tables and figures are placed at the end of each chapter.

2.1.2 Distribution

Green sea turtles are found circumglobally in tropical and subtropical waters with most populations and breeding areas between the northern and southern 20° C marine isotherms (Hirth, 1971). However, green turtles are known to occupy colder waters such as Moreton Bay in southern Queensland (16-28°C) (Limpus, *et al.*, 1994a) and New South Wales (Limpus *et al.*, 1994b) . In the Pacific, green turtles have been documented as far north as Alaska (57° 16' N) (Hodge, 1981) and as far south as southern Chile (52° 57' S) (Frazier, 1990). This Chilean record represents the southernmost sighting of any species of sea turtle in any ocean (Frazier, 1990). In the Atlantic, green turtles are known from as far north as the Netherlands (Brongersma, 1972).

2.1.3 Life History

Male and female green turtles migrate from their resident feeding grounds to spatially distinct breeding and nesting grounds (Balazs, 1976; Carr *et al.*, 1978; Limpus, 1980; Mortimer, 1981; Meylan, 1982; Limpus *et al.*, 1992). Limpus *et al.* (1992), suggested that all green turtle populations migrate but that there may be portions of populations that only migrate a short distance. Migrations may involve journeys of more than 2,200 km across open ocean (Meylan, 1982). Meylan (1982) cites Galenon's work (1979) in French Polynesia in which a one-way migration of over 4,000 km was recorded. Limpus *et al.* (1992) report a one-way migration of 2,620 km from the Great Barrier Reef.

The season of migration, mating and nesting varies geographically. Males and females arrive on the breeding and nesting grounds in Queensland at about the same time but their departure is asynchronous as males depart at the beginning of the nesting season while the females remain for several months (Limpus, 1980). After arrival, females copulate with multiple partners over a period of several weeks (Limpus, 1980, 1993).

Limpus *et al.* (1984) have found that green turtles from the southern Great Barrier Reef rarely nest in the area in which they copulate and may travel up to 92km to nest. Meylan and Meylan (1994) reported that green turtles travelled 240 km from their mating site in Panama to their nesting beach at Tortuguero, Costa Rica. The purpose of this behavior remains unexplained.

Green turtles lay a variable number of eggs ranging from an average of 105 eggs in Sarawak (Hendrickson, 1958) to 138 per clutch in Surinam (Schulz, 1975). Green turtles nesting on Heron Island deposit an average of 115 eggs per clutch (Limpus *et al.*, 1984). Schulz (1975) cites a record of 226 eggs in Surinam. The number of clutches laid per year is even more variable among populations than the number of eggs laid per clutch. Although some females may nest only once or twice during a nesting season (Schulz, 1975; Carr *et al.*, 1978; Ehrhart, 1979), multiple nesting crawls are typical. It has been suggested that the incidence of single nesting occurs less frequently than reported because tag loss and the possibility of multiple-beach nesting by some individuals may have biased these observations (Limpus *et al.*, 1984: Limpus, 1992a). Sarawak green turtles may produce as many as 11 clutches (Hendrickson, 1958) and Heron Island green turtles up to 10 clutches with a mean of 5 clutches (C.J. Limpus, pers. comm.).

Like most other aspects of reproduction in green turtles, the interval between successive nesting migrations (remigration interval) varies between and within populations. While remigration has been documented for all sea turtle species, there appears to be no fixed pattern and it has been suggested that some members of a population may not remigrate (Carr, 1980; Hughes, 1982). However, tag loss and movement between rookeries in subsequent years has most likely influenced these observations (Limpus *et al.*, 1984; Limpus, 1992a). Carr *et al.* (1978) found that female

green turtles in Costa Rica had a remigration interval averaging 3 years while green turtles nesting on Heron Island remigrate on average every 5.8 years (s.d=1.48, range=1-9 yrs.) (Limpus *et al.*, 1994c). The proportion of these populations that remigrate at least once was estimated to be 20% (Carr *et al.* 1978) and >50% (C.J. Limpus, pers. comm.) respectively. However, these estimates are most likely underestimates as they do not take into account tag loss and, in the study of Carr *et al.*, not all of the nesting beach was surveyed for nesters.

After leaving their natal beach, green turtle hatchlings are believed to occupy several habitats as they mature (Carr *et al.*, 1978, 1986; Carr and Meylan, 1980; Limpus, 1978; Balazs, 1980b; Lanyon *et al.*, 1989). The first developmental habitat for Atlantic and Caribbean populations involves a pelagic stage (Carr, 1967a, b, 1986,1987; Carr and Meylan, 1980; Witham, 1980). Turtles from hatchling size to several years old are commonly found along oceanic convergence zones where food is concentrated along current boundaries and areas of downwelling (Carr, 1967a, b, 1986, 1987; Carr and Meylan, 1980; Witham, 1980). Walker (1994) suggested that post-hatchling green turtles from eastern Australia may also pass through a pelagic stage before returning to coastal habitats. Although probable, direct evidence of a pelagic stage in Pacific and South Pacific Ocean green turtle populations has not been documented. Balazs (1980b) describes a complete absence of green turtles <35 cm standard carapace length[2] (SCL) from any waters in the Hawaiian Archipelago and an absence of hatchlings from the stomach contents of Hawaiian tiger sharks (*Galeocerdo cuvier*), the primary predator of green turtles in Hawaii. Similarly, Limpus and Reed (1985a)

[2]SCL (Standard Carapace Length) is the maximum straight-line distance along the midline from the anterior margin of the precentral (nuchal, cervical) scute to the posterior margin of the postcentral scutes. Compare with CCL (Curved Carapace Length) and TCL (Total Carapace Length).

found that turtles of <35 cm curved carapace length[3] (CCL) are not represented in the green turtle population of Heron Reef or on any other reefs studied along the Great Barrier Reef (C. J. Limpus, pers. comm.). These findings suggest that the Hawaiian Archipelago and the Great Barrier Reef are not used as developmental habitats for very young turtles (<35 cm). In contrast to the findings cited above from Hawaii and Australia, Meylan *et al.* (1994) have documented green turtles as small as 22 cm SCL occupying inshore feeding grounds along the coast of Bermuda.

It has been suggested that young green turtles may remain in pelagic habitats for several years before moving to near shore feeding grounds (Carr *et al.*, 1978; Limpus, 1978,1980a; Limpus *et al.*, 1984; Balazs, 1980b; Balazs *et al.*, 1987). This multiple habitat model is supported by the work of Pitman (1990) in the tropical eastern Pacific. Pitman spent over 60 months at sea during a 15 year period during which he documented sightings of 2,742 turtles in pelagic areas. Although he was not able to identify many turtles to species, only ten green turtles were identified and six of these turtles were associated with islands. This relative absence of juvenile and older green turtles in pelagic habitats suggests that young green turtles leave the pelagic habitat for littoral habitats which may offer a broader and more abundant food supply than pelagic areas. Although 35 cm SCL is generally considered to be the size at which green turtles leave the pelagic habitat, green turtles as small as 22 cm SCL are known to occupy coastal habitats in Bermuda (Meylan *et al.*, 1994). Excluding breeding migrations, green turtles spend the remainder of their life cycle in these littoral feeding grounds.

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[3]CCL (Curved Carapace Length) represents the greatest distance from the anterior edge of the central scute (nuchal, cervical scutes) along the curve of the carapace midline to the posterior terminus of the border between the postcentral scutes. Compare with SCL (Standard Carapace Length) and TCL (Total Carapace Length).

2.1.4 Morphology[4]

The green turtle is the largest member of the Cheloniidae on the basis of both mass and length. Size-based sexual dimorphism occurs and may be variable between populations. Limpus (1993) reports that, on average, adult males from the southern Great Barrier Reef are 6.4 cm (CCL) shorter than the females ($\overline{X}$=107.03 cm CCL, s.d=5.32). This trend is also supported by data for the Gulf of Carpentaria (Limpus and Reed, 1985b), Arabian Gulf (Miller, 1989), Papua New Guinea (Kwan, 1990), Gulf of Aden/Red Sea (Hirth and Carr, 1970), Baja California (Caldwell, 1962) and Aldabra (Frazier, 1971). In addition to the sexual dimorphism observed in carapace length, adult male green turtles also possess an elongated tail[5] (Limpus *et al.*, 1994a) and a large curved claw on the front flippers.

Some nesting adults exceed 140 cm TCL[6] (Carr and Hirth, 1962). Carr (1970) reports the mean SCL of nesters in Costa Rica to be 100 cm. Nesters at Ascension Island average 108 cm SCL (Carr and Hirth, 1962) while Queensland nesters average 107 cm CCL (Limpus *et al.*, 1984). Adult females weighing up to 240 kg have been reported from the Atlantic and Caribbean with females weighing 200 kg not uncommon (Carr and Hirth, 1962; Schulz, 1975). Both Carr (1952) and Pritchard (1979) cite a green turtle (sex not indicated) weighing 386 kg without providing corroborating references.

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[4] Detailed age class delineations are presented in Section 4.2.1. As used in this chapter, pelagic phase= turtles usually <35 cm CCL in pelagic waters. Postpelagic phases includes juveniles (35-65cm CCL), subadults (>65-~90cm CCL)and adults (sexually mature; >90 cm CCL) associated with shallow water habitats.

[5] Adult male green turtles in Queensland typically possess tails that extend >30 cm from the posterior edge of the midline junction of the supracaudal scutes (Limpus *et al.*, 1994a)

[6] TCL (Total Carapace Length) is the maximum straight-line distance (parallel to the midline) from the anterior margin of the carapace to the posterior margin of the postcentral scutes. Compare with CCL (Curved Carapace Length) and SCL (Standard Carapace Length).

As the body size of the female increases, so does its capacity to store vitellogenic follicles, eggs and the large fat reserves that are required for the long and energy demanding migration to the breeding grounds and back. Green turtles swim at least 2,200 km through nutrient poor pelagic waters to reach Ascension Island (Meylan, 1982) with little or no feeding during the trip or while at Ascension (Carr and Goodman, 1970). Carr and Goodman (1970) suggested that the reason that green turtles nesting on Ascension Island are the largest green turtles in the world is due to their requirement for fat storage in order to meet the energetic requirement for the roundtrip swim to Ascension.

2.1.5 Growth

The growth rate of both wild and captive green turtles is well documented (Hendrickson, 1958; Wood, 1974; Wood and Wood, 1977a,b, 1980, 1981; Kowarsky, 1977; Witham and Futch, 1977; Limpus and Walter, 1980; Garnett, 1980; Mendonca, 1981; Hadjichristophorou and Grove, 1983; Frazer and Ehrhart, 1985; Bjorndal and Bolten, 1988; Boulon and Frazer, 1990; Bolten *et al.*, 1992; Bjorndal *et al.*, 1995 and others). Growth rates of immature wild turtles have been shown to be as slow as $\overline{X}$=0.75 cm/yr (SCL) at Heron Reef and as fast as 8.8 cm/year (SCL) in the Bahamas (Bjorndal and Bolten, 1988). Subadult captive females (2 years before first nesting) raised on artificial diets high in protein and energy showed an average growth rate of up to 7.4 cm /yr (CCL) and mean weight gain of 22 kg per year (Wood and Wood, 1980). Balazs (1980) reports a growth rate of 9.36 cm/yr (SCL) for a captive green turtle fed on an artificial diet.

In addition to geographic influences upon the growth rates of green turtles, it has been shown that differential growth rates exist between age classes of wild turtles from the same population and that growth is almost negligible after maturity (Carr and

Goodman,1970; Limpus 1980, 1993; Balazs, 1982; Bjorndal and Bolten, 1988; Limpus and Walter, 1980; Boulon and Frazer, 1990). These findings are supported by growth rate studies of captive green turtles (Wood and Wood, 1980). The near absence of growth in mature turtles is most likely a result of the redirection of energy to the reproductive process rather than to growth (Kwan, 1994).

The age at maturity of wild female green turtles remains unclear and appears to be variable among populations. Estimates of age at maturity are based upon the relationship between known or estimated growth rates and known minimum or mean breeding size. Female green turtles in Hawaii are estimated to require from 9 to 59 years to breed after they reach 35 cm (SCL) (Balazs, 1980,1982) while green turtles from the southern Great Barrier Reef are believed to require more than 40 years to reach maturity (Limpus and Chaloupka, *in press*). Turtles in Florida may require up to 27 years (Frazer and Ehrhart, 1985). Captive animals raised on artificial diets high in protein and energy will lay eggs as early as 8 years of age (Wood and Wood, 1980). Green turtles from the same wild (Carr and Goodman, 1970; Limpus and Reed, 1985a; Boulon and Frazer, 1990; Limpus, 1993) or captive population (Wood and Wood, 1980) may mature at different sizes. The smallest sexually mature female on Heron Reef measured 91.0 cm (CCL) while the largest immature female reached 98.5 cm (CCL) (Limpus and Reed,1985a). Captive females fed artificial diets matured at a minimum length of 81.3 cm (CCL) and 79.5 kg and at a maximum length of 111.8 cm (CCL) and 231.8 kg (Wood and Wood, 1980).

2.2 Diet, Feeding and Nutritional Ecology

2.2.1 Diet Components

The data summarised in Tables 2.2 & 2.3 clearly indicate that in their postpelagic phase, green turtles are generally euryphagous, facultative herbivores that eat

seagrasses, algae, mangrove leaves and fruits and limited animal matter. However, some green turtle populations are stenophagous herbivores feeding upon one species of seagrass (Bjorndal, 1979a,1980; Mortimer, 1976,1981) while others may feed upon many species of algae while still consuming seagrass (Carr, 1954; Ross 1985; Garnett *et al.*, 1985; Read 1991; Brand, 1995). The capacity of green turtles to digest algae and seagrass is enhanced by the rich cellulytic bacterial and protozoan community in their caecum and large intestine (Bjorndal, 1979a,b; Fenchel, *et al.*, 1979). Green turtles are therefore hindgut fermenters.

It is clear from the existing literature that green turtles are able to consume a wide variety of plant material. It may be this ability that has allowed the green turtle to successfully occupy so many different marine habitats around the world. However, when the diet of different populations are compared, it is of interest to note that the genera or species consumed by one green turtle population may not be consumed by a another population even though the genus or species is readily available. It would therefore follow that some level of diet selection must be operating in at least some green turtle populations.

Most reports on the diet of the green turtle are qualitative descriptions of stomach samples from a limited number of individual turtles sampled only once (Tables 2.2 & 2.3). Although these studies have provided information on what green turtles eat, they are of limited ecological value. Few studies have examined the components of the green turtle's diet quantitatively and even fewer have attempted an ecological approach by quantitatively assessing both the available forage crop and the dietary components in order to determine if green turtles feed selectively. An objective of this study was to examine the ecological aspects of the diet of juvenile, subadult and adult green turtles

feeding in an algal community by simultaneously quantifying the diet and the available forage.

2.2.2 Feeding Behaviour and Site Fidelity

In their postpelagic phase, green turtles appear to limit their resting and feeding both spatially and temporally to distinct areas and times, respectively (Bjorndal, 1980; Mendonca, 1983; Ogden *et al.*, 1983). Green turtles leave their sleeping areas shortly after dawn and travel to their feeding areas (Bjorndal, 1980; Ogden *et al.* ,1980) where they forage intermittently throughout the day with peaks in the early morning and late afternoon (Bjorndal, 1980; Ogden *et al.* ,1980, 1983; Mendonca, 1983). Mendonca (1983) found that periods of low water temperature (<19° C) resulted in a significant change in behaviour with erratic movements over the seagrass beds and long-distance swims of up to 15 km in one day and the apparent cessation of feeding. Mendonca (1983) attributes this behaviour to avoidance of low water temperature. The turtles returned to their "normal behaviour" when the water warmed supporting Mendonca's proposal. In contrast, Read (1991) found that juvenile and subadult green turtles in Morton Bay, Queensland did not display this erratic behaviour and continued feeding in water temperatures below 20°C.

Ogden *et al.* (1983) describe separate feeding and sleeping areas for green turtles while Bjorndal (1980) describes the use of separate sleeping, resting and feeding areas for semiwild turtles. Both studies indicate that the resting areas are 6-7 m deep, typically free of seagrasses and may be covered by coral, rubble or sand. Separate resting and feeding areas have also been described for green turtles in Hawaii (Balazs, 1980b). In warm water (>19° C), acoustically tagged turtles in central Florida returned faithfully from their feeding areas each afternoon to their customary sleeping area (Mendonca, 1983). During cold water (<19° C) conditions, none of the monitored turtles returned to

the previous night's sleeping area but moved as far away as 4.8 km. Although similar discrete feeding, resting and sleeping areas have not yet been identified for green turtles using the reef around Heron Island, C. J. Limpus (pers. comm.) has noted that turtles can be regularly found sleeping or resting at predictable locations on the reef slope.

Green sea turtles are generally considered to be diurnal feeders although few attempts have been made to observe turtles foraging at night (Balazs, 1980; Bjorndal, 1980; Mendonca, 1983; Ogden *et al.*, 1983; C. J. Limpus pers. comm.). Although turtles occur in known feeding grounds at night, their presence does not necessarily indicate feeding as the turtle may be resting or in transit. Even the presence of food particles in the mouth does not confirm recent feeding as food can become lodged on buccal structures and remain there for many hours (pers. obser.). C.J. Limpus (pers. comm.) observed green turtles that were active at night in the feeding grounds around Heron Island and at Shoalwater Bay on the central Queensland coast. Bjorndal (1980) observed immature green turtles in the Bahamas that were active over the feeding areas during moonlight nights but indicates that this was not a frequent occurrence. Ogden *et al.* (1983) describe "presunrise activity" in one of three acoustically tagged subadult green turtles in the Virgin Islands but it is unclear as to whether or not this animal was feeding or merely in the feeding area. Mendonca (1983) followed nine acoustically tagged turtles in a seagrass lagoon on the east coast of central Florida and found that after dusk, "...almost no change in position was observed until dawn." Balazs (1980b) describes night time net captures of green turtles with food particles in their mouths but, as discussed above, these items may have become lodged during a previous feeding bout. Williams (1988) found no nocturnal feeding in five radio tagged green turtles tracked in their feeding ground in the Virgin Islands. Although direct observations of green turtles

feeding at night have not been made, there is no reason to conclude that such feeding does not occur.

Feeding site fidelity is well known in green turtle populations. Immature green turtles feeding in seagrass beds in Florida had a mean home range of 2.9 km^2 with the center of feeding activity consisting of a 0.16 km^2 area (Mendonca, 1983). C. J. Limpus (pers. comm.) has found that green turtles on Heron Reef are captured infrequently outside the immediate area of their previous capture(s) even though they may have been returned to the water several kilometres from that spot. Ireland (1980) found that juvenile green turtles captured on their feeding grounds and relocated 1.5-4 km away, were able to return to within tens of meters of their original point of capture within two days. Five were followed for more than two weeks and all remained at the same feeding site for the duration of the observation. Read (1991) found that only one out of 30 immature green turtles repeatedly captured within his study site was ever recaptured out of its original sector of capture (~±1.5 km) during his five month study. Balazs (1980b) stated that "at all of the resident foraging areas thus far investigated, tagged Hawaiian *Chelonia* have been found to feed repeatedly at the same locations. This fixation has been documented on both a short-term basis (daily and weekly), and for longer periods ranging up to 37 months."

Several studies (Balazs, 1980; Ross, 1985; Read, 1991; Brand, 1995; C. J. Limpus, pers. comm.) have identified the presence of alternating monospecific food boluses along the digestive tract of dissected green turtles. These discrete masses of macerated food have been interpreted as representing several periods of foraging (Read, 1991; Brand, 1995; C.J. Limpus, pers. com). Read (1991) describes discrete alternating boluses of the seagrass *Halophilia ovalis* and the red alga *Hypnea cervicornis* along the digestive tract of a single animal. In his study area, *H. ovalis* was

restricted to the shallows and could be accessed by the turtles only at high tide. Read suggests that during low tide turtles may switch to *H. cervicornis* in deeper channels. C. J. Limpus (pers. comm.) has found a similar situation in Shoalwater Bay, Queensland where at high tide turtles feed upon mangrove fruits and leaves and during lower tides feed upon seagrasses. Ross (1985) also found alternating monospecific boluses in green turtles from Arabia but interpreted them as indicating periods of differential feeding irrespective of tidal sequence. However, he reported that turtles followed the rising tide to the intertidal zone where algae were more abundant than in subtidal areas. Balazs (1980b) speculates that the alternating bolus groups identified in Hawaiian turtles may be a behaviour that helps the turtles meet their requirements for essential nutrients by balancing their diet.

No study has documented the occurrence of any of the following: a social hierarchy in feeding, aggressive behaviour during feeding or territoriality in wild or semiwild populations. All assemblages of turtles on feeding grounds appear to be feeding aggregations or aggregations of internesting animals rather than social groupings (Bjorndal 1980; Mendonca, 1983; Ogden *et al.*, 1983, Lanyon *et al.*, 1989; Limpus *et al.*, 1992).

2.2.3 Nutritional Influence Upon Growth, Reproduction and Migration

While genetic variation will undoubtedly have an influence upon the differential growth rates seen among populations of green turtles, the environment will also have an influence within and among populations. Some of the fastest growth rates recorded for wild green turtles occur at Kau in the southern Hawaiian Islands. Some of the slowest growth rates are also found in Hawaii at French Frigate Shoals in the mid archipelago (Balazs, 1980b,1982). At least 90% of Hawaiian green turtles migrate to French Frigate Shoals to breed (Balazs, 1983a; Balazs *et al.*, 1987). There is no evidence to suggest

that migrants to French Frigate Shoals mate only with animals from their home feeding grounds and it is likely that Hawaiian green turtles comprise a panmictic population with gene flow between the different feeding grounds. If this is so, the significantly different growth rates of green turtles from various parts of Hawaii suggest that growth rate within a population is influenced more by environment than genetics. Balazs (1982) proposed that diet is the major determinant of the wide variation in growth rates within the archipelago. Support for his conclusion is provided by the rapid growth of a captive reared turtle released at French Frigate Shoals. This turtle resided on a reef outside a U.S. Coast Guard Station and Coast Guard personnel regularly fed fish scraps to the turtle (Balazs, 1982). The turtle grew at a rate of 8.52 cm/yr (SCL) over eight months, the fastest growth rate recorded for any Hawaiian green turtle living in the wild and far greater than that of the other green turtles at French Frigate Shoals (0.96 cm/yr SCL).

The nutrition of green turtles may also have a strong influence upon the number of eggs laid per clutch, the number of clutches per year and the interval period between breeding migrations (Carr and Carr ,1970; Bjorndal, 1980, 1982, 1985; Limpus and Nichols, 1988; Kwan, 1994). The energy required for reproduction is considerably higher for females than for males (Kwan, 1994). Both sexes migrate to the breeding and nesting grounds but the females must also catabolise energy stores for egg production, multiple nesting crawls and body and egg pit excavation. Males need energy only for migration and for maintenance during their short stay on the mating ground. This difference may be why female green turtles require at least two years between nesting migrations while males may migrate each year (Limpus *et al.*, 1984; Kwan, 1994). Support for this conclusion is provided by both wild and captive populations of green turtles. Breeding males remigrate to Heron Island each 1-2 years while females require 4-5 years (Limpus, 1993). Only 0.4% of female turtles at Tortuguero remigrate after one year (Carr *et al.* , 1978) and only 4.0% of females

nesting in Surinam remigrate after one year (Schulz, 1975). Nesting intervals of only one year were recorded for 70.4% of the green turtles held captive and fed high protein and energy diets at the Cayman Turtle Farm (Wood and Wood, 1980, 1981). Therefore, when energetic and nutrient limitations are removed, female green turtles have the physiological capability to nest each year. To date, there are no known green turtle populations with a mean or modal remigration of one year.

The energy required for the complete migration and nesting sequence has been estimated by Bjorndal (1982) for green turtles nesting at Tortuguero, Costa Rica. Taking into account migration distance and speed, mean number of clutches and eggs per clutch, nesting and internesting activity, Bjorndal determined that 30% (241,800 kJ) of the animal's energy budget for the year (805,800 kJ) is required for the complete reproductive effort. When this energy requirement is averaged over the mean remigration interval of three years, the percentage of the yearly energy budget devoted to reproduction is reduced to 10% or 5.7 kg of fat or 4.5% of the mean weight of a turtle nesting at Tortuguero. The amount of energy required for reproduction varies among feeding ground populations due to varying migration distances, the number of clutches laid, internesting periods, duration of the nesting activity, remigration intervals and other factors. Using data provided by Schulz (1975) for adult Surinam female green turtles, Bjorndal (1982) calculated that the percentage of the yearly energy budget devoted to reproduction was 24% in contrast to the 10% allocated by the Tortuguero turtles. The amount of fat required from departure to the return to the feeding grounds would be 16 kg of fat or 8.8% of the mean weight of a turtle nesting in Surinam. Green turtles in Surinam lay more eggs per season and also migrate a distance four times greater than Tortuguero turtles (Schulz, 1975; Carr *et al.*, 1978). Additionally, turtles in Surinam remigrate on average every two years rather than three years at Tortuguero (Schulz, 1975; Carr *et al.*, 1978). Bjorndal (1985) speculates that the ability of the Surinam

turtle to meet its higher reproductive energy demand (1,270,000 kJ/yr.) is facilitated by its diet of algae rather than the seagrass diet of the Tortuguero turtles. However, Bjorndal points out that growth rates for turtles feeding on seagrass and algae are similar and concludes that if some nutritional value is imparted by an algae diet, it must somehow affect reproductive effort and not growth. However, Bjorndal stated that growth rates for juvenile and subadult green turtles from Surinam are not available for direct comparison.

It would be maladaptive to migrate to the breeding and nesting grounds if the minimum amount of fat required to balance the energy requirement of reproduction has not been stored. Parmenter (1980) proposed that nesting females must represent the fittest animals (with suitable energy stores) from their respective populations and that the great fluctuations in nesting numbers from year to year may somehow be influenced by the overall fitness of the females from a given region. Parmenter stated that "...the most obvious criticism of such an energetic hypothesis is that any factor(s) affecting fat storage by females would have to be simultaneously operating over a huge area." Limpus and Nicholls (1988, 1994) found a strong positive correlation between the occurrence of the Southern Oscillation (SO) and the number of nesting turtles and courting males (Limpus, 1993) two years later. The SO is a periodic fluctuation in atmospheric pressure in the Indian and tropical Pacific Oceans which results in a coherent pattern of temperature, pressure and rainfall fluctuations throughout the region. The SO is related to and occurs in conjunction with the El Nino phenomenon which has a demonstrated effect upon marine and terrestrial communities (Rasmusson and Carpenter, 1982; Colgan, 1990; Hansen, 1990; Nicholls, 1991). Preparation for breeding in female green turtles requires at least one year for fat deposition (Kwan, 1994) and at least nine months for vitellogenesis (Limpus and Nicholls, 1988). Limpus and Nicholls (1988, 1994) point out that a significant change in the environment, such

as the El Nino Southern Oscillation (ENSO), may interfere with the nutritional regime required to deposit the required fat stores for reproduction. Although my study was not of sufficient duration to draw conclusions on the effects the ENSO, an objective of my study was to deterrnine if green turtles foraging on Heron Reef face barriers to growth and reproduction as a result of changes in forage quality and abundance such as those that may be produced by the ENSO.

It has been suggested that slow growth, delayed sexual maturity and long intervals between breeding migrations may be a characteristic of the Family Cheloniidae and not a consequence of the diet of the green turtle (Lanyon *et al.*, 1989). Although there is undoubtedly a genetic influence upon growth, there must also be a nutritional influence as demonstrated by the accelerated growth rates, the greatly reduced age at first breeding and the yearly nesting observed in captive turtles. A goal of this study was to atternpt to identify the dietary strategy by which green turtles foraging upon algae meet the challenges of a nutrient-limited life cycle.

2.3 Diet Selection

2.3.1 Diet Selection vs. Diet Preference

Diet selection and diet preference are terms that are frequently used synonymously in the nutrition literature. However, the two terms represent separate concepts. Diet selection is fundamentally a behavioural process that involves the interaction between a free ranging animal and its food source (Malechek and Balph, 1987). Diet selection may be defined as the animal's choice of food items from the options available (Lanyon, 1991). Diet preference represents the animal's choice of food when all possible options are presented in equal proportions (Johnson, 1980). Determining the dietary preferences of a wild animal requires that all possible diet items be available in equal quantities and be equally accessible in the environment. This is an almost impossible

situation in a natural system. Determining dietary selection is more readily accomplished but must involve both an analysis of the food consumed and of the food available in the habitat.

Food availability represents more than the presence of a diet item in the habitat. The food items must be accessible. Access to the food source by green turtles feeding at French Frigate Shoals in Hawaii is limited both spatially and temporally. Due to shallow water depth, the turtles are limited to feeding during high tide (Balazs, 1980b). Access to the food source is also spatially limited. Many of the recesses in the reef substrate are large enough to be accessed by the heads and beaks of juveniles but they exclude larger turtles (Balazs, 1980b). Therefore, young turtles were less affected by spatial and temporal limitations than were larger turtles. Including food items in selection indices that are temporally or spatially unavailable to a portion or all of the population may lead to erroneous conclusions. Since food selection indices are based upon the food items consumed as a function of the food items available in a defined area, the definition of this forage area and its component species is essential if accurate conclusions are to be drawn from the data. To achieve this goal in my study, the available forage species were quantified during each sampling occasion (Section 5.2).

2.3.2 Influences Upon Diet Selection

It has been shown that the diets of herbivores, as well as carnivores and omnivores, are the result of an interaction of anatomical, physiological, environmental and behavioural influences acting upon diet selection (Janzen, 1978; Malechek and Balph, 1987; van Marken Lichtenbelt, 1993; Belovsky and Schmitz, 1994; Focardi and Marcellini, 1995) Influences upon diet selection are discussed below with reference to green sea turtles.

2.3.2.1 Optimal Foraging Theory and Reinforcement

A fundamental assumption of all optimal foraging theories is that diet selection behavior can be predicted. Optimal foraging models vary from one another in the criterion or criteria that are considered to be of paramount importance in the animal's decision to include an item in its diet. Optimal foraging theory as originally proposed by MacArthur and Pianka (1966) and later modified by Schoener (1969) stated that an animal should optimise its energy return per unit of time spent searching for food.

Since the introduction of the original energy-based models, optimal foraging theory has experienced many revisions. Many new criteria have been proposed as the principal influence or influences acting upon diet selection decisions and therefore the attainment of an optimal diet. Owen-Smith and Novelli (1982) proposed that herbivores select their optimal diets as a function of protein levels while Horn *et al.*, (1986) have shown that temperate herbivorous fishes select optimal diets based upon either energy or protein as a function of season. Still other investigators (Westoby, 1974; Pulliam 1975; Milton, 1979; Pyke,1984; Dearing and Schall, 1992) have proposed that optimal diets are selected based upon a mixture of nutrients rather than energy or protein per se.

While not excluding the importance of nutrient and energy considerations in diet optimisation, it has been proposed that other criteria are of equal importance in the selection of an optimal diet. Demment and Van Soest (1985) have suggested that, amongst other considerations, the body mass of an herbivore may influence its optimal foraging strategy. Belovsky and Schmitz (1994) proposed that broad spectrum nutritional considerations are of the utmost importance in diet optimisation and that selection of a diet item based upon narrow nutritional benefits is of less relevance.

Still other investigators have focused upon broader physiological and ecological influences upon diet optimisation than had earlier models. Several authors (Stephens and Krebs, 1986; Focardi and Marcellini, 1995) have suggested that predictive models of optimal foraging in herbivores should consider both forage digestibility and biomass. Belovsky and Schmitz (1994) stated that diet optimisation is achieved, in part, by the avoidance of antiherbivore defenses, while Stamp (1992) suggests that optimal foraging models based upon antiherbivore defenses are not yet able to predict selection effectively. Malechek and Balph (1987) suggested that caring for young, migrations and other life cycle requirements may temporarily reduce an animal's ability to forage optimally. They proposed that it may be more appropriate to ask to what extent an animal optimises its diet in relation to its potential under specific conditions. Senft *et al.* (1987) recommend that optimal foraging models for large herbivores be based upon ecological hierarchies of the environment including landscape ecology. Senft *et al.* add that useful foraging theories must take into account variations in foraging behaviour with variations in ecological scale, e.g. patch *versus* community foraging.

It is apparent from the discussion above that there may be many cues or criteria by which herbivores select their optimal diet. However, a fundamental assumption in most optimal foraging models is that the animal has knowledge of the rewards or profitability associated with the selection of various dietary items or use of particular foraging areas. Studies have shown that this assumption may be unrealistic (Pyke, 1984; Abrahams, 1986; Rapport, 1991; Gray and Kennedy, 1994) and in the absence of some form of reinforcement, this knowledge may not be obtainable.

Behavioural reinforcement, when applied to foraging theory, predicts that an animal's future selection of a dietary item will be based, in part, upon positive and negative experiences with that item (Malechek and Balph, 1987). The consequences of

consuming a particular dietary item may be either immediate or delayed. Stimuli such as taste, odour, texture and difficulty of harvest provide immediate reinforcement while gastronomic distress would result in delayed reinforcement (Malechek and Balph, 1987). However, delayed reinforcement will only occur if the animal is able to associate the distress with a particular dietary item. This association, known as conditional food aversion, (Braveman and Bronstein, 1985) has been shown to occur in rats, sheep and cattle (Malechek and Balph, 1987).

A review of the literature indicates that optimal foraging theory is still evolving and that no single model will allow predictions across groups of animals or habitats and possibly not even within a particular species over time as suggested by models of optimal reaction norms (Stearns and Koella, 1986; Kawecki and Stearns, 1993). Models of optimal reaction norms suggest that fitness is influenced by all of the habitats occupied by a population and not just a single habitat. If optimal reaction norms are applied to optimal foraging models in highly migratory animals such as green turtles, the identification of an optimal foraging strategy becomes even more difficult.

The optimal foraging models that have been proposed to date have attempted to identify the variables that influence the selection of an optimal diet. Many of these models are limited in their ability to predict foraging behaviour across a range of animal species, habitats and seasons. While many of these models have been limited to nutritional or energetic criteria, other models have taken a more physiological or ecological approach in an attempt to predict foraging behaviour. It appears that many animals, including generalist herbivores such as the green turtle, respond to multiple criteria in the selection of their diet and that these criteria may be dynamic. One of the objectives of this study was to determine if the green turtles on Heron Reef exhibited

diet selection and if they did, attempt to identify the influences acting upon the selection of an optimal diet.

2.3.2.2 Diet Selection and Age

Although green turtles are herbivorous, small amounts of animal matter are known to occur in the diets of juvenile, subadult and adult turtles. A series of authors has proposed that this limited carnivory in green turtles is a function of age (Moorhouse, 1933; Hirth, 1971; Bjorndal, 1979a; Carr, 1980, Balazs, 1980b). Although it is commonly held that green turtles are almost obligate carnivores for their first several years (Moorhouse, 1933; Carr, 1980; Hirth, 1971, Balazs, 1980b; Lanyon *et al.*, 1989), the empirical evidence is absent. However, carnivory in green turtle hatchlings fits many models for growth in vertebrates, especially herbivores (Mattson, 1980). It is well known that vertebrates require high levels of nitrogen, protein and energy during their early development (Mattson, 1980). A carnivorous diet provides these requirements better than an herbivorous diet as the structural components of animal tissues are proteins whereas in plants they are carbohydrates (Mattson, 1980; Horn, 1989).

Herbivores in general (White, 1985) and fishes in particular (Bellwood, 1988; Horn, 1989) are known to pass through a carnivorous period before adopting their herbivorous diet. In order for nitrogen to be utilised most efficiently, it must be consumed in the appropriate ratio to energy (Mattson, 1980). A higher nitrogen content in a carnivorous diet is usually accompanied by a higher energy content and therefore nitrogen assimilation would be increased. The increased nitrogen assimilation and energy content from a carnivorous diet would facilitate a more rapid weight gain than would a strictly herbivorous diet. A carnivorous diet would therefore benefit pelagic-phase green turtles by allowing them to grow rapidly thereby decreasing their exposure to predation.

Carnivory in the pelagic-phase of green turtle development would also make sense in light of the scarcity of plant material in pelagic areas.

Carnivory may extend even into the juvenile age classes. Bjorndal (1979a) found that the 8 kg size class of green turtle consumed significantly more sponges (*Chondrilla nucula*) than did the 30 kg and larger size classes. She found that young turtles (~8 kg) feeding upon a diet of seagrass (*Thalassia testudinum*) experienced decreased apparent digestibility coefficients for organic matter, energy, hemicellulose and protein compared to larger turtles (≥30 kg) in the same population. Bjorndal (1980) speculated that the digestive system of the 8 kg age class turtle may not yet have attained the full adult level of digestive efficiency. If juveniles have a decreased digestive efficiency, it may be possible that in some habitats, younger turtles may be meeting their energy and nutritional requirements by consuming animal matter or dietary items that are more easily assimilated than those consumed by older animals. Ontogenetic changes in diet have also been identified in tropical and temperate reef fish species that are herbivorous as adults (Barton, 1982; Horn *et al.*, 1982, 1985). Some of these changes were associated with changing nitrogen requirements while others may reflect changes in the requirements of other nutrients (Fishelson *et al.*, 1987).

Although carnivory in young turtles has received limited attention, changes in diet selection by green turtles as a function of age have not been addressed for green turtles feeding amongst seagrasses and algae. An objective of this study was to investigate the possibility of diet selection as a function of age class.

2.3.2.3 Diet Selection and Nutritive Potential

Nutrients are commonly referred to as those substances in the diet which are necessary for the animal to support the functions of maintenance, growth, and reproduction

(Lassiter and Edwards, 1982; Van Soest, 1982). Nutrients include organic compounds, inorganic compounds, elements and water. Energy is not normally considered a nutrient but a metabolic product from organic nutrients.

A food item may contain high levels of nutrients and energy and still be of low or no nutritious or energetic value if it cannot be digested and assimilated properly. As digestive physiology varies between species, different animals may gain differential benefits from the same food item. Additionally, it has been demonstrated that dependent, nonadditive effects from a mixed diet may influence the digestibility of some or all of the components of the diet (Westoby, 1978; Rapport, 1980; Van Soest, 1982; Robins, 1983; Kukor *et al.*, 1988; Bjorndal, 1991). Due to this variability, the value of a dietary item to a particular animal is usually described in terms of its "nutritive value" to that animal. The nutritive value of a food is therefore a function of the availability of the nutrients and energy to the animal (van Soest, 1982). However, in the absence of empirical knowledge of the nutritive value of a food item to a given animal, it may be more appropriate to refer to the "nutritive potential" of that dietary item. An item with a high nutritive potential would therefore be expected to contain nutrients and energy that should be metabolically available based upon our existing knowledge of the animal's physiology and the properties of the nutrient.

Green turtles in the Caribbean are known to graze selectively upon young seagrasses as a result of the higher nutritive potential of young plants. Semi-wild (Bjorndal, 1979a, 1980) and wild turtles (Ogden, *et al.*, 1980) have been observed to maintain grazing plots of young seagrasses (*Thalassia testudinum*). Regrazing the same plot sustains the growth of young leaves and provides the turtle with a higher quality diet than a diet composed of mature leaves. Young leaves have 6-11% more nitrogen than older leaves from ungrazed plots (Bjorndal, 1979a, 1980). Lignin, which shows an inverse

relationship to digestibility, was reduced by 50% in grazed *versus* ungrazed plots (Bjorndal, 1979a, 1980).

Grazing plots were not observed in beds of *Thalassia testudinum* in the U.S. Virgin Islands even though juvenile green turtles were known to feed within these beds (Ogden *et al.*, 1983). Ogden *et al.* (1983) speculate that the absence of grazing plots may be an artefact of the small turtles (~6.5-8.5 kg) in their study area and that grazing plots may only be established by larger or older animals. Mortimer (1981,1982) found that green turtles feeding amongst seagrass beds (*Thalassia testudinum*) along the Nicaraguan coast may not maintain grazing plots but selectively feed upon the blade bases of *Thalassia testudinum* where there are few epibionts and nitrogen levels are high and lignin levels are low. C. J. Limpus (pers. comm.) also found that turtles feeding in seagrass beds in northern and eastern Australia are cropping the younger blades of several seagrass species. The maintenance of grazing plots or selective feeding upon various regions of a plant has not been identified in green turtles feeding in algal communities. It was an objective of this study to determine if such behaviours were present in green turtles on Heron Reef.

Although considered strict herbivores, postpelagic green turtles are known to consume limited amounts of animal material in their diet (Tables 2.2 &2.3). Although some animal material may be consumed accidentally while foraging on benthic plants, animals such as the hydrozoan *Physalia* , which is found at the top of the water column, are consumed intentionally. Like green turtles, dugongs (*Dugong dugon*) (Anderson, 1989; Preen, 1995) and manatees (*Trichechus manatus*) (Powell, 1978; O'Shea *et al.*, 1991) will also supplement their almost exclusive herbivorous diet with animal matter. Lanyon (1991) suggested that dugongs may have difficulty meeting their nitrogen requirement at certain times of the year due to decreases in the nitrogen

content of the seagrasses. Preen (1995) proposed that dugongs supplement their diet with animal matter in order to compensate for the low nitrogen content of their diet at these times. It was an objective of this study to determine if green turtles feeding on Heron Reef were consuming animal matter and if so, to determine if the consumption of animal matter was seasonal and whether it provided a significant source of nitrogen.

2.3.2.4 Diet Selectivity and Reproductive Status

Authors have speculated that during the round-trip migration to the breeding and nesting grounds or upon their arrival, green turtles either do not feed or significantly reduce their intake (Carr and Goodman, 1970; Carr and Carr, 1970; Hirth, 1971; Bjorndal, 1982; Kwan, 1994). Mortimer (1981, 1982) found that green turtles migrating along the east coast of Nicaragua to their nesting grounds had consumed red algae and seagrasses along with terrestrial debris that had been deposited offshore by river effluents. Nesting turtles at Tortuguero, Coast Rica are also known to feed upon the debris of water hyacinth and other flotsam deposited at the mouth of the Tortuguero River (Mortimer, 1982). There are anecdotal accounts from Panamanian fishermen of green turtles stopping and feeding for 2-3 days before resuming their migration to Tortuguero (Meylan, 1982). Balazs (1980b) stated that stomach samples taken from males and females on the breeding grounds in Hawaii show evidence of feeding during the breeding season but Balazs does not indicate if the animals sampled were actively breeding or nesting.

If female turtles do feed during their migration or while at the breeding and nesting grounds, the rate and volume of feeding may not be adequate enough to meet their metabolic requirements. In his study of loggerhead turtles (*Caretta caretta*), Limpus (1996) found that the length of the breeding migration was inversely related to egg production suggesting that energy and nutrients are being diverted from egg production

to body maintenance. An objective of this study was to determine if nesting turtles continued to feed while adjacent to the nesting beaches.

2.3.2.5 Diet Selectivity and Availability

It has been suggested that all seagrass consumers are capable of gaining nutrition from a diet of algae (Bjorndal, 1980). Some seagrass herbivores such as green turtles (Mortimer, 1982), dugongs (Heinsohn and Birch, 1972; Lipkin, 1975; Wake, 1975; Marsh *et al.*, 1982; Lanyon *et al.* 1989), urchins and herbivorous fishes (Ogden, 1976) appear to feed selectively upon algae and seagrasses based upon availability and/or preference (Ogden, 1976; Garnett *et al.*, 1985; Horn, 1989). There has been debate as to whether or not the green turtle demonstrates preference for seagrasses in lieu of algae (Bjorndal, 1979a, 1980; Mortimer, 1981,1982; Mendonca, 1983; Garnett *et al.*, 1985). Immature green turtles foraging in mixed seagrass/algal beds in Moreton Bay (Read, 1991; Brand, 1995) and the Torres Strait (Garnett *et al.*, 1985), Queensland and in the Masirah Channel near Oman (Ross, 1985) were found to feed extensively on both seagrasses and algae. These findings demonstrate that green turtles are quite capable of feeding upon a mixed diet of algae and seagrasses and that when both are available, selection of one to the exclusion of the other does not take place. However, to date, no study has adequately addressed the degree to which green turtles select between seagrasses and algae when both are readily available. Although a similar preference for seagrasses is shown by dugongs (Heinsohn and Birch, 1972; Lipkin, 1975; Marsh *et al.*, 1982; Erftemeijer *et al.*, 1993; Preen, 1995), this preference is most likely a function of the dugong's anatomical specialisation for a seagrass diet (Lanyon, 1991).

Mortimer (1981) found that the diet selection of green turtles in Nicaragua was modified according to the composition of the forage. Garnett *et al.* (1985) supported Mortimer's

findings and suggested that the diet of a turtle is determined by the food available at its site of residence rather than the food governing its residence site. In contrast, green turtles in Oman select one species of the brown alga *Sargassum* while completely avoiding two other species of *Sargassum* which were equally abundant and accessible (Ross, 1985).

As there are no detailed studies to date examining the relationship between forage availability and diet in a complex habitat, an objective of this study was to determine if diet selection in Heron Reef turtles was a function of availability of the forage species or whether other influences on selection were operating.

2.3.2.6 Diet Selectivity and Gender

Mortimer (1981) found no significant gender differences in the diets of subadult and adult Nicaraguan green turtles. These findings are supported by work from Torres Strait (Garnett *et al.*, 1985). The only account which claims a gender-based difference is Read (1991). His conclusion is questionable as it is based on only one of more than a dozen diet items. Since this diet component comprised only 1.1% of the mean relative volume of all of the stomach samples combined, its value as an indicator of preference is in question. The existence of gender-based diet selection was investigated during this study.

2.3.2.7 Diet Selection and Season

Only three studies published to date (Bjorndal, 1979a,1980; Mendonca, 1983; Garnett *et al.*, 1985) have traced the diet of the green sea turtle through at least two complete seasons. Bjorndal (1979a,1980) studied the diet of immature turtles feeding in stands of *Thalassia testudinum* in the Bahamas for over a year. She did not find any evidence of significant seasonal change in the diet of her turtles (Bjorndal, pers.

comm.). Garnett *et al.* (1985) examined the diet of Torres Strait subadult and adult turtles by examining the stomach contents of animals harvested by islanders from a variety of habitats. The study was limited by a single sample per animal, a large geographical sampling area and a small sample size. None the less, Garnett *et al.* found no evidence of a change in diet as a function of season. Mendonca (1983) studied the diet of immature turtles in a Florida seagrass community for one year and found no change in diet as a result of season. Each of these studies was limited by a small sample size and only Bjorndal (1979a,1980) was able to obtain multiple samples from the same animal over time. To date, no study has included a large sample size over an extended period of time and no study has been made of turtles limited to an algae diet. Therefore, an objective of this study was to determine if the overall (pooled) and individual diets of green turtles on Heron Reef changed as a function of season.

2.3.2.8 Diet Selection and Secondary Compounds

Herbivory is known to be a significant influence upon the dynamics and structure of both terrestrial and marine plant communities (Ogden and Lobel, 1978; Hay 1981a, b, 1991; Crawley, 1983; Hay and Fenical, 1988; Choat, 1991). Herbivory on coral reefs is more intense and has a greater influence upon benthic flora than in any other marine habitat (Hay *et al.*, 1987; Hay, 1991). Coral reef grazers are known to remove as much as 50-100% of the total reef plant production (Hatcher and Larkum, 1983; Carpenter, 1986, 1988; Russ, 1987; Klump and Polunin, 1989; Hay, 1991). As a response to grazing pressure, both terrestrial and marine plants have evolved structural and chemical defenses against herbivores. Secondary compounds (secondary metabolites, phytotoxins) represent what is believed to be the plant's attempt at chemical defence against herbivory. The secondary compounds produced in plants include terpenes, aromatic compounds, acetogenins, amino acid-derived compounds, and polyphenolics (Hay and Fenical, 1988; Hay, 1991). Marine algae differ from terrestrial plants in that

only algae incorporate halogens into their secondary compounds and only terrestrial plants (primarily legumes) produce nitrogen containing alkaloids (Hay and Fenical, 1988; Hay, 1991). The Cyanobacteria produce metabolites with halogen substitutes and unlike the algae, produce nitrogen compounds in amide or indole constellations (Hay and Fenical, 1988; Hay 1991).

The influence of secondary compounds upon diet selection has been examined extensively in a variety of organisms including herbivorous fishes (Steinberg, 1986; Targett *et al.*, 1986; Hay *et al.*, 1987; Hay and Fenical, 1988; Steinberg and Paul, 1990; Hay, 1991), the hoatzin (Grajal *et al.*, 1989), reptiles (Schall and Ressel, 1991), gastropods (Steinberg, 1985), arboreal herbivorous vertebrates (Janzen, 1978), including mammals (Meyer and Karasov, 1989), insects (Raubenheimer, 1992) and a variety of other marine herbivores (Hatcher, 1981; Hay *et al.*, 1987; Hay and Fenical,1988). A general overview of the influence of secondary metabolites upon herbivores is provided by Barry and Blaney (1987). Hay and Fenical (1988), Duffy and Hay (1990) and Hay (1991) provide a review of marine herbivore and secondary compound interactions and discuss the difficulties of the application of these findings across taxonomic groups. These reviews demonstrate that compounds that act as effective grazing deterrents against one herbivore species may have little or no effect upon another species.

Although the interaction between secondary compounds and diet has been investigated in many vertebrate and invertebrate groups, similar work has not been carried out on green turtles. The green turtle consumes sponges (*Chondrilla nucula*) (Bjorndal, 1979a) known to be toxic to fishes (Green, 1977) and algal species known to contain secondary compounds (Balazs, 1980b; Ross, 1985). The green alga *Caulerpa* is commonly consumed by green turtles although it is known to contain an impressive

compliment of secondary compounds in the forms of caulerpin, caulerpicin and linear terpenoids (Blackman and Wells, 1978; Paul and Fenical, 1982; Capon *et al.*, 1983; Paul, 1985). The brown alga *Sargassum* is also consumed (Ross, 1985) although it contains acetogenins, terpenes, terpene-aromatics and phlorotannins[7] (Hay and Fenical, 1988). The red alga *Laurencia* is also consumed by green turtles although it contains complex acetogenins and over 400 different terpenoid compounds of at least 26 distinct structural classes (Hay and Fenical, 1988). One of these terpenoids, the sesquiterpenoid elatol, is known to be cytotoxic, ichthyotoxic, insecticidal and to deter feeding by reef fishes (Hay and Fenical, 1988).

Over 500-600 different secondary compounds have been identified from the three divisions of marine algae and the cyanobacteria (Hay and Fenical, 1988) and over 600-800 papers dealing with secondary compounds have been published (Hay and Fenical, 1988). However, Hay *et al.* (1987, 1988) found that the general structure of these compounds and their pharmacological assays were not useful predictors of antiherbivore properties.

As discussed above with reference to the diet of the green turtle, certain animals are able to consume items known to be toxic to other species (Hay and Fenical, 1988; Duffy and Hay,1990; Hay, 1991). In light of this paradox and in the absence of species specific toxicity studies, the mere presence of secondary metabolites may not indicate toxicity and care should be exercised in evaluating the significance of secondary compounds in a food item which is uncommon or absent from the diet. A goal of this

[7]Phlorotannins are polyphenolics believed to function like the true tannins from terrestrial plants although they are structurally distinct from the true tannins in that they are derived from the C_6 precursor, phloroglucinol (Ragan and Flombitza, 1986; Hay and Fenical, 1988)

study was to determine if those algal species known from the literature to contain rich metabolite profiles were avoided or selected by green turtles on Heron Reef.

2.4 Study Justification

The review of the literature presented above indicates that to date, no study has focused upon the feeding ecology of green turtles in an algal community. Also, no investigation has examined the diet of green turtles feeding in a complex habitat over an extended period of time while simultaneously quantifying the nutrient and energy content and availability of the forage. There are also no studies that have addressed the feeding ecology of green turtles in a habitat that contains turtles from all post-pelagic age classes and both resident and migratory animals. In the absence of such studies, the degree to which green turtles select their diet and the factors influencing these optimal diet decisions remains unclear as do the consequences of these decisions upon the life history of the green turtle. This study is the first to address these questions by describing the diet of juvenile, subadult and adult green turtles feeding in an algal-based community and attempting to identify criteria by which optimal dietary decisions are made across the age classes and sexes.

Table 2.1- Selected references to comprehensive literature reviews of selected topics pertaining to green sea turtles.

Topic	Reference
History of the systematics of the genus *Chelonia*	Groombridge and Luxmoore, 1989
Pelagic sightings of young green turtles	Carr, 1986, 1987
History of sytematics of the genus *Natator* and *Chelonia depressa(us)*	Limpus *et al.* , 1988 Zangerl *et al.* , 1988
Distribution records of sea turtles in the North Atlantic	Brongersma, 1972
Nesting migrations	Meylan, 1982
Nesting seasons	Schulz, 1975
Courtship behaviour	Ehrhart, 1985
Clutch sizes	Hirth, 1971, 1980; Ehrhart, 1982
Clutch numbers	Hirth, 1980
Nesting cycles and remigration intervals	Hirth, 1971, 1980
Reproductive biology of sea turtles	Hirth, 1971, 1980; Ehrhart, 1982
Carapace lengths of nesting green turtles	Hirth, 1980; Frazier, 1971
Methods for sea turtle growth rate studies and interpretation	Bjorndal and Bolten,1988
Estimated ages at first breeding	Mortimer, 1984
Growth rates of wild green turtles	Boulon and Frazer, 1990

Table 2.2-Published accounts of the diet of postpelagic phase green sea turtles.

Region	Location	Sample Size & Age Class[1]	Principal Diet	Major Component(s) of Principal Diet	Diet Breadth and Notes	Method of Analysis	References
Caribbean	Great Inagua, Bahamas	12 8kg,30kg 48kg,66kg	Seagrass	Seagrass-*Thalassia testudinum*	Seagrass-*Thalassia testudinum* Invertebrates-Porifera	Observation, Faecal analysis	Bjorndal (1979a, 1980)
	Gulf of Fonseca, Honduras	4 NS	Algae & seagrass	Algae Seagrass-*Zostera sp.*	Algae-Taxa unspecified Seagrass-*Zostera sp.* Invertebrates-Porifera	Necropsy	Carr (1952)
	Nicaragua	2 50kg,82kg	Seagrass	Seagrass-*Thalassia testudinum*	Seagrass-*Thalassia testudinum*	Necropsy	Bjorndal (1979b) Thayer *et al* . (1982)
	Nicaragua	243 50kg,82kg	Seagrass	Seagrass-*Thalassia testudinum*	Algae-Chlorophyta, Phaeophyta, Rhodophyta Seagrass-*Halodule wrightii, Halophila baillonis, Syringodium filiforme, Thalassia testudinum* Invertebrates-Anthozoa, Hydrozoa, Porifera Chordata-Urochordata	Necropsy	Mortimer (1976, 1981)
	Tortuguero, Costa Rica	11 A	Terrestrial & freshwater plants via fluvio-deposition	Terrestrial and freshwater plants	Algae-Phaeophyta Seagrass-*Syringodium sp.,Thalassia sp.* Invertebrates-Bivalvia, Crustacea, Porifera, polychaete tubes, Terrestrial and freshwater plants (consumed as floatsam and not as anchored plants)	Necropsy	Meylan (1978)
	St. Croix, U.S. Virgin Islands	1 J	Seagrass	Seagrass-*Thalassia testudinum*	Seagrass-*Thalassia testudinum*	Faecal analysis	Ogden *et al* . (1983)
	St. John, U.S. Virgin Islands	Not Stated SA	Seagrass	Seagrass-*Thalassia testudinum*	Algae; Seagrass-*Halodule wrightii, Syringodium filiforme, Thalassia testudinum*	Observation	Williams (1988)
	Virgin Islands	35 I	Seagrass	Not Stated	Seagrass	Unknown	Boulon (1983)

Table 2.2 (cont.)

Region	Location	Sample Size	Principal Diet	Major Component(s) of Principal Diet	Diet Breadth and Notes	Method of Analysis	References
Gulf of California (Sea of Cortez)	Sonora, Mexico	Not Stated NS	Insufficient Data	Seagrass	Seagrass-*Zostera marina*	Necropsy	Felger & Moser (1973)
Indian Ocean	Aldabra Atoll, Seychelles	6 4A,2SA	Seagrass	Seagrass-*Cymodocea sp.*	Algae-Chlorophyta, Rhodophyta Seagrass-*Cymodocea sp., Thalassia sp.*	Necropsy	Frazier (1971)
	Masirah Channel, Oman	9 NS	Algae & seagrass	Algae-Chlorophyta, Phaeophyta Seagrass-*Halophila ovalis, Halodule uninervis*	Algae-Chlorophyta, Phaeophyta, Rhodophyta Seagrass-*Halophila ovalis, Halodule uninervis*	Necropsy	Ross (1985)
	Yemen, Gulf of Aden	5 A	Seagrass	Seagrass-*Cymodocea sp., Syringodium sp.*	Seagrass-*Cymodocea sp., Syringodium sp.* (The inference is made that *C. sp.* is *C. serrulata* and *S. sp.* is *S. isoetifolium*)	Necropsy	Hirth *et al* . (1973)
North Atlantic	Mosquito Lagoon, Florida, USA	18 I	Seagrass	Seagrass-*Syringodium filiforme, Halophila engelmanni*	Algae-Chlorophyta, Rhodophyta Seagrass-*Halodule wrightii* , *Halophila engelmanni, Syringodium filiforme*	Necropsy (n=12), lavage (n=6)	Mendonca (1983)
	Broward County, Florida, USA	18 J	Algae	Algae-Rhodophyta	Algae-Rhodophyta Seagrass-*Halodule wrightii, Syringodium filiforme, Thalassia testudinum*	Necropsy	Wershoven and Wershoven (1989, 1991, 1992)
South Atlantic	Ceara, Brazil	94 J,SA,A	Algae	Algae-Chlorophyta, Rhodophyta	Algae-Chlorophyta, Phaeophyta, Rhodophyta Seagrass-*Halodule wrightii* Invertebrates-Bryozoa, Crustacea, Echinodermata, Mollusca, Porifera Chordata-Urochordata	Necropsy	Ferreira (1968)

Table 2.2 (cont.)

Region	Location	Sample Size	Principal Diet	Major Component(s) of Principal Diet	Diet Breadth and Notes	Method of Analysis	References
North Pacific	Hawaii, USA	Not Stated J,SA,A	Algae	Algae-Chlorophyta, Phaeophyta, Rhodophyta	Algae-Chlorophyta, Phaeophyta, Rhodophyta Seagrass-*Halophila hawaiiana* Invertebrates-Anthozoa, Echinoidea, Hydrozoa Monera-*Lyngbya majuscula, Microcoleus lyngbyaceus, Oscillatoria sp.*	Lavage, necropsy	Balazs (1980b,1982, 1983b, 1985d); Balazs *et al* . (1987); Forsyth and Balazs (1989); Balazs, *et al* . (1994)
	Oahu Island, Hawaii, USA	Not Stated NS	Algae	Algae-Chlorophyta, Rhodophyta	Algae-Chlorophyta, Rhodophyta	Faecal analysis	Balazs *et al* . (1990)
	Ogasawara Is., Japan	5 J,A	Algae	Algae	Algae-Taxa unspecified	Necropsy	Bjorndal *et al* . (1991)
	Ogasawara Is., Japan	4 J,A	Algae	Algae-Phaeophyta	Algae-Chlorophyta, Phaeophyta, Rhodophyta Invertebrates-Hydrozoa	Necropsy	Kurata *et al* . (1978)
	Yellow, E. China, & Fujian Seas, China	Not Stated NS	Insufficient data	Algae, invertebrates, fish	No identification of diet species is provided.	Not stated	Chu-Chein (1982)
Southern Pacific	Fairfax Island, Queensland, Australia	2 H	Invertebrates	Insufficient data	Invertebrates-Ctenophora, Hydrozoa, Anthozoa Chordata-Urochordata	Observation. Data from neonates tethered while feeding	Booth & Peters (1972)
	Galapagos, Equador	>23 NS	Insufficient Data. Algae is most probable	Algae	Algae-Taxa unspecified Mangrove-(The inference is made that the mangrove is *Rhizophora sp.*)	Necropsy (n=23), observ. (n= "many")	Fritts (1981)
	Galapagos, Equador	NS NS	Algae	Algae	Algae >30 spp.	Not stated	Green (1994)

Table 2.2 (cont.)

Region	Location	Sample Size	Principal Diet	Major Component(s) of Principal Diet	Diet Breadth and Notes	Method of Analysis	References
Southern Pacific (cont.)	Gulf of Carpen-, taria, N. Territory, Australia	2 A	Seagrass	Seagrass-*Halodule pinifolia*	Seagrass-*Halodule pinifolia, Halodule uninervis, Halophila spinulosa*	Necropsy (n=5), faecal analysis (n>30)	Limpus & Reed (1985b)
	Heron Island, Queensland, Australia	507 J,SA,A	Algae	Algae-Rhodophyta, Chlorophyta	Algae-Rhodophyta, Chlorophyta, Phaeophyta	Lavage	Forbes (1994 & This Study)
	Heron Island, Queensland, Australia	Not Stated NS	Algae	Insufficient data	Algae-Chlorophyta, Phaeophyta, Rhodophyta	Mouth sample	Limpus & Reed (1985a)
	Moreton Bay, Queensland, Australia	269 I	Algae & seagrass	Algae-Rhodophyta Seagrass-*Halophila ovalis*	Algae-Chlorophyta, Phaeophyta, Rhodophyta Seagrass-*Halophila ovalis, Halophila spinulosa, Halodule uninervis, Syringodium isoetifolium, Zostera capricorni* Invertebrates-Anthozoa, Scyphozoa Mangrove-*Avicennia marina*	Lavage	Read (1991)
		20 J	Algae & seagrass	Algae-Rhodophyta Seagrass-*Halophila ovalis*	Algae-Rhodophyta Seagrass-*Halophila ovalis, Halodule uninervis, Syringodium isoetifolium, Zostera capricorni* Invertebrates-Trace fragments	Lavage	Brand (1995)
	Pisco, Peru	39 J,SA,A	Insufficient data	Algae, Invertebrates, Fish Eggs	Algae-Phaeophyta, Rhodophyta Invertebrates-Crustacea, Mollusca, Polychaeta, Scyphozoa Chordata-Osteichthyes eggs	Necropsy	Brown & Brown (1982)
	Peru	20 NS	Insufficient data	Algae, invertebrates, Fish	Algae-Taxa unspecified Invertebrates-Scyphozoa, Mollusca Chordata-Osteichthyes	Necropsy	Paredes (1969) cited in Brown & Brown (1982)

Table 2.2 (cont.)

Region	Location	Sample Size	Principal Diet	Major Component(s) of Principal Diet	Diet Breadth and Notes	Method of Analysis	References
	Torres Strait, Queensland, Australia	44 SA,A	Algae	Algae-Rhodophyta	Algae-Chlorophyta, Phaeophyta, Rhodophyta Seagrass-*Cymdocea sp., Halophila spinulosa, Thalassia hemprichii* Invertebrates-Bryozoa, Cnidaria, Echinodermata, Mollusca, Porifera Monera-*Lyngbya sp.* Chordata-Urochordata	Necropsy	Garnett *et al* . (1985)

[1] As there were no standardized criteria for determining age class between the studies cited and in some cases, no criteria were stated, the age class or size category used in the original work has been repeated in this table as follows: H=Hatchling, J=Juvenile, SA=Subadult, A=Adult, NS=Not Stated, I=Immature, **kg size class.

Table 2.3-Historical accounts of diets of postpelagic phase green turtles as cited by Hirth (1971) and Frazier (1971). Note: The accounts cited below include references to anecdotal accounts, third party accounts, speculative accounts, unpublished manuscripts and obscure literature that I could not verify. Age class information was not provided by Hirth or Frazier.

Region	Location	Diet	Reference	Cited In
Caribbean Sea	Bermuda	Seagrass	Babcock (1937)	Hirth
	Jamaica	Seagrass-*Thalassia sp.* ; Inverts-Crustacea, Mollusca	Underwood (1951)	Hirth
	Nicaragua	Seagrass-*Cymdocea sp.* , *Thalassia sp.*	Carr (1954)	Hirth
Gulf of Mexico	Mexico	Seagrass-*Cymdocea sp.* , *Thalassia sp.*	Mexico (1966)	Hirth
Indian Ocean	Ceylon (Sri Lanka)	Seagrass-*Cymodocea sp.* , *Halophila sp., Thalassia sp, Zostera sp.*	Deraniyagala (1939, 1953)	Hirth, Frazier
	Gulf of Aden	Algae-Phaeophyta, Rhodophyta; Seagrass-*Posidonia sp.* or *Enhalus sp.*	Hirth & Carr (1970)	Hirth
	Krudadai Is.	Algae-Phaeophyta, Rhodophyta; Seagrass-*Cymodocea sp.*	Kuriyan (1950)	Hirth
	Rep. of Seychelles	Algae-Phaeophyta; Seagrass-*Cymodocea sp.*	Hornell (1927)	Hirth, Frazier
	Rep. of Seychelles	Seagrass-*Cymodocea sp.*	Veevers-Carter (1962)	Frazier
North Atlantic Ocean	E. Seaboard, U.S.A.	Algae; Seagrass-*Thalassia sp.* , *Zostera sp.* ; Inverts-Crustacea, Mollusca, Scyphozoa	Carr(1952)	Frazier
	Florida, U.S.A.	Seagrass-*Cymodocea sp.* , *Thalassia sp.*	Carr & Caldwell (1956)	Hirth, Frazier
	Florida, U.S.A.	*Sagittaria, Vallisneria*	Neil (1958)	Hirth
North Pacific Ocean	Fiji	Algae-Chlorophyta, Rhodophyta; Seagrass-*Syringodium sp.*	Hirth (unpub. manu.)	Hirth
	Hawaii, U.S.A.	Algae-Chlorophyta	Hirth (unpub. manu.)	Hirth

Table 2.3 (cont.)

Region	Location	Diet Breadth	Reference	Cited In
	Mexico	Algae-Chlorophyta, Phaeophyta, Rhodophyta; Seagrass- *Cymodocea sp., Thalassia sp.*	Anonymous (1966*), Carr (1966), Marquez (pers. comm.)	Hirth
North Pacific Ocean (cont.)	Sulu Sea, Philippines	Algae-Chlorophyta, Phaeophyta	Domantay (1953)	Hirth
	Tonga	Seagrass-*Halodule sp.* , *Halophila sp.* , *Syringodium sp.*	Hirth (unpub. manu)	Hirth
South Pacific Ocean	Chile	Algae; Seagrass, Inverts-Porifera	Yanez (1951) Donoso-Barros (1966)	Hirth
	Galapagos	Algae-Chlorophyta; Mangrove (roots and shoots)	Pritchard (unpub. manu.) (Probably; Pritchard, 1971)	Hirth
	Kermadec Is., New Zealand	Algae-Rhodophyta	Oliver (1910)	Hirth
	Queensland, Australia	Seagrass	Yonge (1930)	Hirth
Unspecified		Seagrass-*Thalassia sp.* , *Zostera sp.*	Pritchard (1967)	Frazier
		Seagrass-*Enhalus sp.* , *Thalassia sp.* , *Zostera sp.*	Parsons (1962)	Frazier

*No citation is provided by Hirth for this reference.

Chapter 3

Study Site, Materials and Methods (General)

3.1 Choice of Study Area

In the evaluation of potential study sites for use during this investigation, I considered the following criteria essential for the successful completion of the study: 1) a venue which is logistically feasible; 2) a turtle population with mixed age classes and sexes; 3) water clarity and depth suitable for sighting and capturing turtles; 4) a turtle population with reproductively active individuals; 5) a population of turtles large enough to provide a large sample size while at the same time providing the opportunity for recaptures.

In addition to Heron Island and the surrounding reef meeting all the above requirements, the turtles feeding and nesting in this area have been the focus of a comprehensive, long term study under the direction of Dr. Colin Limpus of the Queensland National Parks and Wildlife Service (Dept. of Environment and Heritage) since 1974. During his study, Dr. Limpus has developed a detailed data base relating to the distribution, growth and reproductive history of a large number of individual turtles on Heron Reef. Dr. Limpus invited me to join his project and offered me access to his data base, the turtles captured by his team and his wealth of experience in capturing turtles. Furthermore, Dr. Limpus provided me the opportunity to use my own team to capture turtles from Heron Reef when he and his personnel were not present. The ability to access Dr. Limpus' data base and the experience of Dr. Limpus and his team and their offer to join their project were significant in my decision to utilise this site.

3.2 Description of Study Area

3.2.1 Physical Factors

Heron Island is one of 15 coral cays situated atop the 20 coral reefs which comprise the Capricorn-Bunker Group within the Capricornia Section of the southern Great Barrier Reef, Queensland, Australia (23° 26' S, 151° 55' E) (Fig. 3.1). Heron Island is situated approximately 80 km northeast of Gladstone, Queensland.

Heron Island Reef is an elongate lagoonal platform reef approximately 26 km in circumference (Limpus and Reed, 1985a). It is 11 km long and 5 km wide at its greatest breadth (Flood, 1984). The reef extends over 27 km^2 (Heatwole, 1984) and is dominated by a large deep lagoon in the eastern half of the reef (Fig 3.2). Heron Island, a coral sand cay, occupies the leeward western end of the reef. The island is approximately 830 m long by 300 m and at its highest point, rises 4.5 m above mean sea level. The cay is covered by a dense forest of pisonia trees (*Pisonia grandis*). The island is bordered by a sand bottomed moat which is, on average, 1m below the level of the adjacent reef (Flood, 1984). A detailed description of the island and its vegetation is provided by Jell and Flood (1978), Flood (1984), and Ward and Saeger (1984).

Prevailing currents strike the reef from the east-southeast with ocean swells of 1-3 m amplitude. Waves in excess of 2 m may break on the reef rim and refract around the reef (Flood, 1984). The tidal range is approximately 1m during neap tides and up to 2.5 m during spring tides. Spring ebb tides will fall below the level of the platform reef leaving over one meter of the reef rim exposed. Water cascades from the rim back into the open ocean effectively preventing the movement of large animals (fishes, turtles and sharks) across this barrier.

Mean water temperatures range from 26-27° C in the summer (January) down to 20-21° C in the winter (July) (Flood, 1984) with corresponding mean daytime air temperatures of 29.6° C and 21.2° C, respectively (Anonymous, 1988). Storms with associated high winds and rain may occur at any time of the year although most occur during the cyclone season (Jan-March).

3.2.2 Reef Zones

For this study, Heron Reef was divided into five component habitats following a modification of the general scheme proposed by Flood (1984) and Cribb (1984, 1985) which is based upon substrate, coral and algal composition and depth of submersion (Fig. 3.2).

3.2.2.1 Reef Slope

The entire reef platform is bordered by a steep slope that extends down to the reef base at approximately 30 m. As the reef slope terminates at the reef base, the sand covered bottom slopes down to the continental shelf at 100 m (Grimes *et al.*, 1984). The upper 15 m of the slope is covered by dense growths of coral which on the southern side of the reef is permeated by a well-developed spur and groove formation. The high energy swells moving across the southern reef slope and constant grazing pressure by fishes, combined with other factors, limit the predominant algal growth to calcified forms such as *Halimeda spp.* and encrusting coralline red algae although some fleshy forms such as the chlorophyte *Chlorodesmis* and the rhodophyte *Laurencia* are present. The calmer northern reef slope supports localised areas of fleshy algal species such as *Laurencia* , *Hypnea* and *Codium* .

3.2.2.2 Rubble (Reef) Crest

The apex of the reef slope terminates with the rubble crest (reef rim). This is the highest area of the reef and extends around the entire reef platform with the exception of the harbour entrance and in limited sections of the northeastern corner. The rubble crest is composed of coral rubble that is frequently cemented together by coralline algae that incorporate sand and foraminiferans into the matrix (Flood, 1984). Several areas of the rubble crest possess large reef blocks greater than 1 m in height and width. These large reef blocks sit atop the ridge of the rubble crest and are clearly visible during any low tide.

Abrasion by sand, hydraulic compression by storm waves and heavy grazing pressure by fishes frequently limit the growth of algae to stunted, prostrate or encrusting coralline forms in this area. The calcareous rhodophyte, *Yamadaella cenomyce* , is a good indicator species for this habitat as it is limited almost entirely to the rubble crest (Cribb, 1984, 1985). Together, the reef slope and rubble crest occupy approximately 5.49 km^2 of reef habitat (Limpus and Reed, 1985a).

3.2.2.3 Reef Flat

The reef flat is that portion of the reef that extends from the rubble crest sloping reefward towards the central lagoon. The reef flat is characterised by extensive growths of coral and fleshy algae. Coral genera such as *Acropora, Favia, Favites*, and *Goniopora* are quite common. Among the many algal genera represented in this habitat are *Laurencia, Lobophora, Sargassum, Halimeda, Padina, Chlorodesmis* and *Turbinaria*. The algal turf assemblage is well represented in this habitat.

The dense and well developed growths of coral on the outer reef flat (bordering the rubble crest) are exposed during spring ebb tides. This periodic emergence produces

an almost table-top like surface to the coral which is transversed by sand-bottomed channels which run perpendicular to the rubble crest. The inner reef flat (bordering the lagoon sand) is characterised by sporadic growths of coral including microatolls of *Acropora* and *Porites*. Dead coral in this area is heavily laden with growths of macroscopic algae.

3.2.2.4 Lagoon Sand

This habitat is restricted to the southern half of the reef where it separates the reef flat habitat from the lagoon patch habitat. Corals do not grow in this habitat as the sand substrate is unstable and shifting. This shifting of sand occasionally exposes the underlying Pliocene sand pavement. Algal growth is ephemeral and normally limited to filamentous species such as *Enteromorpha* , *Polysiphonia* and to those species with anchoring systems capable of securing the plant to a shifting substrate e.g., *Caulerpa* and *Halimeda*. When the sand pavement is exposed, *Laurencia* will colonise the substrate until the pavement is covered by sand once again. The combination of the reef flat and lagoon sand habitats cover 14.28 km^2 of the reef (Limpus and Reed, 1985a). The lagoon sand habitat is not exposed during low spring tides although the shallower areas may be covered by only 50 cm of water.

3.2.2.5 Lagoon Patch Reef

The lagoon patch reef habitat occupies most of the eastern reef. It is 4.4 km long and 1.2 km wide with an average depth of 3.5 m (Flood, 1984). The fine sand bottom of the lagoon is colonised by many small patch reefs (microatolls, bommies) ranging in diameter from 6 m to 25 m. These patch reefs are composed predominantly of species of *Acropora* (Flood, 1984) and although the top several centimetres may be exposed on low spring tides, they remain submerged most of the time. The lagoon patch reef habitat is the only portion of the reef with deep and continuous water cover during low

spring tides. The majority of these patch reefs possess vertical or steeply sloping sides with growths of macroscopic algae and algal turf assemblages. The same algal species that grow on the reef flat are found in this habitat. The algal turf assemblage is particularly well developed and abundant here. The lagoon occupies 8.35 km^2 (Limpus and Reed, 1985a).

3. 3 Turtle Resources

Heron Reef and the other reefs in the Capricorn Bunker Group of the Southern Great Barrier Reef are very important as feeding and or breeding grounds to three of the six species of sea turtles that occur in Australia (Moorhouse, 1933; Bustard, 1972; Limpus, 1981, 1985b; Sternberg, 1981; Limpus *et al.*, 1984; Limpus and Reed, 1985a). These species are the green turtle (*Chelonia mydas*), loggerhead turtle (*Caretta caretta*) and the hawksbill turtle (*Eretmochelys imbricata*). The flatback turtle (*Natator depressus*) is limited to the mainland coast and its islands while the olive ridley turtle (*Lepidochelys olivacea*) may also be found further offshore (Limpus, 1981). The Great Barrier Reef is not considered to be an important feeding or breeding area for the leatherback turtle (*Dermochelys coriacea*) (C.J. Limpus, pers. comm.).

Hawksbill, loggerhead, and green turtles utilise the reef as a feeding ground. Only the loggerhead and green turtle nest on Heron Island (Limpus, 1980, 1985b; Limpus *et al.*, 1984, Limpus and Reed, 1985a). During peak nesting years, over 1,000 individual green turtles nest on the island while as few as 100 nest during low density years (Limpus, 1980, 1981; Limpus *et al.*, 1984). Fewer than 10 loggerheads nest on Heron Island annually (Limpus *et al.*, 1984). Estimates of turtles resident on Heron Reef suggests that it supports 800-1000 green, ~180 loggerhead and ~100 hawksbill turtles (C. J. Limpus, pers. comm.).

The green turtles on Heron Reef are represented by two populations: residents and nonresident migratory breeders (Limpus and Reed, 1985a). Limpus and Reed (1985a) found the majority of the resident green turtles on the reef (78.7%) to be sexually immature while 8.1% of the population was comprised of adult females and13.2% were adult males. The size of resident *C. mydas* ranges from 35 cm CCL juveniles to adult males ($\overline{X}$=98 cm CCL) and females ($\overline{X}$=103 cm CCL) (Limpus and Reed, 1985a). The sex ratio of the resident green turtle population is 1:1 across the age classes (Limpus and Reed, 1985a).

The nonresident population is composed of adult males and females which travel to the reef to copulate and nest. To date, the sex ratio of the nonresident population has not been determined (C. J. Limpus, pers. comm.). Individual nonresident males will remain on the reef and court females for several weeks while individual nonresident females will stay to nest for several months (Limpus, 1980). A summary of annual green sea turtle reproductive activity on Heron Island and Reef is presented in Figure 3.3.

3. 4 Materials and Methods (General)

3.4.1 Sampling Periods

Due to the expense and logistical considerations of transporting a study team to Heron Island and supporting the team while on the island, the number of sampling sessions and their timing were determined by the following criteria: 1) representative distribution of sampling periods throughout the year; 2) availability of support facilities on the island e.g., boat, fuel, and lodging; 3) availability of research assistants; 4) weather and tides; 5) availability of transport for personnel and supplies to the island.

The above criteria taken into account, the following sampling sessions were

successfully conducted: March 7-April 7, 1988; October 26-November 16, 1988; January 15-February 3, 1989; March 15-April 19, 1989; May 24-June 7, 1989; July 21-August 4, 1989; March 26-April 12, 1990. Two sampling sessions in 1988 and two sampling sessions in 1989 were terminated after commencement due to difficulties with either boats, personnel, or weather.

3.4.2 Establishment of Sampling Area

One of the objectives of this study was to recapture green turtles throughout the year to determine if the diet of individual turtles changed temporally. Another goal was to document the temporal change of the algal assemblage in the area where the turtles were feeding. The absolute expanse of Heron Reef (27 km^2) precluded sampling all regions of each habitat. Therefore, the reef was divided into sampling sectors which extended from the north reef slope across the reef flat and lagoon to the south reef slope. Each of these sampling sectors ran parallel to each other from east to west. These sampling sectors were essentially the same as the original sectors established by Limpus *et al.* (1985c) during his investigation of the turtles on Heron Reef.

Each sector was approximately 400 m wide and the borders of every third sector were permanently marked with a row of galvanised steel fence posts of the type used for barbed wire fences (Fig. 3.4). Sectors that were not marked by permanent posts were marked with buoys attached to anchors. Compass bearings from fixed Island and reef locations were used to identify the location of each permanent post in the event that it was destroyed by a storm. This would allow a post to be replaced exactly. Each of these fence posts was covered with a 10m section of white heavy duty PVC (polyvinyl chloride) plumbing pipe which was secured to the post to prevent its loss during storms. A large red flag was attached to the top of each pole to increase its visibility. As the sector markers on the reef slopes were placed in deep water, they were not marked

with a PVC pole and flag. Rather, a float system was attached to the galvanised post and adjusted to float 1 m below the mean low tide level. This reef marking system allowed the area of turtle capture to be described accurately and provided a method of navigation around the reef during inclement weather.

The study area encompassed all of the habitats in sectors #0-9 inclusive. This is an east to west distance of approximately 4.0 km and a north to south distance ranging from 3.3-4.0 km for a total study area of approximately 14.5 km^2. The west end of the reef was not selected for study because the reef had been altered as a result of the development on the Island. In addition, the presence of bathers and divers in the western reef waters precluded high speed pursuit of turtles by boat. The extreme eastern sector (Sector # -1) was not sampled due its being very shallow and it was impossible to sample during inclement weather conditions (This is the section of the reef that is most strongly influenced by storm waves). However, time and conditions permitting, turtles sighted outside of the study area on Heron Reef (peripheral areas) were captured. The resultant data have been treated separately from the study site captures in the data analyses.

3.4.3 Capture of Turtles

Turtles were located by patrolling habitats with a 4.2 m boat occupied by two observer/divers and one driver/observer. Each of the three observers was assigned a portion of the 360° search arc around the boat as his/her search area. After we sighted a turtle, it was pursued in the boat until a diver could be positioned to dive on the turtle from the boat. The turtles were captured by hand and brought to the surface and then placed into the boat. Should the first diver miss the turtle, the second diver was placed into position to make a dive. This technique is described by Limpus (1978) and Limpus and Walter (1980c).

Upon capture, the sector and habitat of the first sighting of the turtle were recorded along with the time of capture. The turtles were kept cool and the capture process repeated with other turtles until the boat could hold no more turtles, or time, tides or weather required that the boat return to the Island.

Boat patrols for turtles occurred from first light until dusk, weather and tides permitting. Sampling occurred in all weather conditions including heavy rain and winds up to 20 knots. Attempts were made to capture all *C. mydas* sighted in the study area regardless of age class, sex or difficulty of capture i.e. depth of water. This capture technique was effective under a wide range of capture conditions and few turtles escaped capture once spotted.

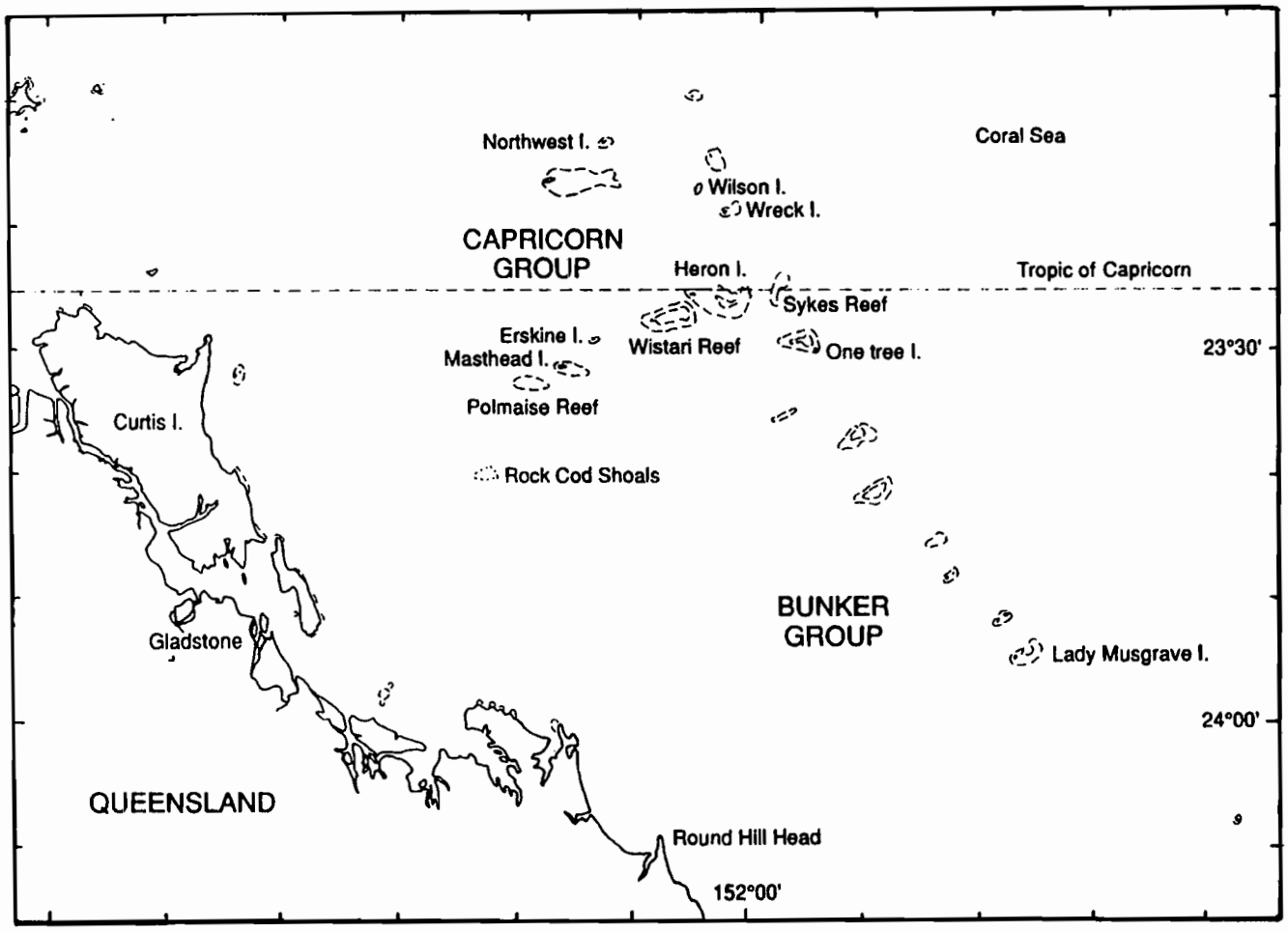

Figure 3.1- Heron Island, Capricornia Section, Great Barrier Reef, Queensland (From Limpus, 1992b)

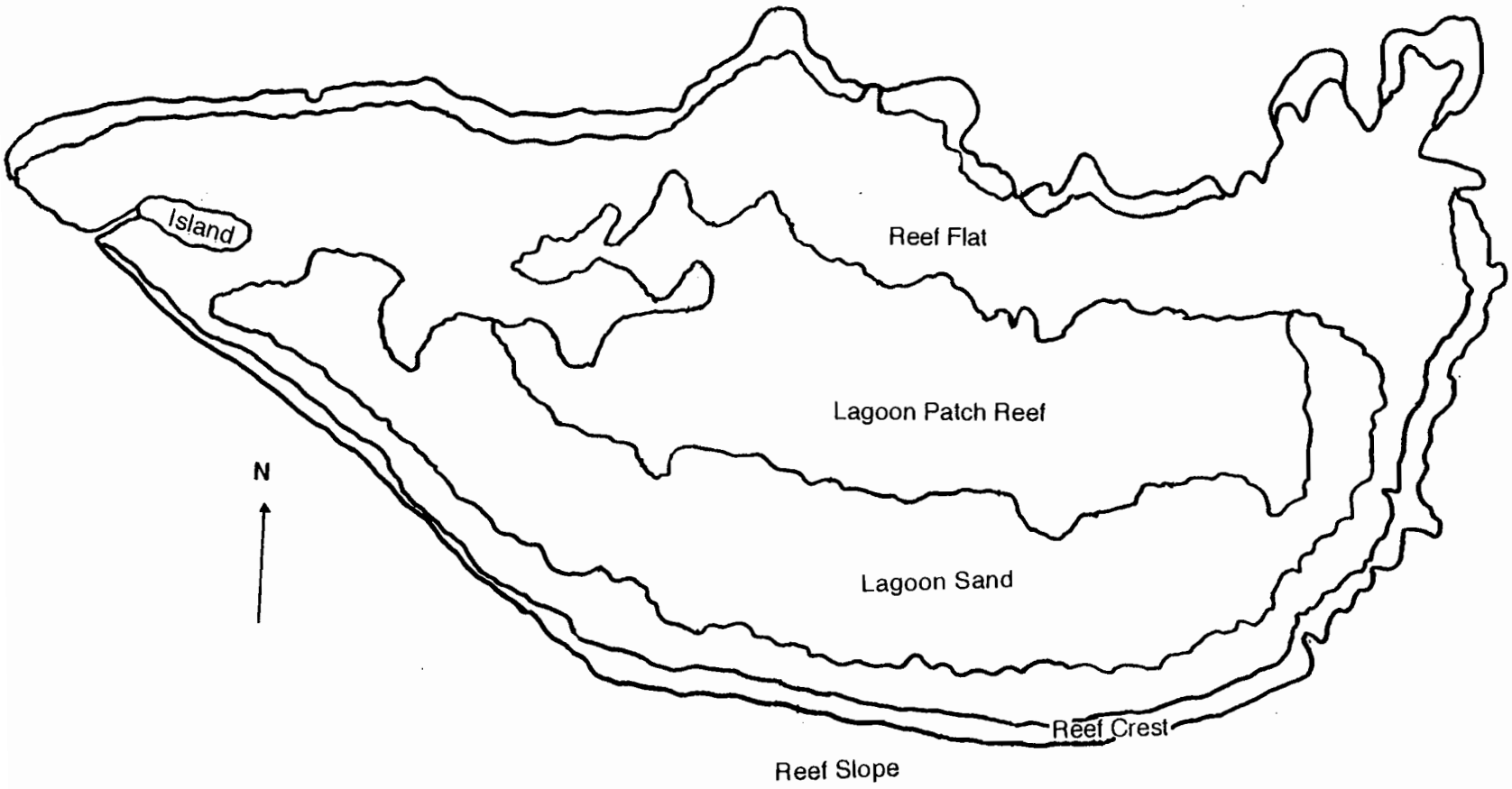

Figure 3.2- Habitats of Heron Reef, Capricornia Section, Great Barrier Reef, Queensland.

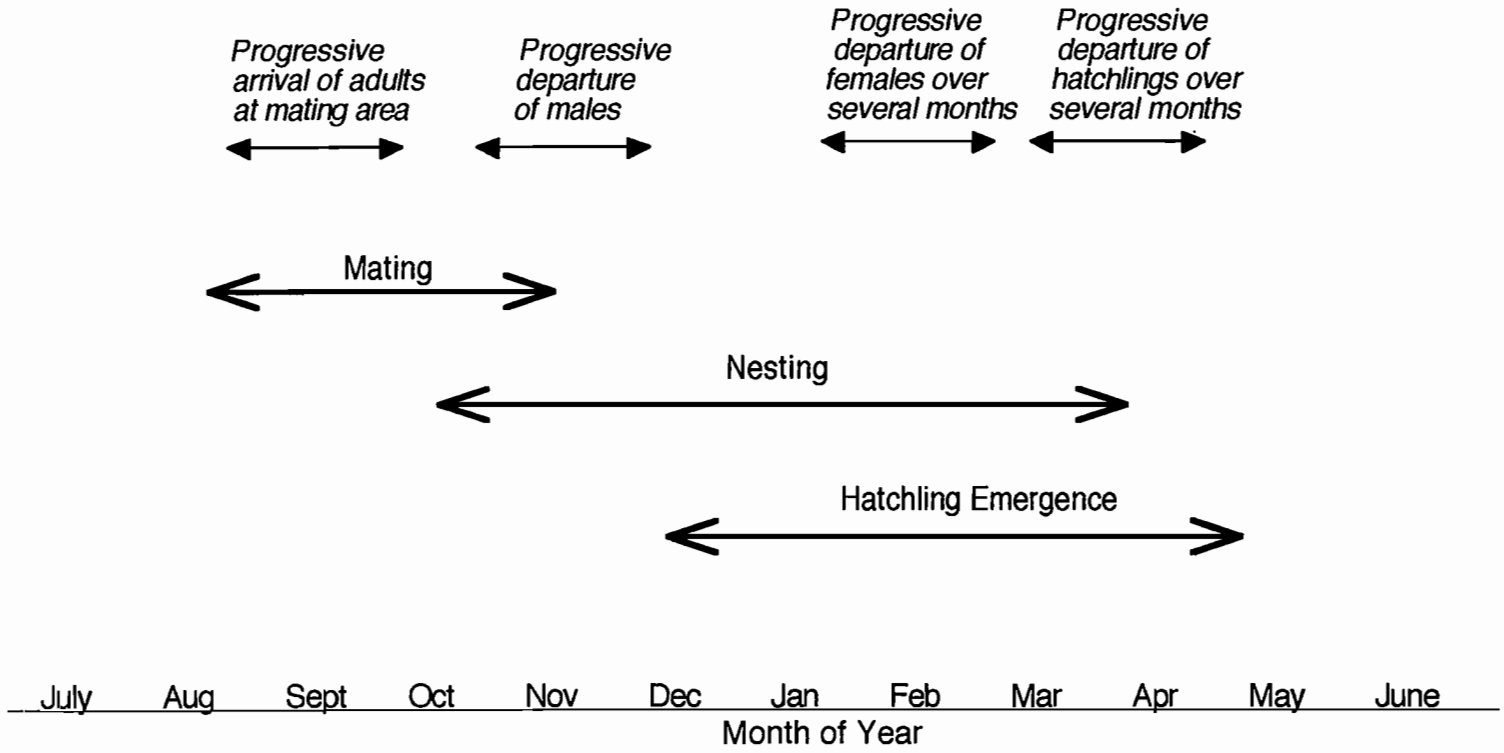

Figure 3.3- Summary of green turtle reproductive activity, Heron Island, Queensland. (Modified from Limpus, 1978)

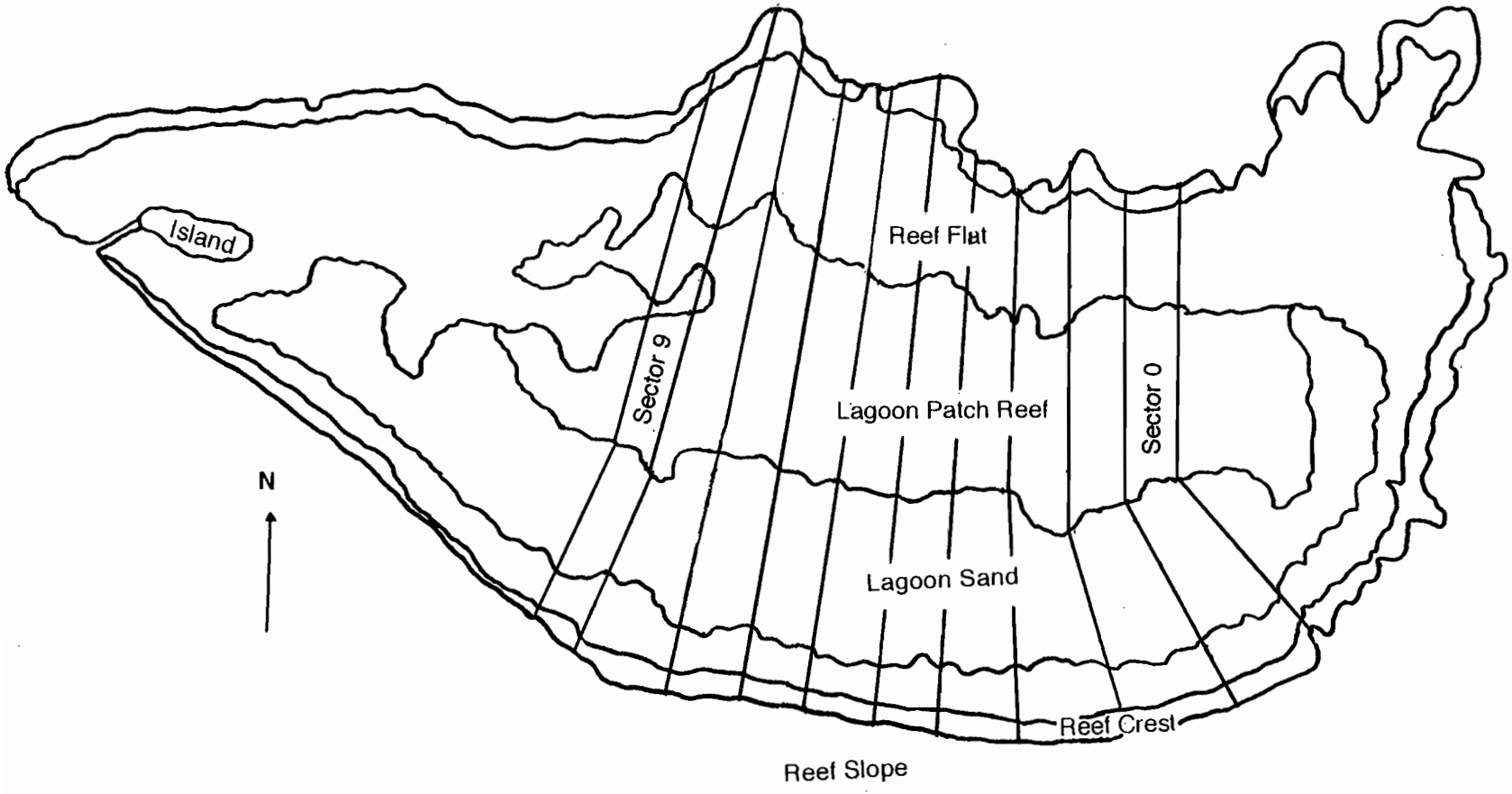

Figure 3.4- Location of the 10 sampling sectors that comprised the study area. Each sector was approximately 400 m wide. The sectors were numbered from 0 to 9 in an east to west direction.

Chapter 4

Green Turtle Population Profile

4.1 Introduction

The composition of the diet of wild animals may be influenced by factors extrinsic to the animal such as food availability, the nutrient content of a dietary item, risk of predation and the energetic costs associated with obtaining food. Factors intrinsic to the animal such as dietary preference, reproductive status, sex and age may also influence diet. Each of these factors may influence the diet independently or they may act in various combinations. These and other influences acting upon diet selection are reviewed by Westoby (1974, 1978), Pyke (1984), Abrams (1991) and Robbins (1993) and are addressed in Chapter 9.

One of the primary goals of this project was to determine which factors may influence the choice of diet in green sea turtles feeding in an algal community. In addition to examining the influence of forage quality and availability upon diet, the influence of age class, reproductive status and sex upon diet selection were of particular interest as their impact upon the diet of sea turtles has not been adequately addressed.

The demographic features of green sea turtle populations such as age, sex ratio and reproductive status are known to vary both spatially and temporally (Balazs, 1980b, 1983a; Carr *et al.*, 1978; Mortimer and Portier, 1989; Limpus, 1992a). Members of some sea turtle populations are thought to pass through a series of habitats (developmental habitats) as they develop towards maturity (Carr, 1967a, b, 1986, 1987; Carr *et al.*, 1978; Limpus, 1978, 1980a; Carr and Meylan, 1980; Limpus *et al.*, 1984; Balazs, 1980b; Balazs *et al.*, 1987). Once mature, sea turtles periodically migrate from their

feeding grounds to often remote habitats for courtship and mating. A proportion of females do not nest on beaches immediately adjacent to their place of courtship and may undergo further habitat shifts as they move into their internesting habitat (C. J. Limpus, unpublished data). This mobility results in a very dynamic population structure varying with the time of the year.

This chapter reports on the structure of the green turtle population at Heron Reef based upon episodic sampling of both the resident and migratory population. The population on Heron Reef includes animals from all post hatchling (>35 cm CCL) size and age classes. Immature animals comprise the majority of the population although breeding animals and nesting females are also represented. The sex ratio of the resident population is not significantly different from 1:1.

4.2 Material and Methods

Although the greatest turtle capture effort was concentrated within the designated study area (Chapter 3), turtles sighted outside of the study area on Heron Reef were captured and lavaged if time and conditions permitted. These turtles are referred to as peripheral captures while turtles captured within the study area are designated as study site captures. Turtles in data sets incorporating both study site and peripheral animals are referred to as combined captures.

The sex, reproductive status and age class of live sea turtles can be determined by a variety of noninvasive methods including assessing serum levels of testosterone (Owens *et al.*, 1978; Owens, 1981; Licht *et al.*, 1985; Wibbels et al, 1987a; Wibbels *et al.*, 1987b; Wibbels *et al.*, 1990), estradiol-17ß (Wibbels *et al.* 1990), progesterone (Licht, 1980; Owens, 1980; Owens and Morris, 1985; Wibbels *et al.*, 1990), luteinizing hormone (Licht, 1980; Owens, 1980; Owens and Morris, 1985), follicle-stimulating

hormone (Licht, 1980) and haemoglobin (Wood and Ebanks, 1984). Ultrasound imaging has been employed successfully to assess ovarian activity in adult sea turtles (Rostal *et al.*, 1989; Rostal *et al.*, 1990) and in freshwater turtles (Kuchling, 1989). Radiology has been used successfully in the detection of oviductal eggs in freshwater turtles and tortoises (Gibbons and Greene, 1979; Turner *et al.*, 1986).

Serum assessments are of benefit in determining gender and estimating the reproductive status of adult turtles. However, these assays are limited in that they currently are unable to provide detailed information regarding gonadal development in the pubescent developmental stages. Serum assays are also unable to detect previous breeding activity in adult females. Radiography and ultrasound share the same limitations as serum assays in addition, they are currently limited in their ability to identify sex in immature individuals. Radiographic and ultrasound assays also require expensive equipment that may be damaged by field conditions.

Laparoscopy has been used successfully to assess the sex, age class and reproductive history of sea turtles (Wood *et al.* 1983; Limpus, 1984, 1985; Limpus and Read, 1985 a; Rostal *et al.*, 1990). Laparoscopy provides the same information as endocrinological, radiographic and ultrasound techniques plus provides detailed information regarding the breeding history of females and gonadal development in the pubescent developmental stages. The equipment required for laparoscopy is less expensive than that required by other techniques and it is also quite field durable. The major disadvantage of laparoscopy is that it is an invasive technique and extreme care must be exercised in performing the procedure. A comparison of ultrasound and laparoscopy is provided by Rostal *et al.* (1990) while Kuchling (1989) presents a comparison between radiography and laparoscopy.

4.2.1 Laparoscopic Examination

The sex, age class, reproductive status and reproductive history of turtles captured in this study were determined laparoscopically by Drs. Colin Limpus and Jeffrey Miller of the Queensland Turtle Project (Queensland Dept. of Environment and Heritage). The resulting data were then provided for use in my project. Sex, age class, and reproductive history of the green turtles were assessed by the criteria of Limpus and Reed (1985a) and Limpus (pers. comm.) as follows:

Male

Juvenile: Testis very compact with seminiferous tubules hard to distinguish through the investing tunica albuginea. Epididymis not protruding from peritoneum. CCL[1] usually 35<65.0. cm.

Subadult[2]: Testis compact usually without distinguishable seminiferous tubules. Epididymis not protruding from peritoneum. CCL usually >65 cm.

Subadult Pubescent: Testis expanding with obvious seminiferous tubules. Epididymis ridged and extending from peritoneum. CCL usually >65cm.

Adult Nonbreeding: Testis expanded with obvious seminiferous tubules. Epididymis pendulous and hanging from body wall. CCL usually >90.5 cm.

Adult Breeding: Testis with tightly packed and coiled seminiferous tubules. Epididymis bright white and pendulous. CCL usually >90.5.

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[1]CCL (curved carapace length) represents the greatest distance from the anterior edge of the central scute (nuchal, cervical scutes) across the curve of the carapace midline to the posterior terminus of the border between the postcentral scutes. CCL is compared with SCL (standard carapace length) and TCL (Total Carapace Length) in Chapter 2.

[2]Subadult pubescent animals were grouped with the subadults until the March 1989 sampling session when they were placed into their own group. For comparison with other studies, the subadult and subadult pubescent animals were placed into one group as subadults.

Female

Assessments of females were made by examining both anterior and posterior regions of the ovary. Oviduct measurements were made at the junction of the oviduct and the ovary. The diameter of the oviduct was estimated using the diameter of the field of view of the laparoscope as a reference.

Juvenile: Oviduct straight, white, and without convolutions. Stroma unexpanded, corpora lutea, corpora albicantia, corpora atretica absent. CCL 35<65 cm.

Subadult: Oviduct straight, white and without convolutions. Stroma unexpanded, corpora lutea, corpora albicantia, corpora atretica absent. CCL >65 cm.

Subadult Pubescent: Oviduct greater than 2 mm in diameter, turning pink with convolutions. Stroma unexpanded, corpora lutea, corpora albicantia, corpora atretica absent. CCL >65 cm.

Adult Nonbreeding: Oviduct greater than 1.5 cm in diameter, pink and very convoluted. Stroma expanded. Previtellogenic follicles greater than 3 mm in diameter. Regressing atretic follicles and corpora albicantia less than 5 mm in diameter may be present from ovulations in previous nesting seasons. CCL >91.5 cm.

Adult Breeding: Oviduct greater than 1.5 cm in diameter, pink and very convoluted. Stroma expanded, vascularization obvious. Many mature follicles 2-3 cm in diameter present. Shelled eggs may be present. Corpora lutea (corpus hemorrhagicum) with pronounced open center or corpora albicantia greater than 5 mm in diameter with radiating lines may be present if ovulation has taken place during current season. CCL >91.5 cm.

Time and/or equipment limitations sometimes prevented turtles from being examined laparoscopically. However, mature male green turtles could still be identified using

external secondary sexual characteristics (Limpus, 1980; Limpus and Reed, 1985a). Mature males display a pronounced curved claw on each front flipper and have elongated tails which extend more than 25 cm beyond the carapace. Those turtles which were not laparoscopically examined and did not display secondary male characteristics were assessed as follows: CCL <65 cm= Juvenile, CCL ≥65 cm and <90.5 cm= subadult, CCL≥ 90.5 cm= unsexed adult.

Turtles were measured twice, once on the boat at the time of capture and on the beach where they were also weighed. Length measurements were curved carapace lengths (CCL). CCL measurements were made to the nearest 0.5 cm. Tail lengths from the carapace (TLC) were also taken. Measurements were made from the posterior terminus of the border between the postcentral scutes (or base of notch if present) to the tip of the tail. Measurements were made using flexible fibreglass measuring tapes which were regularly checked against a standard. Weights were recorded to the nearest 0.5 kg using Salter® hanging scales of either 10 kg, 50 kg, or 200 kg capacities. All weights were taken prior to each animal being lavaged (Chapter 8).

As per the tagging protocol of Queensland Turtle Research (Dept. of Environment and Heritage), turtles were released at the beach wearing two 4.1g titanium turtle tags (cattle ear tags) (Stockbrands Co. Pty. Ltd. , Western Australia) placed adjacent to or through each axillary tagging scale (the second and largest proximal scale on the trailing edge of the front flipper). These scales continue to grow towards the edge of the flipper throughout the life of the turtle carrying any embedded tag with them (C. J. Limpus, pers. comm.). To avoid the eventual loss of a tag, every attempt was made to place the tag in the soft flesh at the anterior end of the scale.

4.3 Results

In excess of 550 captures of green turtles (420 individual animals) were made within the study site and peripheral areas during this study. Of these animals, 507 green turtles were lavaged with 435 of these originating from the study site. The demographic profile that follows represents data from the first capture of individual green turtles. Recaptures are not included.

Immature animals (juvenile, subadult, subadult/pubescent) accounted for 73.7% of the combined captures and 72.9% of the study site captures. Juveniles represented 27.0% of the combined captures (n=392) while subadults represented 42.1%; subadult pubescents, 4.6% (subadults and subadult pubescents combined, 46.7%) and adults 26.3% (Table 4.1, Fig. 4.1). The age class distribution of green turtles captured within the confines of the study area (n=345) was similar to the combined captures with juveniles comprising 24.3%; subadults, 44.0%; subadult pubescents, 4.6% (subadults and subadult pubescents combined, 48.6%) and adults 27.0%.

Females accounted for 48.5% of the combined captures and 48.1% of the study site captures. Males comprised 35.2% of the combined captures and 33.6% of the study site captures. Animals of undetermined gender (indeterminate sex) comprised 16.3% of the combined captures and 18.3% of the study site captures (Table 4.1).

There was no significant difference between the number of males and females (all age classes combined) in 5 of the 7 sampling sessions. Only in January, 1989 (M/F=1:1.29 at α =0.05, [$\chi^2_c{}^*$=8.31, v=1 (Yates corrected), 0.001<P< 0.005, n=39])[3] and March 1990 (M/F=1:1.66 at α =0.05, [$\chi^2_c{}^*$=5.70, v=1 (Yates corrected), 0.01<P< 0.025, n=101])[4] was

[3] Only animals of known sex were used in the χ^2 calculation.

[4] Only animals of known sex were used in the χ^2 calculation.

the sex ratio significantly different from the expected 1:1 sex ratio if all size classes are considered. Adult turtles showed no significant difference in the expected 1:1 sex ratio in 6 of the 7 sampling sessions; the exception being March 1988 (M/F 5.5:1 at α =0.05 [$\chi^2_c{}^*$=4.92, v=1 (Yates corrected), 0.025<P< 0.05, n=13]).

The curved carapace length of the green turtles captured during the study ranged from 39.5 to 115.5 cm CCL (Table 4.2, Fig 4.2). The mean CCL of the combined captures was 78.5 cm (s.e.= ±1.04 cm, mode=97.5 cm) while the mean study site turtle CCL was 79.8 cm (s.e.= ±1.07 cm, mode=97.5 cm). On all sampling occasions except two, there were significantly more immature than mature animals (p <0.05). The exceptions were November, 1988 (α =0.05 [χ^2_c=0.26, v=1 (Yates corrected), 0.75<P< 0.5, n=34]) and January, 1989 (α =0.05 [χ^2_c=3.15, v=1 (Yates corrected), 0.10<P< 0.05, n=54]) which were both during the breeding season.

There was a highly significant difference in the ratio of immature to mature turtles in all sampling sessions except in November. In all other sampling occasions, there were significantly more immature than mature animals.

4.4 Discussion

The green turtle population occupying Heron Reef contains representatives from all size, age and maturation classes with the exception of the post hatchling size class (CCL<35 cm). These findings are in agreement with those of Limpus and Reed (1985a) who studied the same population. They found that the sex ratio of their sample was not significantly different than 1:1, a finding that is in agreement with the results for 5 of the 7 sampling sessions of this study. The discrepancy for January, 1988 and March, 1990 may be a result of the presence of migrant adult females on the Reef but unidentified as migrants in the sample. Females were considered to be migrants if they

were tagged and had never been seen on the reef outside of the migration period or were untagged and were observed nesting or had barnacles on their shells (resident turtles do not carry barnacles). Although Limpus and Reed did sample during the nesting season (Dec-Feb), they did not include migrant females in their data set. Therefore, the difference in the sex ratio data between the two studies is most likely due to the inclusion of nesting females in my data set. Two of the seven sampling sessions (May and July) did not include unidentified migrant breeding animals as none are present on the reef at these times. When only these resident animals are used in the chi-square analyses, there was no significant difference from the expected sex ratio of 1:1 for the May data (M/F 1:1.6 at α =0.05 [χ^2_c=1.37, v=1 (Yates corrected), 0.10<P< 0.25, n=34]) or the July data (M/F 1.8:1 at α =0.05 [$\chi^2_c{}^*$=3.14, v=1 (Yates corrected), 0.05<P< 0.10, n=40]). These findings agree with those of Limpus and Reed.

My study found that the green turtle population on Heron Reef is dominated by immature turtles (73.7%), a result in good agreement with that of Limpus and Reed (1985a) (78.7% immature turtles). When my data sets from May and July (no nesters) are compared with the findings of Limpus and Reed (1985a) (no nesters; Dec-Feb.& April-May), there is no significant difference between the ratio of mature to immature animals in the two studies (α =0.05, $\chi^2_c{}^*$=0.92, v=1 (Yates corrected), 0.75<P< 0.9, n=127).

The abundance, proportion and extremely variable size of immature turtles captured during this study demonstrates that Heron Reef offers those resources that are required in a developmental habitat for juvenile and subadult green sea turtles. The presence of resident adult turtles in the population throughout the year indicates that Heron Reef also provides those resources required in a feeding ground for mature green turtles.

4.5 Conclusions

1. The Heron Reef green sea turtle population is characterised by animals from all age classes excluding post hatchlings (<35 cm CCL). The size of green turtles in this study ranged from 39.5 to 115.5 cm CCL. ($\overline{X}$ CCL=78.5 cm, mode=97.5 cm)
2. The Heron Reef green turtle population is dominated by immature animals (73.7%).
3. The sex ratio of resident green turtles on Heron Reef is not significantly different from 1:1.
4. Heron Reef provides resources for both immature and mature turtles.

Table 4.1-Summary demographic profile of green sea turtles captured from Heron Reef and lavaged during this study. Data include individuals from the combined area (study site and peripheral areas) and those exclusively from the study site. Animals recaptured within a sampling session are counted only once for that session. Values in parentheses are percentages.

		Juvenile		Subadult		Subadult Pubescent		Total Immature		Adult		Total	
		Combined	Study Site	Combined	Study Site	Combined	Study Site	Combined	Study Site	Combined	Study Site	Combined	Study Site
Mar-88	Female	13	12	28	28	0*	0*	41	40	2	1	43	41
	Male	8	7	18	17	0	0	26	24	11	9	37	33
	Indeterminate	0	0	0	0	0	0	0	0	0	0	0	0
	Total	21	19	46	45	0	0	67	64	13	10	80	74
Nov-88	Female	0	0	11	11	0*	0*	11	11	8	8	19	19
	Male	0	0	3	4	0	0	3	4	7	7	10	11
	Indeterminate	2	2	3	3	0	0	5	5	0	0	5	5
	Total	2	2	17	18	0	0	19	20	15	15	34	35
Jan-89	Female	7	5	11	11	0*	0*	18	16	11	10	29	26
	Male	3	4	1	0	0	0	4	4	6	6	10	10
	Indeterminate	8	8	4	4	0	0	12	12	3	3	15	15
	Total	18	17	16	15	0	0	34	32	20	19	54	51
Mar-89	Female	22	20	9	9	5	4	36	33	4	4	40	37
	Male	12	12	11	11	0	0	23	23	2	2	25	25
	Indeterminate	1	1	0	0	0	0	1	1	0	0	1	1
	Total	35	33	20	20	5	4	60	57	6	6	66	63
May-89	Female	3	3	11	11	0	0	14	14	7	7	21	21
	Male	2	2	5	4	0	0	7	6	5	5	12	11
	Indeterminate	3	3	12	12	0	0	15	15	4	4	19	19
	Total	8	8	28	27	0	0	36	35	16	16	52	51
Jul-89	Female	1	1	10	10	0	0	11	11	3	3	14	14
	Male	1	1	13	12	4	4	18	17	8	8	26	25
	Indeterminate	1	1	22	22	0	0	23	23	5	5	28	28
	Total	3	3	45	44	4	4	52	51	16	16	68	67
Mar-90	Female	22	10	22	15	8	8	52	33	11	10	63	43
	Male	12	5	12	10	1	0	25	15	13	10	38	25
	Indeterminate	0	0	0	0	0	0	0	0	0	0	0	0
	Total	34	15	34	25	9	8	77	48	24	20	101	68
Animals recaptured during the study are counted only once in the values listed below even though they may have been recaptured in multiple sampling sessions as indicated in the data above.													
Project	Female	57(14.5)	43(12.5)	74(18.9)	69(20.0)	13(3.3)	12(3.5)	144 (36.7)	124 (36.0)	46(11.7)	42(12.2)	190(48.5)	166(48.1)
Total-	Male	34(8.7)	26(7.5)	54(13.8)	47(13.6)	5(1.3)	4(1.2)	93 (23.8)	77 (22.3)	45(11.5)	39(11.3)	138(35.2)	116(33.6)
	Indeterminate	15(3.8)	15(4.3)	37(9.4)	36(10.4)	0(0.0)	0(0.0)	52 (13.2)	51 (14.7)	12(3.1)	12(3.5)	64(16.3)	63(18.3)
	Total	106(27.0)	84(24.3)	165(42.1)	152(44.0)	18(4.6)	16(4.6)	289 (73.7)	252 (72.9)	103(26.3)	93(27.0)	392	345

*The subadult/pubescent age class was not established until the March 1989 sampling session. Prior to this time, subadult pubescents were grouped with the subadults. For comparison with other studies, the subadult pubescents and subadults may be grouped together.

Table 4.2-Distribution of curved carapace lengths (CCL) for green sea turtles captured on Heron Reef. Data are arranged by trip and are also summarized for the study. Only the data from the first capture of an animal during a sampling session are used in the calculations for that session. Only the first capture for the study is used in the calculation of the study summary data .

	CCL (cm) of Combined Captures							
	Mar-88	Nov-88	Jan-89	Mar-89	May-89	Jul-89	Mar-90	Study
n	69	34	55	65	52	68	101	376
Minimum	41.0	43.5	42.5	42.5	43.0	42.0	39.5	39.5
Maximum	114.0	112.5	115.5	107.5	111.0	108.0	109.0	115.5
Mean	75.1	86.7	78.0	66.8	83.8	84.0	75.3	78.5
Std. Error	2.16	2.99	2.96	2.47	2.29	1.57	2.07	1.04

	CCL (cm) of Study Site Captures Only							
	Mar-88	Nov-88	Jan-89	Mar-89	May-89	Jul-89	Mar-90	Study
n	62	35	51	62	51	67	68	337
Minimum	41.0	43.5	42.5	42.5	43.0	42.0	39.5	39.5
Maximum	110.0	112.5	115.5	107.5	111.0	108.0	109.0	115.5
Mean	77.0	86.2	78.8	66.5	84.0	84.1	80.6	79.8
Std. Error	2.31	2.96	3.09	2.55	2.32	1.58	2.32	1.07

Figure 4.1-Summary demographic profile of green sea turtles captured from Heron Reef and lavaged during study. Data include individuals from combined areas. Animals recaptured within the study are counted only once.

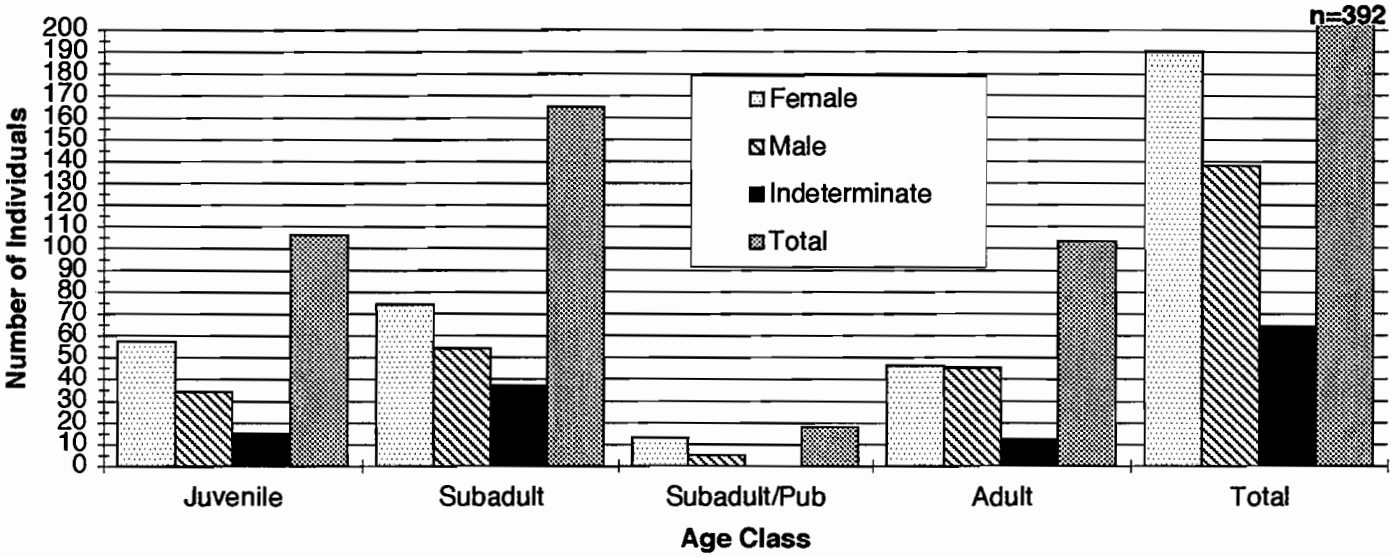
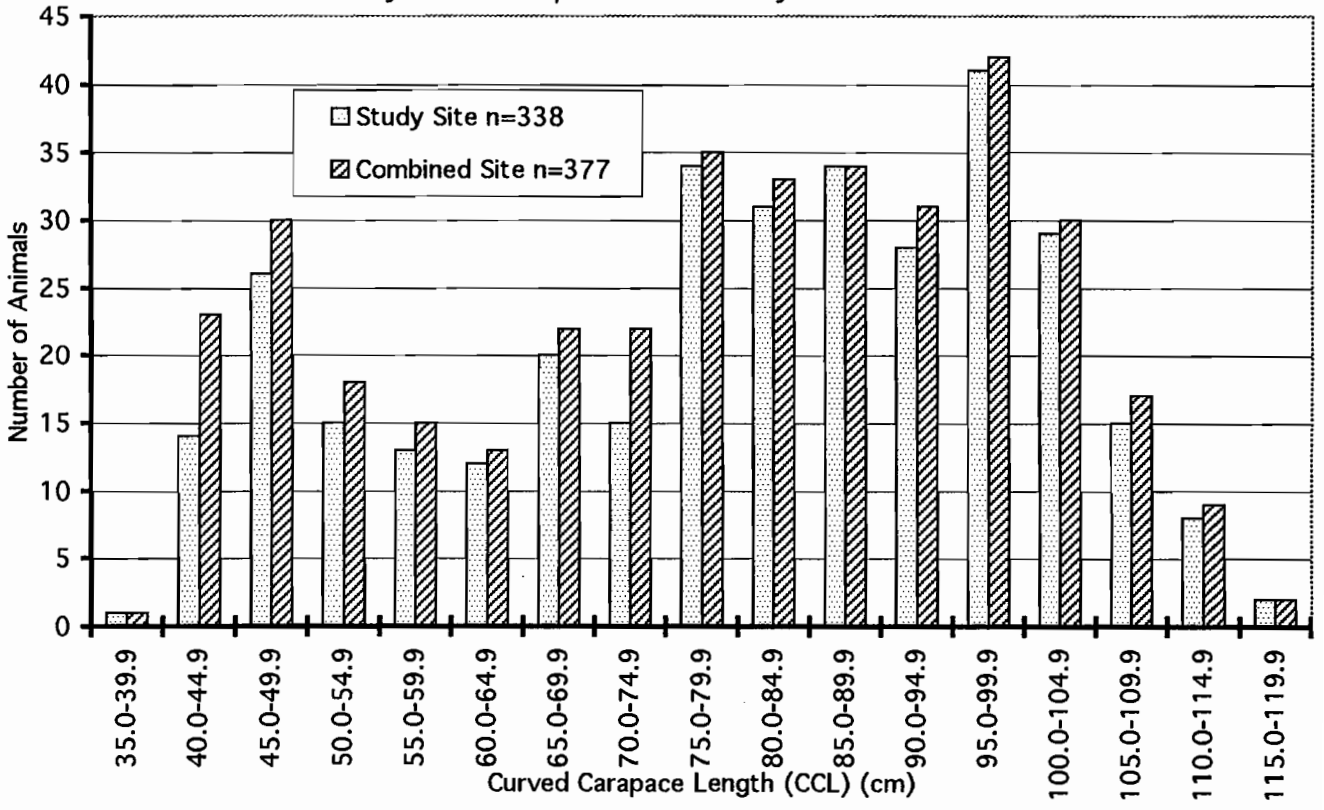


Fig 4.2-Frequency distribution of curved carapace length (CCL) of green turtles captured on Heron Reef. Only the first capture of the study is used in the data set.



Chapter 5

Algal Assemblage

5.1 Introduction

Optimal foraging models suggest that the composition of an animal's diet is a function of a variety of interrelated factors including the energetic and nutritive benefit of securing food balanced against the energetic costs and the risks associated with foraging (Abrams, 1982, 1984, 1989, 1991; Dill, 1987; Mangel and Clark, 1986, 1988; Houston *et al.*, 1988; Pyke, 1984 ; Lima and Dill 1990). Optimal foraging strategies should maximise obtainable benefit (fitness) while decreasing the costs associated with foraging.

In order to achieve optimal fitness, euryphagous animals living in dynamic environments with ephemeral dietary resources may elect to change their foraging strategies or behaviour in response to variations in food availability. This response will need to be particularly rapid in the case of herbivores living on ephemeral foliage as changes in food resources are not buffered by intermediate trophic levels. Thus, such herbivores might be expected to evolve feeding strategies that will readily accommodate shifts in their food supply.

One of the primary objectives of this study was to determine the relationship between the reef algal assemblage and the diet of the green turtle. To accomplish this goal, the algal assemblage in each of the various reef habitats was sampled during each turtle sampling session in order to document the spatial and temporal changes in the algal community which, anecdotal accounts suggest, are ephemeral (Borowitzka, 1981). This chapter reports on the nature and timing of these changes.

Overall, the composition and areal cover of the algal community on Heron Reef was found to be dynamic in all reef habitats due to the significant proportion of emphemeral species. However, the areal cover of the algal turf component was relatively constant and accounted for the greatest proportion of algal cover. If optimal foraging models apply to green sea turtles, these animals might be expected to exhibit a feeding strategy that exploits both the stable and ephemeral components of the algal assemblage.

5.2 Materials and Methods

5.2.1 Selection of a Substrate Sampling Technique

Sampling a diverse algal flora is problematic in that it is difficult to sample filamentous and prostrate forms as easily and accurately as the larger thalloid forms. The algal turf assemblage is a very heterogeneous association of species that is extremely variable in composition both spatially and temporally although its areal coverage is relatively constant. The species composition of the algal turf and its density and stature are greatly influenced by the grazing pressure of herbivores such as invertebrates, fishes and green turtles (Ch. 8). Some turf species mature at less than 1-2 cm in height while others represent the early developmental stages of algae that mature into plants greater than 20 cm in height unless. These large mature plants may in turn develop into monospecific stands eliminating the algal turf assemblage of earlier seral stages. Additionally, many turf species are epiphytic on other turf species and may obscure their host plant.

Time constraints made it impractical to separate the turf assemblage in the field to delineate the relative contribution of each of its component species or to harvest large "representative samples" for analysis in the laboratory. Such harvesting was also undesirable as it would have modified the algal assemblage within the sample site.

Consequently, the algal turf assemblage was treated as a separate component of the algal coverage, distinct from monospecific stands. However, qualitative data on the composition of the turf assemblage was obtained by harvesting and analysing samples from random reef locations during each sampling session.

The statistical treatment of the algal data required a quantitative assessment of coverage. Several methodologies have been successfully employed to sample benthic marine organisms including line transects (Loya, 1972; Moody, 1979; Morrissey, 1980; DeVantier *et al.*, 1985; Johnson *et al.*, 1985; Coles *et al.*, 1987; Williams, 1988), quadrat sampling (Hirth *et al.*, 1973; Greenway, 1974; Mortimer, 1976; Mendonca, 1983; Ross, 1985) and still and video photography (Neushul, 1966; Loya, 1972; Done, 1981; Littler and Littler, 1985).

To quantify the temporal change in the algal assemblage and reduce the effect of spatial variability, it was desirable to sample the same location of the reef during each sampling session. Establishing permanent transect lines marked by a line fastened to the bottom presented several problems. Algae will settle on any hard substrate and thus the presence of the line influences the composition of the community. Movement of the line across the substrate with the tides and surge also has the potential to alter the composition of the benthos. Anchoring the line to the substrate at numerous points would reduce this effect but this was impractical due to the irregular topography of the reef substrate and the many delicate coral formations that were present. A permanent line would also be a source of possible entanglement for the three turtle species that forage on the reef. Placing permanent points of attachment for a removable transect line was not feasible as there is normally a strong tidal or storm surge moving across the reef that would bow the line. Numerous anchoring points would be required to reduce line bowing and those anchoring points established across open areas of the

reef were repeatedly displaced by storms. Permanent sampling quadrats were not considered feasible for two reasons; 1) they provided an artificial substrate 2) they were difficult to use due to the variation in the vertical relief of the bottom within the lagoon and reef slope habitats.

In order to overcome the problems associated with using line transects and quadrats, a methodology was developed for photographically sampling a permanent circular plot marked by a single pole at its center (Section 5.2.2). This system provided a rapid and precise method for repetitive sampling while at the same time providing a permanent photographic record of the benthic assemblage.

5.2.2 Substrate Sampling

Each of the reef zones (Chapter 3) was sampled during each turtle sampling session using the protocol described below. However, sampling was discontinued on the rubble crest due to safety and logistical considerations. Access to the rubble crest required very calm sea conditions and this situation was rare. Additionally, the only access to the rubble crest during low tide was from the seaward side which required a very long and sometimes dangerous passage across open water and anchorage in deep water.

Poles of the same design and installation as those used to mark the reef sector boundaries (Chapter 3) were placed along the sector 3 and 6 boundaries within each reef zone (Fig. 5.1). In order to avoid edge effects, the poles were placed in the center of the zone. Each pole served as the center of a "circular sampling plot" with a circumference of 100 m and a diameter of 31.8 m. A 15.9 m (1/2 the plot diameter) nonstretching, floating nylon line was attached over the pole and uncoiled so photographs of the substrate could be taken at predetermined "subplot" compass

locations around the circumference of the circle using an underwater camera and flash attached to the line.

The size of the subplot was determined by the height above the substrate at which a photograph could be taken and still produce a quality image that could be interpreted. Trials at different distances showed that a camera to substrate distance (focal length) of 101.5 cm was optimal producing a subplot photographic field of 95 cm x 61 cm for a sampling area of 0.5795 m^2 per subplot.

The number of subplots required per circular plot was determined empirically by sampling the reef flat, the most diverse habitat on the reef. Twenty-one equally spaced subplots were sampled around the perimeter of each of six circular plots to determine when the relationship between the number of species and the number of subplots plateaued. The curves for these six trial circular plots leveled off at 13 subplots. To ensure adequate sampling, 17 subplots were photographed per circular plot for a total sampling area of approximately 10m^2 (9.852 m^2) per circular plot. This equalled 118.2m^2 per sampling session. The 17 subplots were equally distributed along the circumference of the circular plot at compass bearings of every 20° from 20°-340° inclusive.

The photographic assembly was composed of a monopod stand constructed from 2 cm square hollow aluminium stock. The following were attached to the monopod: 1) two bubble levels to ensure vertical and horizontal positioning of the camera and to reduce photographic parallax, 2) a Silva® model 7NL compass, corrected for Queensland's magnetic declination, 3) a Nikonos® V underwater camera fitted with a 28 mm wide angle lens and a Nikonos® model SB 103 automatic underwater flash and Kodak® Kodachrome® 64 ASA slide film. Edge parallax and distortion produced by the 28 mm

lens at the selected focal length were insignificant. The monopod mounted compass facilitated accurate relocation of the subplot using the compass bearing from the central post.

5.2.3 Quantification of Substrate Cover

Algae were identified to the lowest taxon possible using Cribb (1966a, b; 1983) for the Rhodophyta. The Chlorophyta and Phaeophyta were identified using Womersley (1984,1987), Cribb (1966a, b; 1985) and Littler *et al.* (1989). Seagrasses were identified from Lanyon (1986). Herbarium specimens from the James Cook University herbarium collection and the University of Queensland, Heron Island Research Station herbarium collection were used as reference standards. Verification and assistance in the identification of difficult specimens was provided by Dr. Ian Price of James Cook University, and Dr. Karen Edyvane of the South Australian Department of Fisheries. Some species can only be identified by microscopic examination of cellular structures and or reproductive bodies and could not be identified from photographs. Identification was also limited by the lack of comprehensive taxonomic guides for Great Barrier Reef algae. As a result, polyspecific genera were treated at the generic level in subsequent statistical analyses.

Each 35mm slide was projected to a standard size onto white paper. Each substrate component was outlined directly onto the paper to produce a "substrate map." Any substrate component of 4 cm^2 or greater was identified. Smaller components were included with the background component that they contacted; either sand, rubble, crustose coralline algae or algal turf. A total of 204 subplot photographs were taken per sampling trip, resulting in 1,224 subplot photographs for the study. The area of each substrate component was measured using a Kurta® Model IS/ONE® 30.5 x 30.5 cm

digitising pad linked to an IBM® PC computer loaded with the Sigma-Scan® software package. (Jandel Scientific, Corte Madera, California.)

A composite aerial photograph (parallax reduced) of Heron Reef (Great Barrier Reef Marine Park Authority) was digitised to determine the area of each of the reef habitats. The contribution of each substrate component to the total reef cover could then be estimated by multiplying its area contribution within a habitat by the percentage of the reef area that was occupied by that habitat.

5.2.4 Statistical Analysis

For each sampling session and site, the areal coverage (cm^2) of a substrate component (absolute cover) and the areal coverage by a component in relation to the total algal or total reef cover (relative abundance) were calculated for use in subsequent analyses. Due to their crustose and prostrate thallus form, the crustose coralline algae are not available to green turtles as forage items and were omitted from calculations dealing with total algal cover. However, the crustose coralline algae are included elsewhere in the calculations of total reef cover.

5.2.4.1 Temporal and Spatial Change in Cover

A basic assumption of analysis of variance techniques is that sampling units must be independent (Zar, 1984). The Runs Test (SPSS Inc., Chicago) was used to test if the presence or absence of the cover of a particular algal component within each sequential subplot was random or demonstrated dependence.

Due to the large number of zero values in the data sets and to stabilise the variance across factors, the data were $\log_{10}$ transformed. A series of univariate ANOVAs was

then performed using habitat (6 levels), algal component (7 levels) and time (6 levels) as fixed factors and transect (2 levels) a random factor.

Two designs were used for the univariate ANOVA analyses:

1) Transects nested within habitat and crossed with time in order to examine habitat variation over time for each algal component ([$Transects_2$ ($Habitats_6$)]*$Time_6$ for each algal $component_7$]).
2) Algal component, time and transect were treated as crossed factors in order to examine algal component variation over time for each habitat (algal component * $time_6$ * $transect_2$ for each $habitat_6$).

Prior to analysis with the above models, the data were examined for normality (q-q plots) and homoscedasticity of residuals (residual plots against fitted values). Absolute algal cover of sequential subplots within radial sampling plots was not independent (Runs Test) violating one of the ANOVA assumptions. Accordingly, the mean coverage of each primary algal component for each radial sampling plot in each habitat at each time was used as the response in the statistical analyses.

A primary algal component was defined as one that contributed ≥2% of total algal cover during ≥ 2 sampling sessions.

5.2.6 Limitations of Methodology

Care should be exercised in the interpretation and application of the data (Tables 5.1-5.3) with respect to the relative importance of the Rhodophyta, Chlorophyta and Phaeophyta to the algal flora. Species from each of these divisions are important ephemeral components of the algal turf. As relative abundance data were not available for component species of the algal turf, comparing the coverage data for the monogeneric stands of each algal division may not represent their actual ecological

importance to the complete algal assemblage if their contribution to the algal turf is also not considered.

5.3 Results

5.3.1 Contribution of the Primary Substrate Components to the Reef Benthos

The algae (fleshy and crustose coralline combined) had the greatest areal coverage of any substrate component on Heron Reef during all sampling sessions (Table 5.1). The total algal cover averaged 14.43% (s.e.=1.17) of the reef area, over four times the cover of hard and soft corals combined ($\overline{X}$ = 3.40%, s.e.=0.35). Considered separately, the fleshy algae ($\overline{X}$ = 11.4%, s.e.=1.08) or the algal turf ($\overline{X}$ = 6.09, s.e.=0.48) were still more abundant than living corals ($\overline{X}$ = 3.4%, s.e.=0.35) during all sampling sessions.

When the algal cover was considered separately from the other substrate components, the monospecific and monogeneric stands of rhodophytes ($\overline{X}$ = 2.30%, s.e.=0.71) had the greatest areal coverage for all sampling sessions except November, 1988 followed by the chlorophytes ($\overline{X}$ = 1.9%, s.e.=0.64) and phaeophytes ($\overline{X}$ = 1.15%, s.e.=0.69) in all sampling sessions except November, 1988 (Table 5.2). The algal turf ($\overline{X}$ = 6.09%, s.e.=0.48) exceeded the combined coverage of the Rhodophyta, Chlorophyta and Phaeophyta ($\overline{X}$ = 5.31%) at all times except in July, 1989 when there was a bloom of psammophilous chlorophytan and rhodophytan algae. This ranking held true even when the rhodophytan crustose coralline algae were excluded from the calculation of algal cover resulting in mean cover values of 55.5%, 19.9%, 15.1% and 9.1% for the algal turf, Rhodophyta, Chlorophyta and Phaeophyta, respectively (Table 5.3).

Living hard and soft corals covered a greater area of the reef than attached dead coral colonies during all sampling sessions with living corals averaging 3.4% (s.e.=0.35) and dead corals averaging 0.3% (s.e.=0.14) of the total reef area (Table 5.1). The total

nonliving cover (dead coral, sand, rubble) exceeded the living cover (algae and corals) during all sampling sessions. Nonliving cover averaged 80.4% (s.e.=1.6) while living cover averaged 17.9% (s.e.=1.26) of the reef area.

5.3.2 Composition of the Algal Assemblage

Forty-five genera and at least 71 species of algae and two genera of cyanobacteria were identified from Heron Reef during this study (Table 5.4). These species combined with those listed by Cribb (1966a,b, 1973) (Appendix Table 5.1) suggest that Heron Reef supports over 115 species of algae and at least 18 species of cyanobacteria although it is difficult to give a precise number as additional systematic work at the species level is still required for both the algae and the cyanobacteria. These species vary in morphology and include filamentous, sheet, saccate, branched, jointed calcareous and crustose thalli that form monogeneric stands and heterogeneous algal turf. Sixteen noncrustose genera formed monospecific or monogeneric stands within the study site during the various sampling sessions. These taxa include the chlorophytan genera *Caulerpa*, *Chlorodesmis*, *Codium*, *Enteromorpha*, *Halimeda* and *Valonia*; the phaeophytan genera *Chnoospora*, *Hydroclathrus*, *Lobophora*, *Padina* and *Turbinaria*; the rhodophytan genera *Amphiroa*, *Hypnea*, *Laurencia*, *Plocamium* and *Polysiphonia* (Tables 5.2 & 5.3). *Lithophyllum* was also present in monospecific stands but it does not form a fleshy thallus.

Only seven genera ever exceeded 2% contribution to the total algal cover (relative abundance) at any time. These primary algal components included the rhodophyte *Laurencia*, the chlorophytes *Enteromorpha*, *Halimeda* and *Chlorodesmis* and the phaeophytes *Hydroclathrus*, *Turbinaria* and *Lobophora*.

The algal turf assemblage on Heron Reef is composed of a dense heterogeneous mixture of prostrate species and the early developmental stages of larger macroalgal species. The Heron Reef algal turf assemblage represents a seral stage which may mature into either a polygeneric or monogeneric macroalgal assemblage unless repeatedly cropped by grazers. Thirty-eight genera and at least 60 species of algae and two genera of cyanobacteria were identified in the algal turf assemblage from Heron Reef during the visual and lavage (Chapter 6) sampling (Table 5.5). The presence and contribution of each of these species varies greatly with time. However, *Caulerpa* spp., *Halimeda* spp., *Amphiroa* spp., *Turbinaria ornata*, *Lobophora variegata*, *Laurencia spp.*, *Acanthophora spicifera*, *Gelidiella acerosa*, *Chnoospora implexa*, and *Hydroclathrus clathratus*. were identified as the principle components of the algal turf association on Heron Reef. Cribb (1966a, b, 1973) and Borowitzka and Larkum (1986) list a similar composition for other Capricorn- Bunker reefs.

Seagrasses were not found on the reef flat of Heron Reef by Cribb (1966a,b; 1973) or on the reef flat or slope during this study; however, fresh samples of three seagrass species were found in the stomach samples of several green turtles feeding in the waters around the reef (Chapter 7). C.J. Limpus (pers. comm.) reports that species of *Halophila* are found in low density at dispersed sites on the reef slope of Heron Reef.

5.3.3 Temporal and Spatial Change in Algal Cover

Five of the seven primary algal components examined varied significantly with time (sampling session) while only the algal turf and *Turbinaria ornata* showed no significant temporal variation in cover (Table 5.6). The temporal changes in the cover of *Chlorodesmis fastigiata*, *Halimeda* spp., *Laurencia* spp. and total algae were spatially complex, varying with habitat as indicated by the significant time by habitat interactions in Table 5.6. There was no apparent or consistent basis for these interactions (Table

5.7, Appendix Figures 5.1, 5.2, 5.3). *Lobophora variegata* and algal turf showed no significant time by habitat interaction although algal turf did show a significant difference in cover between habitats. Only *Laurencia* spp. and *Halimeda* spp. showed a significant difference in habitat cover between transects.

The complexity of the changes in algal cover is further evidenced by consideration of the changes at each habitat (Table 5.8, Appendix Figures 5.2, 5.3). There was a significant interaction between algal component by time in all habitats except Reef Flat South where there was a highly significant algal component main effect. There was a significant interaction between transect and time in three (Reef Slope South, Reef Flat South, Reef Flat North) of the six habitats whilst only Lagoon Patch showed a significant transect by algal component interaction.

Individual means and standard errors plots for the absolute coverage of each algal component within each habitat were produced in an attempt to identify possible causes of the significant effects and interactions seen in the ANOVA results (Appendix Figure 5.2). No such patterns or trends could be identified.

5.3.4 Seasonal Distribution of the Algal Turf

The algal turf assemblage remained the most important component of the algal cover (relative abundance by area; $\overline{X} = 6.09\%$, s.e.=0.48) on Heron Reef during all sampling sessions except in July 1989 when it was exceeded in relative abundance by monogeneric stands of the rhodophyte *Laurencia* and almost equaled by stands of the chlorophyte *Enteromorpha* (Table 5.2). This increase in *Laurencia* and *Enteromorpha* accounts for the decrease in relative abundance of the algal turf assemblage in July. Although there was a decrease in the relative abundance of algal turf in July, there was no significant temporal change in absolute cover.

Working on the reef surrounding Magnetic Island, a continental island of the central Barrier Reef, Morrissey (1980) also found the algal turf assemblage (excluding the crustose coralline algae) to be the most important contributor to the algal flora (50.5% relative abundance compared to 55.8% in this study).

5.3.5 Seasonal Distribution of Chlorophyta

Only three genera of chlorophytan algae (*Enteromorpha* , *Halimeda* , *Chlorodesmis*) contributed more than 2.0% to the total algal cover (relative abundance) of monospecific or monogeneric stands at any time during this study (Table 5.3). *Enteromorpha* was found in the sampling area only once during the study when it reached a relative abundance of 26.57% in the winter (July) of 1989. *Enteromorpha* is a psammophilous alga and it was the most ephemeral alga I encountered on the reef. Under favorable conditions, dense mats of *Enteromorpha* formed where just several days before there had been only a darkening of the sand indicating the beginning of an *Enteromorpha* bloom that would mature into dense "pastures" in excess of 20 cm tall. When present, these pastures could account for more than 26% of the total algal cover (excluding the crustose coralline algae).

Although limited to well lit coral substrates, *Chlorodesmis fastigiata* was present at all times of the year with a summer (January 1989) maximum in relative abundance of 7.57%. *Halimeda* was common in all regions of the reef during all times of the year, reaching a maximum relative abundance of 8.12% in March of 1989. *Chlorodesmis* and *Halimeda* were the only two large thalloid chlorophytes commonly found on the reef slopes.

Species of four additional genera formed monospecific or monogeneric stands at some point during the study but only in trace amounts (relative abundance <2.0%). These species included *Codium* spp., *Valonia ventricosa*, *Chnoospora implexa* and *Caulerpa* spp.. *Caulerpa* was poorly represented in the substrate photographs as the most common *Caulerpa* species on Heron Reef are lithophyllic, growing almost exclusively within crevices in dead coral. This growth may be a defensive response to, or a result of, grazing pressure from herbivores such as green sea turtles, or it may result from other factors. As a result of its cryptic growth habit, *Caulerpa* was not represented in the substrate sampling in proportion to its actual occurrence on the reef.

5.3.6 Seasonal Distribution of the Phaeophyta

Three of the four genera of Phaeophyta that formed monospecific or monogeneric stands exceeded 2.0% of the total algal cover at some time during the study (Table 5.3). *Hydroclathrus clathratus* reached its highest relative abundance of 18.35% during the summer in November of 1988 but was absent from the sampling area during all other sampling sessions, except for July 1989 and March 1990 at which time its relative abundance values were only 0.22% and 0.14%, respectively. *H. clathratus* is a very ephemeral lithophyllic species which experienced blooms under appropriate conditions and produced thalli up to 60 cm long. Large amounts of mature *H. clathratus* often tore loose from the substrate and moved across the reef floor. It is this movement of thalli that accounted for the presence of *Hydroclathrus* in the lagoon sand areas where it does not recruit. During the summer, large amounts of *H. clathratus* accumulated along the shore of the island.

Lobophora variegata also reached its maximum relative abundance (15.67%) during the summer (November 1988) and was missing from the sampling areas only during May of 1989. *L. variegata* was the most important contributor to the phaeophytan algal

cover. *Lobophora* is a lithophyllic species that is an important contributor to the algal turf assemblage in its early growth stages. When mature, *Lobophora* often formed monospecific stands. *Lobophora* was limited to the zones of the reef flat where there was hard substrate available and was absent from the reef slopes.

Turbinaria ornata was a common component of the reef flat and the rubble crest and was present on the reef during each sampling period never exceeding 2.88% in relative abundance. It did not show significant temporal variation in absolute abundance.

Two additional phaeophytan genera, *Chnoospora* and *Padina*, were also found in monogeneric stands but only in trace amounts. Although not present in my substrate data, *Sargassum* is represented by at least three different species on Heron Reef (Dr. K. Edyvane, pers. comm.). *Sargassum* is limited almost exclusively to the reef flat immediately adjacent to the island with the most extensive beds occurring on the south side of the island where it grows along side *Hormophysa triquetra* and dense growths of *Turbinaria ornata*.

5.3.7 Seasonal Distribution of the Rhodophyta

All of the rhodophytan genera forming monospecific and monogeneric stands were observed during at least two sampling periods, but only *Laurencia* exceeded 2.0% of the total algal cover during any sampling session (Table 5.3). *Laurencia* was the most important contributor to coverage of the Rhodophyta with a mean relative abundance of 19.24% (s.e.=4.67) No other rhodophytes even approached this areal cover. *Laurencia* was present in all zones of the reef at all times of the year with blooms occurring periodically, e.g. July 1989, March 1989, 1990. During these blooms, thalli of *Laurencia* dominated the substrate forming a canopy over the algal turf assemblage from which many of the plants of *Laurencia* may have developed.

Polysiphonia was observed in the sampling area only during the May 1989 and July 1989 sampling sessions at which time it reached relative abundance values of 1.44% and 0.19 %, respectively. *Polysiphonia* is a psammophilous species most common in the lagoon sand zone although it also grew epiphytically on turf species. *Polysiphonia* can grow quite rapidly and increases rapidly during favourable conditions.

Other genera forming monogeneric or monospecific stands were *Amphiroa*, *Hypnea* and *Plocamium* although they occurred only in trace amounts. *Plocamium hamatum* was limited exclusively to shaded vertical surfaces within the tongue and spur system along the south reef slope where it formed dense monospecific growths free of epiphytes or interspersion from other species of macroalgae.

5.4 Discussion

There was significant spatial and temporal variation in the absolute cover of the algal species investigated both within and between habitats. However, no obvious trends or patterns have been detected in the data.

Although the distribution and absolute percentage cover of marine algae are influenced by a variety of physical, chemical, and biological factors (Dawson 1966; Cribb, 1966a, 1973; Littler and Littler, 1980; Dawes, 1981), one of most significant factors affecting the distribution of algae on Heron Reef is the availability of hard, stable substrates for thallus attachment. Except for the intertidal beach rock that borders the island, the only hard substrate available for algal attachment is coral. As algae do not grow on live coral and the areal cover of dead coral surfaces is not dynamic in the absence of major distrubances, the significant changes in algal cover observed must be attributed to more

short term changes in other limiting factors such as water temperature, dissolved nutrients and photoperiod.

The very small contribution of bare dead coral to the total reef cover ($\overline{X}$ = 0.29%, s.e.=0.14) (Table 5.1) demonstrates the importance of dead coral as an algal substrate. Most dead coral was colonised by algae and was therefore categorised as algal substrate rather than as "dead coral" per se.

Although Heron Reef owes its genesis to both scleractinian corals and calcareous algae, when the overall substrate composition of the reef is examined, it is clear that living scleractinian and nonscleractinian corals actually account for only a very small percentage of the total reef cover ($\overline{X}$ = 3.40%, s.e.=0.35) (Table 5.1). The contribution of algae (fleshy and crustose coralline) to the total reef cover was over four times ($\overline{X}$ = 14.43%, s.e.=1.17) the combined contribution of scleractinian and nonscleractinian corals, making algae the most abundant benthic biota while nonliving cover accounted for an average of 80.36% (s.e.=1.60) of the total reef area.

As corals are long-lived species and the cover of crustose coralline algae changes slowly over time, I would predict that the areal cover of these two substrate components would change minimally in the absence of major disturbances such as cyclones or crown of thorns seastars (*Acanthaster planci*). Therefore, the November 1988 and March 1990 minima of these two substrate components must be due to factors other than the seasonal dynamics of the coral and crustose algae assemblage. There are two possibilities to explain the observed reduction in the areal cover of these two components. Strong storms had moved across the reef just prior to the November 1988 and March 1990 sampling sessions, shifting significant quantities of sand that temporarily covered the more prostrate growths of coral and crustose algae . As a

result, portions of the components were hidden from view in the substrate photographs. The November 1988 minima in the areal cover of these two components may also be due in part to an increase in the abundance of fleshly macroscopic algae of high stature which obscured adjacent coral colonies. In November 1988 the fleshy algal cover reached the second highest cover level observed during the study (Table 5.1).

If the area available for algal attachment was relatively constant during my study, as seems likely, the significant changes seen in the temporal and spatial composition of the algal assemblage must be due to factors other than substrate availability. If the factors regulating algal growth are constantly changing, as is suggested by the significant spatial and temporal changes in the algal assemblage, herbivores such as the green turtle that forage upon the assemblage need to be able to modify their feeding strategies in order to accommodate the dynamics of their food supply (Ch. 8). One strategy may be to change the composition of the diet while remaining within a constant home range. A second strategy may be to change the home range to accomodate a constant diet.

It may be possible that green sea turtles modify their diet when preferred diet items are scarce or absent. Temporal shifts in the diet of herbivores living in dynamic environments with changing food supplies have been identified in a variety of marine and terrestrial species. Temperate herbivorous fishes are known to switch to less desirable algae species when preferred species become scarce or absent (Horn, 1983). Dugongs are known to increase the amount of algae in their diets when preferred seagrasses are scarce (Spain and Heinshohn, 1973). The Tasmanian bettong (*Bettongia gaimardi*) is a mycophagous marsupial that feeds primarily upon ephemeral hypogeous fungi (Taylor, 1992). When fungi are not available, the bettong shifts towards a frugivorous, spermivorous or insectivorous diet. The potoroid marsupial,

Potorous tridactylus (Bennett and Baxter, 1989), white-tailed deer (*Odocoileus virginianus*) (Brown and Doucet, 1991), ostriches (*Struthio camelus*) (Milton *et al.*, 1994) and many other herbivore groups are also known to change their diets when preferred species become scarce.

Similar temporal shifts in diet have also been observed in omnivores such as whooping cranes and brown bears. When preferred diet items were reduced or absent, whooping cranes (*Grus americana*) were observed to switch to diet items that were previously available but not exploited (Hunt and Slack, 1989). Spanish brown bears (*Ursus arctos*) will modify their diet to incorporate plant materials until the more nutritious hard mast crops become available (Clevenger *et al.*, 1992).

In lieu of shifting to an alternate diet, it is possible that an animal may modify its home range to incorporate areas that offer their preferred diet. Localised spatial shifts have been identified in white-tailed deer (*Odocoileus virginianus*) which will modify their home range to incorporate areas that are producing mast crops of acorns which are an important component of their diet (McShea and Schwede, 1993). As an alternative to localised spatial adjustments to the home range, migrations to access suitable foods have been documented and are well known in many species such as grey whales (*Eschrichtius robustus*), caribou (*Rangifer tarandus*), African ungulates, waterfowl and shorebirds amongst others.

As virtually the entire marine flora of Heron Reef is composed of algae, green sea turtles inhabiting the Reef are limited to foraging amongst an algal assemblage that undergoes significant spatial and temporal changes in composition. Optimal foraging models would suggest that in the face of this variable algal assemblage, green turtles would either have to be dietary generalists within their home range, facultative

specialists (opportunistic specialists) within their home range or modify their home range to accommodate a specialised diet. These options and the strategy used by green turtles on Heron Reef are explored in Chapters 6 and 8.

5.5 Conclusions

1. More than 80% of the reef flat and slopes of Heron Reef consist of nonliving biogenic substrate.
2. Algae account for the greatest areal cover of benthic biota on Heron Reef. Algae cover over four times the area occupied by living corals.
3. Heron Reef supports over 70 genera and a least 115 species of algae and two genera of cyanobacteria. Only 7 of these genera ever exceeded 2% contribution to the total algal cover at any time.
4. The algal turf is composed of a variable and heterogeneous assemblage of 38 genera and at least 60 species of algae and 2 genera of cyanobacteria. The areal cover of the algal turf exceeds the combined cover of monogeneric stands of rhodophyte, phaeophyte and chlorophyte algae.
5. The mean areal coverage of algal groups in decreasing order is as follows; algal turf, Rhodophyta, Chlorophyta, Phaeophyta. This ranking remains unchanged if the crustose coralline algae are excluded from the Rhodophyta.
6. Although no obvious trends or patterns could be detected in the data, in general there is a significant spatial and temporal variation in the absolute cover of the algal species investigated both within and between reef habitats.
7. In order to adapt to the temporally and spatially variable algal assemblage of Heron Reef, green turtles may be foraging as either dietary generalists or facultative specialists within their home range or they may modify their home range to accommodate a specialist diet (Chapter 8).

Table 5.1- Relative abundance (% of area) of various components of the substrate, Heron Reef, Queensland. The data were obtained from photographic sampling within each habitat and have been adjusted to compensate for the differences in the sizes of each habitat.

Sampling Session	Substrate Component	Chlorophyta	Phaeophyta	Rhodophyta	Algal Turf	Total Fleshy Algae	Crustose Coralline Algae[1]	Total Algae[1,2]	Living Hard Coral[1]	Living Soft Coral	Total Living Coral[1]	Total Living Cover[1]	Dead Coral	Sand	Sand & Rubble	Total Sand & Sand/Rubble	Total Nonliving Cover	Unidentified Substrate
Nov-88		1.42	4.54	0.25	6.61	12.82	2.79	15.61	2.23	0.08	2.31	17.92	0.18	58.21	16.67	74.88	75.06	7.01
Jan-89		1.42	0.56	1.53	8.02	11.53	4.19	15.72	3.83	0.21	4.04	19.76	0.04	65.51	14.52	80.03	80.07	0.16
Mar-89		1.29	0.36	2.64	5.49	9.78	2.92	12.70	3.15	0.34	3.49	16.19	0.06	72.48	8.68	81.16	81.22	2.53
May-89		1.39	0.04	1.53	6.07	9.03	3.30	12.33	3.94	0.55	4.49	16.82	0.01	66.32	16.00	82.32	82.33	0.86
Jul-89		4.99	1.02	5.37	4.52	15.90	3.06	18.96	3.12	0.62	3.74	22.70	0.77	66.93	9.55	76.48	77.25	0.03
Mar-90		0.67	0.36	2.48	5.80	9.31	1.94	11.25	2.22	0.26	2.48	13.73	0.67	72.84	12.72	85.56	86.23	0.03
Minimum		**0.67**	**0.04**	**0.25**	**4.52**	**9.03**	**1.94**	**11.25**	**2.22**	**0.08**	**2.31**	**13.73**	**0.01**	**58.21**	**8.68**	**74.88**	**75.06**	**0.03**
Maximum		**4.99**	**4.54**	**5.37**	**8.02**	**15.90**	**4.19**	**18.96**	**3.94**	**0.62**	**4.49**	**22.70**	**0.77**	**72.84**	**16.67**	**85.56**	**86.23**	**7.01**
Mean		**1.86**	**1.15**	**2.30**	**6.09**	**11.40**	**3.03**	**14.43**	**3.08**	**0.34**	**3.40**	**17.85**	**0.29**	**67.05**	**13.02**	**80.07**	**80.36**	**1.77**
s.e.		**0.64**	**0.69**	**0.71**	**0.48**	**1.08**	**0.30**	**1.17**	**0.30**	**0.09**	**0.35**	**1.26**	**0.14**	**2.19**	**1.36**	**1.59**	**1.60**	**1.12**

[1] See section 5.4 for a discussion of the reliability of these November values.

[2] Values represent combined totals for fleshy algae and the crustose coralline species.

Table 5.2- Relative abundance (area) of algae as a percentage of the total reef coverage (biotic and abiotic) including the crustose coralline algae which are not available to green turtles as food; Heron Island Reef, Queensland. The data were obtained from photographic sampling within each habitat and have been adjusted to compensate for the differences in the size of each habitat.

		Percent of Total Reef Coverage (Relative Abundance)									
		Nov-88	Jan-89	Mar-89	May-89	Jul-89	Mar-90	Min.	Max.	Mean[1]	s.e.[1]
	Genus/Species										
Chlorophyta	*Caulerpa spp.*	0.13	0.11	0.02	0.02	0.03	0.00	**0.00**	**0.13**	**0.62**	**0.02**
	Chlorodesmis fastigiata	0.79	0.53	0.47	0.68	0.23	0.32	**0.23**	**0.79**	**0.50**	**0.09**
	Codium spp.	0.00	0.00	0.00	0.02	0.00	0.01	**0.00**	**0.02**	**0.02**	**0.02**
	Enteromorpha spp.	0.00	0.00	0.00	0.00	4.23	0.00	**0.00**	**4.23**	**4.23**	**0.00**
	Halimeda spp.	0.50	0.78	0.80	0.67	0.50	0.34	**0.34**	**0.80**	**0.60**	**0.07**
	Valonia ventricosa	0.00	0.01	0.00	0.00	0.00	0.00	**0.00**	**0.01**	**0.01**	**0.01**
	Total Chlorophyta	1.42	1.42	1.29	1.39	4.99	0.67	**0.67**	**4.99**	**1.86**	**0.64**
Phaeophyta	*Chnoospora implexa*	0.00	0.00	0.01	0.00	0.00	0.00	**0.00**	**0.01**	**0.01**	**0.00**
	Hydroclathrus clathratus	2.35	0.00	0.00	0.00	0.04	0.01	**0.00**	**0.04**	**0.80**	**0.78**
	Lobophora variegata	2.01	0.38	0.24	0.00	0.93	0.08	**0.00**	**2.01**	**0.73**	**0.35**
	Turbinaria ornata	0.17	0.18	0.11	0.04	0.06	0.27	**0.04**	**0.27**	**0.14**	**0.14**
	Total Phaeophyta	4.54	0.56	0.36	0.04	1.02	0.36	**0.04**	**4.54**	**1.15**	**0.69**
Rhodophyta											
	Amphiroa sp.	0.00	0.00	0.04	0.02	0.04	0.02	**0.00**	**0.04**	**0.03**	**0.01**
	Hypnea spp.	0.06	0.01	0.00	0.01	0.06	0.00	**0.00**	**0.06**	**0.04**	**0.01**
	Laurencia spp.	0.19	1.51	2.59	1.38	5.22	2.46	**0.19**	**5.22**	**2.23**	**0.70**
	Plocamium hamatum	0.00	0.00	0.01	0.00	0.02	0.00	**0.00**	**0.02**	**0.02**	**0.01**
	Polysiphonia spp.	0.00	0.00	0.00	0.13	0.03	0.00	**0.00**	**0.13**	**0.08**	**0.05**
	Total Rhodophyta	0.25	1.53	2.64	1.53	5.37	2.48	**0.25**	**5.37**	**2.30**	**0.71**
Algal Turf	Algal turf assemblage	6.61	8.02	5.49	6.07	4.52	5.80	**4.52**	**8.02**	**6.09**	**0.48**

1 Mean and standard error values are caclulated using data only from those sampling sessions during which the species or genus was present.

Table 5.3- Relative abundance (area) of algae as a percentage of the total algal coverage excluding the crustose coralline algae which are not available to green turtles as food; Heron Island Reef, Queensland. The data were obtained from photographic sampling within each habitat and have been adjusted to compensate for the differences in the size of each habitat.

		Percent of Total Algal Coverage (Relative Abundance)									
		Nov-88	Jan-89	Mar-89	May-89	Jul-89	Mar-90	Min.	Max.	Mean[1]	s.e.[1]
	Genus/Species										
Chlorophyta	*Caulerpa spp.*	1.02	0.93	0.19	0.21	0.20	0.00	**0.00**	**1.02**	**0.51**	**0.19**
	Chlorodesmis fastigiata	6.16	4.61	4.79	7.57	1.47	3.44	**1.47**	**7.57**	**4.67**	**0.86**
	Codium spp.	0.00	0.00	0.00	0.22	0.00	0.09	**0.00**	**0.22**	**0.16**	**0.07**
	Enteromorpha spp.	0.00	0.00	0.00	0.00	26.57	0.00	**0.00**	**26.57**	**26.57**	**0.00**
	Halimeda spp.	3.90	6.75	8.12	7.37	3.12	3.65	**3.12**	**8.12**	**5.49**	**0.89**
	Valonia ventricosa	0.00	0.01	0.04	0.00	0.00	0.00	**0.00**	**0.04**	**0.03**	**0.02**
	Total Chlorophyta	11.08	12.31	13.14	15.36	31.36	7.18	**7.18**	**31.36**	**15.07**	**3.44**
Phaeophyta	*Chnoospora implexa*	0.00	0.00	0.07	0.00	0.00	0.00	**0.00**	**0.07**	**0.07**	**0.00**
	Hydroclathrus clathratus	18.35	0.00	0.00	0.00	0.22	0.14	**0.00**	**18.35**	**6.24**	**6.06**
	Lobophora variegata	15.67	3.33	2.47	0.00	5.82	0.88	**0.00**	**15.67**	**5.63**	**2.63**
	Turbinaria ornata	1.34	1.53	1.14	0.49	0.37	2.88	**0.37**	**2.88**	**1.29**	**0.37**
	Total Phaeophyta	35.36	4.85	3.68	0.49	6.41	3.91	**0.49**	**35.36**	**9.12**	**5.31**
Rhodophyta											
	Amphiroa sp.	0.00	0.00	0.45	0.17	0.27	0.25	**0.00**	**0.45**	**0.29**	**0.06**
	Hypnea spp.	0.45	0.12	0.00	0.07	0.36	0.00	**0.00**	**0.45**	**0.25**	**0.09**
	Laurencia spp.	1.52	13.12	26.33	15.24	32.81	26.39	**1.52**	**32.81**	**19.24**	**4.67**
	Plocamium hamatum	0.00	0.00	0.06	0.02	0.15	0.00	**0.00**	**0.15**	**0.08**	**0.04**
	Polysiphonia spp.	0.00	0.00	0.00	1.44	0.19	0.00	**0.00**	**1.44**	**0.82**	**0.63**
	Total Rhodophyta	1.97	13.24	26.85	16.94	33.78	26.64	**1.97**	**33.78**	**19.90**	**4.69**
Algal Turf	Algal turf assemblage	51.58	69.51	55.84	67.21	28.45	62.27	**28.45**	**69.51**	**55.81**	**6.13**

[1] Mean and standard error values are caclulated using data only from those sampling sessions during which the species or genus was present.

Table 5.4- Algae identified from Heron Island Reef during this study and their thallus forms (functional forms). Only the adult thallus form is listed. The thallus groups and their associated characteristics are after Littler and Littler (1980,1989) and Littler *et al.* (1983). See Appendix 5.1 for additional species listed by Cribb (1966a,b, 1984, 1985).

Thallus Form/ Functional Group	External Morphology	Internal Anatomy	Texture	Division[1]	Species	Life Span[2]
Sheet	Thin, tubular & sheet-like (foliose)	Uncorticated, one to several cells thick	Soft	P	*Dictyota bartayressi*	E
				P	*Hydroclathrus clathratus*	E
				P	*Padina sp.*	NE
				R	*Amansia glomerata*	NE
Filamentous	Delicately branched (filamentous)	Uniseriate, multiseriate or lightly corticated	Soft	C	*Cholorodesmis fastigiata* [3]	NE
				C	*Chladophora spp.*	E
				C	*Enteromorpha spp.*	E
				C	*Rhizoclonium sp.*	E
				P	*Ectocarpus sp.*	U
				R	*Polysiphonia spp.*	E
				R	*Tolypiocladia glomerulata*	NE
				CB	*Lyngbya sp.*	NE
				CB	*Microcoleus sp.*	NE
Coarsely Branched	Coarsely branched, upright	Corticated	Fleshy-wiry	C	*Boodlea composita*	E
				C	*Caulerpa brachypus*	NE
				C	*C. cupressoides*	NE
				C	*C. lentillifera*	NE
				C	*C. nummularia*	NE
				C	*C. racemosa*	NE
				C	*C. sertularioides*	NE
				C	*C. webbiana*	NE
				C	*C. sp.*	NE
				P	*Chnoospora implexa*	NE
				R	*Acanthophora specifera*	U
				R	*Centroceras apiculatum*	U
				R	*C. clavulatum*	U
				R	*C. sp*	U
				R	*Ceramium sp.*	U
				R	*Champia parvula*	NE
				R	*C. sp.*	NE
				R	*Chondria minutula*	NE
				R	*C. sp.*	NE
				R	*Chondrococcus hornemannii*	U
				R	*Coelothrix irregularis*	NE
				R	*Coelarthrum boergesenii*	U
				R	*Eucheuma denticulatum*	U
				R	*Galaxaura subfruticulosa*	U
				R	*Gelidiella acerosa*	NE
				R	*G. pannosa*	NE

Table 5.4 (cont.)

Thallus Form/ Functional Group	External Morphology	Internal Anatomy	Texture	Division*	Species	Life Span[2]
				R	*G. sp.*	NE
				R	*Hypnea pannosa*	NE
				R	*H. spinella*	NE
				R	*H. sp.*	NE
				R	*Hypoglossum spathulatum*	U
				R	*Laurencia carolinensis*	NE
				R	*L. intricata*	NE
				R	*L. parvipapillata*	NE
				R	*L. majusculata*	NE
				R	*L. succisa*	NE
				R	*L. sp.*	NE
				R	*Leveillea jungermannioides*	U
				R	*Lomentaria corallicola*	U
				R	*Plocamium hamatum*	NE
				R	*Pterocladia caerulescens*	U
				R	*P. sp.*	U
				R	*Spyridia filamentosa*	U
Saccate/Pulvinate	Cushion-like, sac-like or rugose	Urticlate or vesiculate	Soft and compress-able	C	*Codium spp.*	NE
				C	*Dictyosphaeria sp.*	NE
				C	*Valonia sp.*	NE
Thick Leatherly	Thick blades & branches	Differentiated, heavily corticated, thick walled	Leathery, rubbery	P	*Cystoseira trinoides*	NE
				P	*Hormophysa triquetra*	NE
				P	*Lobophora variegata* [4]	NE
				P	*Sargassum spp.*	NE
				P	*Turbinaria ornata*	NE
Jointed Calcareous	Articulated, calcareous, upright	Flexible genicula, calcified intergenicula	Stony	R	*Amphiroa spp.*	NE
				C	*Halimeda cylindracea*	NE
				C	*H. macroloba*	NE
				C	*H. opuntia*	NE
				C	*H. tuna*	NE
Crustose	Epilithic, prostrate, encrusting	Calcified or unacalcified parallel cell rows	Stony or tough	R	*Lithophyllum spp.*	NE
				R	*Peyssonnelia spp.*	NE

[1]C=Chlorophyta, P=Phaeophyta, R=Rhodophyta, CB=Cyanobacteria

[2]E=Ephemeral species, appearing suddenly on the reef and living for several weeks up to 2 months.
NE=Nonephemeral species persisting >2 months.
UD=Life span undetermined for Heron Reef

[3]Forming a dense entangled tufted thallus with a rhizoidal base

[4]Although not branched as other species of this thallus form, *Lobophora* has a deeply lobate decumbent thallus of clustered corticated fronds.

Table 5.5- The genera and species comprising the algal turf assemblage component, Heron Reef, Queensland. The species listed are known to occur as members of the algal turf assemblage with variable frequency and abundance. Some species will also form monospecific or monogeneric stands.

Rhodophyta
Acanthophora spicifera
Amansia glomerata
Amphiroa sp.
Centroceras apiculatum
C. clavulatum
Centroceras sp.
Ceramium sp.
Champia parvula
Champia sp.
Chondria minutula
Chondria sp.
Chondrococcus hornemannii
Coelarthrum boergesenii
Coelothrix irregularis
Eucheuma denticulatum
Galaxaura subfrut.
Gelidiella acerosa
G. pannosa
Gelidiella sp.
Hypnea pannosa
H. spinella
Hypnea sp.
Hypoglossum simulans
Laurencia carolinensis
L. intricata
L. parvipapillata
L. majusculata
L. succisa
Laurencia sp.
Leveillea jungermannioides
Lomentaria corallicola
Polysiphonia spp.
Pterocladia caerulescens
Pterocladia sp.
Spyridia filamentosa
Tolypiolcladia glomerulata

Chlorophyta
Caulerpa brachypus
C. cupressoides
C. lentillifera
C. nummularia
C. racemosa
C. sertularioides
C. webbiana
Caulerpa sp.
Chlorodesmis fastigiata
Codium spp.
Dictyosphaeria sp.
Halimeda tuna
Halimeda spp.
Rhizoclonium sp.
Valonia sp.

Phaeophyta
Chnoospora implexa
Cystoseira trinodes
Dictyota bartayresii
Hormophysa triquetra
Hydroclathrus clathratus
Lobophora variegata
Padina sp.
Sargassum spp.
Turbinaria ornata

Cyanophyta
Lyngbya sp.

Table 5.6-Temporal and spatial change in algal cover (analysis design #1) by algal component. Transect and time were treated as random factors. Algal component and total algae were the responses.

Total Algae (excluding crustose coralline algae).

Source of Variation	SS	DF	MS	F	Sig of F
Within + Residual	8.97	30	0.30		
Transect (Habitat) (Error 1)	2.38	6	0.40	1.33	0.276
Time	15.27	5	3.05	10.22	0.000
Time * Habitat	21.90	25	0.88	2.93	0.003
Error 1	2.38	6	0.40		
Habitat	31.98	5	6.40	16.11	0.002

Algal Turf

Source of Variation	SS	DF	MS	F	Sig of F
Within + Residual	6.74	30	0.22		
Transect (Habitat) (Error 1)	1.04	6	0.17	0.77	0.600
Time	2.67	5	0.53	2.38	0.062
Time * Habitat	5.81	25	0.23	1.04	0.459
Error 1	1.04	6	0.17		
Habitat	39.58	5	7.92	45.82	0.000

Chlorodesmis fastigiata

Source of Variation	SS	DF	MS	F	Sig of F
Within + Residual	1.72	30	0.06		
Transect (Habitat) (Error 1)	0.54	6	0.09	1.57	0.191
Time	2.79	5	0.56	9.73	0.000
Time * Habitat	4.13	25	0.17	2.88	0.003
Error 1	0.54	6	0.09		
Habitat	15.80	5	3.16	35.21	0.000

Halimeda spp.

Source of Variation	SS	DF	MS	F	Sig of F
Within + Residual	2.45	30	0.08		
Transect (Habitat) (Error 1)	2.70	6	0.45	5.51	0.001
Time	2.74	5	0.55	6.72	0.000
Time * Habitat	6.78	25	0.27	3.32	0.001
Error 1	2.70	6	0.45		
Habitat	4.14	5	2.83	6.28	0.022

Table 5.6 (cont.)

Laurencia spp.

Source of Variation	SS	DF	MS	F	Sig of F
Within + Residual	5.85	30	0.19		
Transect (Habitat)	2.90	6	0.48	2.48	0.045
(Error 1)					
Time	8.22	5	1.64	8.44	0.000
Time * Habitat	14.20	25	0.57	2.91	0.003
Error 1	2.90	6	0.48		
Habitat	15.34	5	3.07	6.34	0.022

Lobophora variegata

Source of Variation	SS	DF	MS	F	Sig of F
Within + Residual	1.40	30	0.05		
Transect (Habitat)	0.46	6	0.08	1.65	0.168
(Error 1)					
Time	0.99	5	0.20	4.22	0.005
Time * Habitat	1.84	25	0.07	1.57	0.117
Error 1	0.46	6	0.08		
Habitat	0.88	5	0.18	2.28	0.172

Turbinaria ornata

Source of Variation	SS	DF	MS	F	Sig of F
Within + Residual	0.70	30	0.02		
Transect (Habitat)	0.28	6	0.05	2.00	0.097
(Error 1)					
Time	0.24	5	0.05	2.10	0.093
Time * Habitat	0.60	25	0.02	1.04	0.458
Error 1	0.28	6	0.05		
Habitat	0.58	5	0.12	2.49	0.149

Table 5.7- Temporal change in the absolute cover of those algal components with significant time by habitat interactions (see Table 6.6). NP=not present, MO=multiple occurrences (≥2 sampling periods).

Algal Component	Habitat	Minimal Absolute Cover	Maximum Absolute Cover
Total Algae	Reef Slope South	Nov-88	Mar-89
	Reef Flat South	May-89	Mar-89
	Lagoon Sand	MO	Jul-89
	Lagoon Patch	Nov-88	Mar-90
	Reef Flat North	May-89	Jul-89
	Reef Slope North	Nov-88	Mar-89
Halimeda spp.	Reef Slope South	MO	Mar-90
	Reef Flat South	May-89	Jul-89
	Lagoon Sand	NP	NP
	Lagoon Patch	Mar-90	May-89
	Reef Flat North	May-89	Mar-89
	Reef Slope North	Nov-88	Jan-89
Chlorodesmis fastigiata	Reef Slope South	May-89	Jan-89
	Reef Flat South	Jul-89	May-89
	Lagoon Sand	NP	NP
	Lagoon Patch	Jul-89	Nov-88
	Reef Flat North	Nov-88	Mar-89
	Reef Slope North	Mar-90	May-89
Laurencia spp.	Reef Slope South	NP	NP
	Reef Flat South	MO	Mar-89
	Lagoon Sand	NP	NP
	Lagoon Patch	Nov-88	MO
	Reef Flat North	MO	Jul-89
	Reef Slope North	NP	NP

Table 5.8-Temporal and spatial change in algal cover (analysis design #2) by habitat. Transect and time were treated as random factors. Algal component and habitat were the responses.

Reef Slope South

Source of Variation	SS	DF	MS	F	Sig of F
Within + Residual	1.84	30	0.06		
Transect	0.72	1	0.72	11.68	0.002
Transect * Time (Error 1)	1.10	5	0.22	3.57	0.012
Transect * Algal Component (Error 2)	0.58	6	0.10	1.56	0.193
Algal Component * Time	7.12	30	0.24	3.86	0.000
Error 1	1.10	5	0.22		
Time	3.74	5	0.75	3.41	0.102
Error 2	0.58	6	0.10		
Algal Component	25.21	6	4.20	43.81	0.000

Reef Flat South

Source of Variation	SS	DF	MS	F	Sig of F
Within + Residual	2.94	30	0.10		
Transect	0.00	1	0.00	0.03	0.861
Transect * Time (Error 1)	2.28	5	0.46	4.66	0.003
Transect * Algal Component (Error 2)	0.31	6	0.05	0.53	0.780
Algal Component * Time	5.06	30	0.17	1.72	0.071
Error 1	2.28	5	0.46		
Time	3.26	5	0.65	1.43	0.352
Error 2	0.31	6	0.05		
Algal Component	29.11	6	4.85	93.35	0.000

Lagoon Sand

Source of Variation	SS	DF	MS	F	Sig of F
Within + Residual	1.66	30	0.06		
Transect	0.03	1	0.03	0.55	0.464
Transect * Time (Error 1)	0.56	5	0.11	2.04	0.101
Transect * Algal Component (Error 2)	0.11	6	0.02	0.34	0.909
Algal Component * Time	15.71	30	0.52	9.49	0.000
Error 1	0.56	5	0.11		
Time	2.74	5	0.55	4.86	0.054
Error 2	0.11	6	0.02		
Algal Component	7.83	6	1.30	68.99	0.000

Table 5.8 (cont.)

Lagoon Patch

Source of Variation	SS	DF	MS	F	Sig of F
Within + Residual	2.12	30	0.07		
Transect	0.48	1	0.48	6.80	0.014
Transect * Time (Error 1)	0.57	5	0.11	1.62	0.186
Transect * Algal Component (Error 2)	1.05	6	0.18	2.48	0.045
Algal Component * Time	5.40	30	0.18	2.55	0.006
Error 1	0.57	5	0.11		
Time	0.37	5	0.07	0.64	0.680
Error 2	1.05	6	0.18		
Algal Component	22.31	6	3.72	21.16	0.001

Reef Flat North

Source of Variation	SS	DF	MS	F	Sig of F
Within + Residual	4.79	30	0.16		
Transect	2.59	1	2.59	16.2	0.000
Transect * Time (Error 1)	2.39	5	0.48	2.99	0.026
Transect * Algal Component (Error 2)	2.01	6	0.33	2.1	0.083
Algal Component * Time	14.23	30	0.47	2.97	0.002
Error 1	2.39	5	0.48		
Time	10.01	5	2	4.19	0.071
Error 2	2.01	6	0.33		
Algal Component	76.42	6	12.74	38.07	0.000

Reef Slope North

Source of Variation	SS	DF	MS	F	Sig of F
Within + Residual	5.85	30	0.19		
Transect	0.11	1	0.11	0.54	0.467
Transect * Time (Error 1)	2.04	5	0.41	2.09	0.094
Transect * Algal Component (Error 2)	2.37	6	0.4	2.03	0.092
Algal Component * Time	11.87	30	0.4	2.03	0.028
Error 1	2.04	5	0.41		
Time	10.12	5	2.02	4.96	0.052
Error 2	2.37	6	0.4		
Algal Component	63.73	6	10.62	26.83	0.000

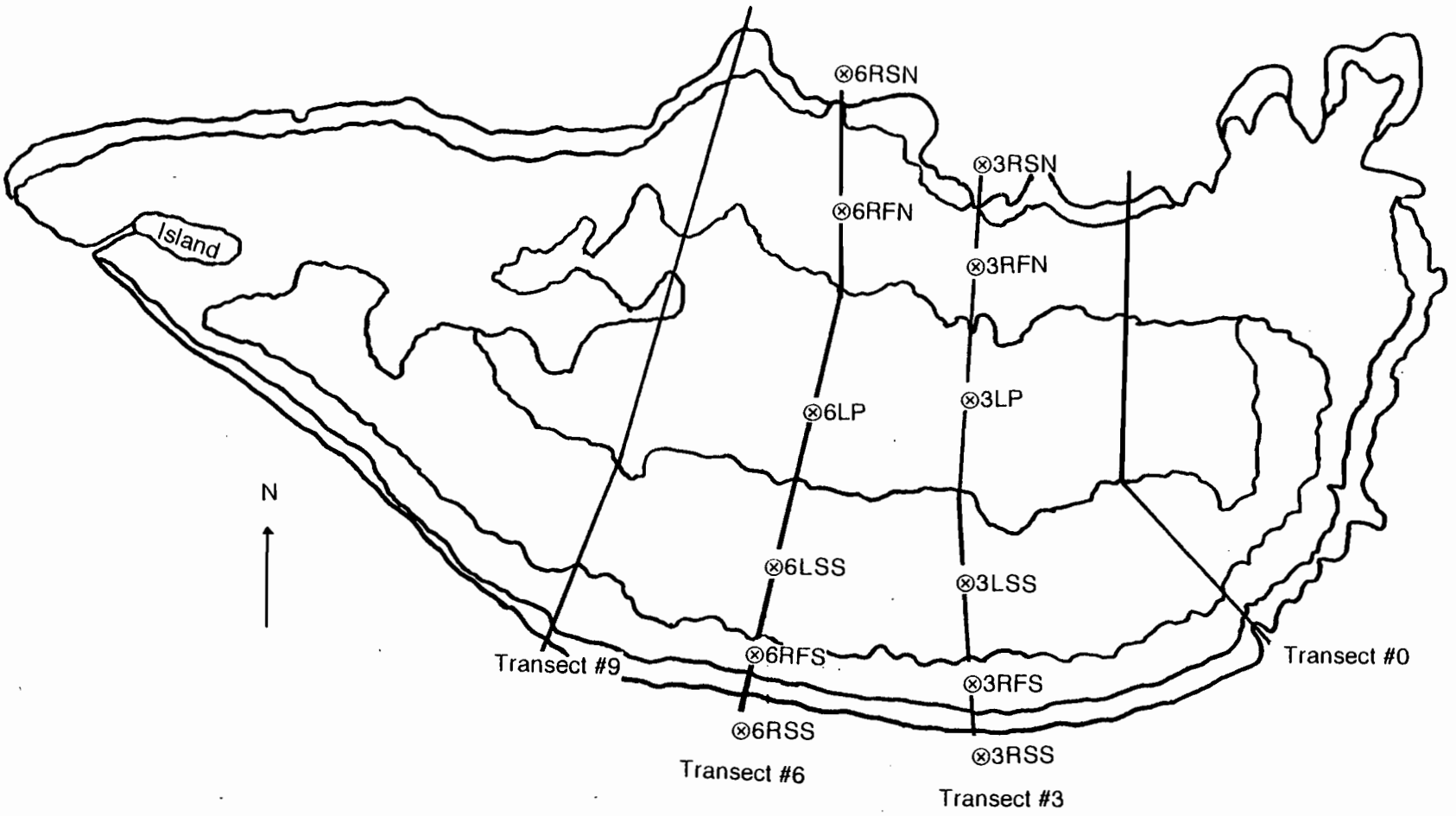


Figure 5.1- Placement of sector marking poles along Transects #3 and #6. Habitats are coded as follows: RSS=Reef Slope South, RFS=Reef Flat South, LSS=Lagoon Sand South, LP=Lagoon Patch, RFN=Reef Flat North, RSN=Reef Slope North.

Chapter 6

Diet of the Green Turtle

6.1 Introduction

Accounts of the diet of the green sea turtle have appeared in the literature since the turn of the century (Chapter 2). However, most of these accounts have been anecdotal or qualitative descriptions based generally upon a few animals or a single sampling period. Studies investigating the feeding ecology of the green turtle are limited in both number and scope. This chapter examines the relationship between the composition of the diet and the age class, sex and food preferences of green turtles. Chapter 9 evaluates the influence of nutritive quality, forage availability and optimal foraging strategies upon diet composition.

This study demonstrates that green turtles on Heron Reef are algivores that forage selectively in the turf community while actively exploiting desirable ephemeral species growing in monogeneric stands. Animal matter is rarely consumed and then mostly by juveniles. The diet varies significantly between age classes and over time but not between sexes.

6.2 Materials and Methods

6.2.1 Evaluation of Diet Sampling Techniques

The feeding habits of turtles can be determined by a variety of methodologies including the analysis of samples from dead or moribund wild turtles (Balazs, 1980b; Shoop and Ruckdeschel, 1982; Plotkin and Amos, 1988; Ruckdeschel and Shoop, 1988; Stanley *et al.*, 1988; Plotkin, 1989; Shaver, 1990; Wershoven and Wershoven, 1992 and others). However, care needs to be exercised in the interpretation of these results as the diets

of these animals may not reflect the diets of healthy individuals. Additionally, as is the case for many diet sampling methodologies, a single sample provides information relating to that animal's diet at only one point in time.

Food habits may also be inferred from observations of animals feeding in the wild (Bjorndal, 1980; Balazs, 1980b; Ogden *et al.*, 1983; Williams, 1988). However, the difficulties of approaching and observing free ranging turtles underwater precludes such studies under most circumstances. To date, observational techniques have provided only qualitative data on the feeding habits of sea turtles. Underwater surveys aimed at locating evidence of turtle feeding activity have also been made (Bjorndal, 1979; Ogden *et al.*, 1983; Vicente and Tallevast, 1995). This technique is based upon the ability to locate physical evidence of turtle cropping, e.g. seagrass grazing plots, bite marks in sponges and gorgonians. The reliability of this technique is a function of the ability of the observer to locate and identify accurately turtle cropping marks on sessile benthic organisms. As green turtles feeding in algal communities rarely leave evidence of their feeding activities (pers. obser.), this technique is of limited value and yields only a qualitative description of diet.

The collection of food fragments from the mouths of turtles captured in the wild also provides information on their diet (Balazs, 1980b; Limpus and Reed, 1985a; Read, 1991). However, the sample present may represent only those dietary items that are hard to swallow (e.g. the tentacled hydrozoan *Physalia*) or are impinged upon various buccal structures such as the papillae of the nasal choanae (e.g. the alga *Gelidiella*). Therefore, although this technique will provide insight into the diet, care should be exercised in attempting to describe the breadth of the diet utilising this technique exclusively.

Data on the food habits of wild sea turtles have also been obtained from the examination of faeces (Bjorndal 1979a; Moodie, 1979; Ogden et al, 1983; Morreale and Standora, 1992; Balazs *et al.*, 1994) however, collecting faecal samples is problematic and time consuming. Faeces produced by free ranging turtles and collected from the flotsam are limited in the information they can provide with our present knowledge. It may be difficult to verify the species that produced the sample let alone the age class and sex. As an alternative to collecting faeces from the flotsam, Bjorndal (1979a) and Moodie (1979) collected faeces by fastening collection bags around the cloacae of semi-wild turtles. Moving wild turtles into a captive situation until they defecate (Moodie, 1979; Ogden *et al.*, 1983) circumvents some of these problems but this option is usually limited by time constraints and the availability of facilities.

The quantitative data available from faecal analyses are limited by the differential digestibilities of various dietary components which affects their representation in the faeces when measured both volumetrically and gravimetrically. Green turtles feeding on algae produce faeces with highly digested components making identification of the algal components difficult. Attempting to quantify a component's importance to the diet by its gravimetric contribution to the faeces has several serious drawbacks. Diet items with a high ash content and therefore high relative weight, e.g. calcareous algae, sponge spicules, exoskeletons, will be overestimated. Conversely, gravimetric analysis underestimates diet items with a high water content as much of the water has been removed by the time the faeces are formed. Gravimetric procedures are further limited by the tendency of some food items to rehydrate or dehydrate when excreted into the water thereby affecting their contribution to the weight of the faecal sample.

Examination of the digestive tract contents from healthy turtles captured in the wild and then sacrificed will also yield information on diet. However, the ecological and ethical

implications of sacrificing sea turtles generally preclude this technique unless turtles are taken incidentally in fisheries activities or directly in traditional fisheries. Also, this practice would prevent additional samples from the same individual.

The objectives of this study required a technique which would allow the sampling of digesta from living, free ranging turtles of known sex and age class. As I also wanted to sample individual turtles on multiple occasions, gastric lavage or stomach flushing was the only technique appropriate for this type of sampling scheme. Various techniques of gastric lavage have been employed for freshwater turtles (Legler, 1977; R. J. Parmenter, 1980), sea turtles (Balazs, 1980; Mendonca, 1983; C.J. Limpus, pers. comm.) and in other vertebrate groups as reviewed by Legler (1977). In association with Dr. Colin Limpus, a new system of non-lethal gastric lavage for sea turtles was developed (Forbes and Limpus, 1992, 1993) from modifications of the techniques previously cited (Appendix 6.1). This system allows for the rapid retrieval of large volumes of food from the oesophagus and anterior stomach regions of sea turtles ranging in size from approximately 25 cm CCL to more than 115 cm CCL (Appendix 6.1). In order to assess the safety of the lavage procedure, the intestines of turtles that had just been lavaged were examined laparoscopically by Dr. C.J. Limpus. No evidence of bloating of the intestine of other signs of digestive tract distress were found during this study. The lavage procedure did not appear to interfere with the normal activities of the turtles. Many turtles were recaptured the following day while feeding and adult females were found nesting several days after a lavage procedure.

A limitation of all of the techniques that examine stomach contents is that plant material may remain relatively undigested in the digestive tract of green turtles for days to several weeks depending upon the physiological status of the animal (C.J. Limpus, per.

comm.; Read, 1991). This may make it difficult to determine when and where the last meal was taken.

6.2.2 Evaluation of Techniques for Determining the Contribution of Diet Components

The quantitative estimation of a species' contribution to a digestive tract sample can be determined from its contribution to the total sample weight or to the total sample volume. Many studies of turtle diet have been based upon the relative importance of dietary components as a function of their contribution to the total weight of the sample (gravimetric analysis) (R. J. Parmenter, 1980; Mendonca, 1983; Garnett *et al.*, 1985 and others). Care must be exercised in this procedure as unless each of the diet components has nearly the same weight to volume ratio, the contribution of some species of both plant and animal will be over estimated while others will be underestimated.

Water and ash account for most of the weight of marine plants (Dawes *et al.*, 1979; Dawes, 1981). Since dietary studies are normally based upon the dry weights of forage species, ash remains the primary contributor to weight. Therefore, those forage species with higher ash contents will contribute more to the total sample weight than those with lower ash contents and will therefore be assigned a greater importance in the diet. The voluntary intake of diet items by ruminants has been shown to be, in part, a function of the volume of food in the digestive tract and not the weight of food in the digestive tract (Van Soest, 1965, 1982). Therefore, assessing the relative value of a diet component as a function of its gravimetric contribution may result in inaccurate conclusions. Due to this limitation, volume was used as the parameter by which the relative importance of each dietary component was assessed in this study.

6.2.3 Lavage Content Analysis

The relative volumes of each dietary component were determined utilising the principles of microstereology (Weibel, *et al.*, 1966; Schaefer, 1970) and a modification of the quantitative technique described by Channells and Morrissey (1981). Microstereology is based upon the principle that the volumetric proportions of a component in a sample can be deduced mathematically from point counts made on a squared grid of dots superimposed upon the surface of the sample.

Each lavage sample was emptied into a large plastic tray and mixed until visually homogenous. A subsample sufficient to cover the bottom of two 10 cm diameter Petri dishes was removed and spread across the dishes to a depth at which substage light could still be transmitted through the sample in sufficient amounts to illuminate the sample. The subsamples were viewed under a Bausch and Lomb® stereo zoom (0.7x-3.0x) dissecting microscope with 10x wide-field ocular lenses fitted with a Weibel graticule (Bunton Instruments, Rockville, Maryland, U.S.A.) consisting of twenty-one straight lines arranged in three rows of seven lines. Filamentous species of algae were viewed with substage lighting transmitted through a blue filter to enhance cellular definition.

Sampling field locations (13mm x13mm) were marked and numbered sequentially every 4 cm along the circumference of the Petri dish. The Petri dish was rotated within a stage mounted template until the sampling field lined up with an indicator line on the stage template. The contribution of each diet component to the volume of a sample was determined by counting the number of graticule line endpoints that it intercepted (21 lines x 2 end points = 42 potential intercepts).

The number of fields required to ensure adequate analysis of the lavage sample was determined by sampling a series of the most diverse lavage samples and plotting the results. The lavage samples were analysed to determine the point at which there was no significant increase in the number of species added with the addition of another sample field and at what point the cumulative percent contribution of each species leveled off. The cumulative percent contribution of each species in each of the samples leveled off at 6-7 sample fields. The number of new species occurring in the samples leveled off at 12 sample fields. To insure adequate sampling, 16 fields (8 per Petri dish) were sampled from each lavage sample. The sampling of 16 fields with 42 intercept points each required the identification of diet components at 672 intercept points per lavage sample for a total of over 337,000 identifications over the course of my study.

A reference collection of Heron Reef algae was made by preserving segments of thallus in 6.5% formalin/seawater solution in screw top vials. Since relatively large pieces (1-10 mm) of undigested thallus were present in the lavage samples, a reference collection of naturally colored algal thalli proved of greater benefit than stained sections mounted on microscope slides. Most of the algae in the lavage sample could be identified from their external morphology under a dissecting microscope with transmitted light. When observation of cellular structure was necessary, thalli were sectioned with a scalpel, stained and viewed under a compound microscope. Algal species were identified to the lowest taxon possible using Cribb (1966,1983) for the Rhodophyta. The Chlorophyta and Phaeophyta were identified using Womersley (1984,1987), Cribb (1966 a, b; 1985) and Littler *et al.* (1989). Seagrasses were identified from Lanyon (1986). Herbarium specimens from the James Cook University herbarium collection and the University of Queensland, Heron Island Research Station herbarium collection were used as reference standards. Verification and assistance in the identification of

difficult specimens was provided by Dr. Ian Price of James Cook University, and Dr. Karen Edyvane of the South Australian Department of Fisheries.

6.2.4 Explanation of Sample Populations

The data set contains information from lavage samples taken from animals captured within the study site (sectors 0-9) and also from areas peripheral to the study site. In order to address the objectives of this study, it was necessary to separate these data groups in some analyses while in other analyses, these data were treated together. Descriptions of these sample populations and the analyses in which they were used are presented in Table 6.1.

6.2.5 Statistical Analysis

6.2.5.1 Diet Preference

Numerous studies have focused upon the relationship between the occurrence of an item in a species' diet and its occurrence in the environment as a basis for evaluating diet preference. In order to quantify this relationship, many electivity, selectivity or preference indices have been developed (e.g., Ivlev, 1961; Jacobs, 1974; Swanson *et al.* 1974; Gilmer *et al.*, 1975; Chesson, 1978; Strauss, 1979; Vanderploeg and Scavia, 1979 a,b; Johnson, 1980). A review of these indices is provided by Johnson (1980) and by Lechowica (1982).

The validity of many of these indices is a function of the accuracy with which the investigator determines that a diet item is available to the animal. The inclusion or exclusion of a single item may significantly alter the index results (Johnson, 1980). Many indices such as Ivlev's Forage Ratio E' (Ivlev, 1961), Strauss' Linear Index L (Strauss, 1979) and Vanderploeg and Scavia's relativised E^* index (1979b) are also sensitive to the inclusion of diet items that are rare or only moderately common in either

the diet and or environment. Indices such as Ivlev's Forage Ratio E' (Ivlev, 1961) suffer from marked asymmetry over the full range of utilisation and availability while Chesson's α (Chesson, 1978) and Vanderploeg and Scavia's W (Vanderploeg and Scavia, 1979a) are also nonlinear and the pattern of asymmetry will shift as the number of diet items changes (Lechowica, 1982).

To circumvent the inherent problems associated with the electivity or preference indices, a preference ranking system was used. One of the significant benefits of ranking procedures (e.g. Thompson, 1965; Mulkern, 1967; Landenberger, 1968; Pyke *et al.*, 1977; Johnson 1980) is that they are more robust than the indices discussed above. Ranking is less sensitive to the inclusion or exclusion of questionable diet components and to sampling errors in the assessment of availability. Statistical methods utilising ranks do not necessarily result in a significant loss of information (Lehmann, 1975) and are more robust to violations of the basic assumptions of the analysis e.g., normality (Johnson, 1980). Measurements of relative preference are statements of selection order rather than absolute preference and avoid the ecological errors associated with the latter (Johnson, 1980).

The resource preference ranking system of Johnson (1980) was used as it accommodates tests of significance that allow comparisons between dietary components. The Johnson system uses the difference between the rank of the usage of a dietary item (consumption) and the rank of availability of that item in the animal's habitat. This difference can be averaged across animals to obtain a mean for each component. The averages of each dietary component can then be compared to determine which components are more preferred. When the dietary components are ordered by their average differences, the resultant ranking will be from least to most preferred. Data for the Johnson ranking index were analysed using the Prefer 5.1

statistics package (Prefer, 1995). F values were calculated with I - 1 and J - I + 1 degrees of freedom where I = number of diet components and J = number of individual turtles. Critical values for the Waller-Duncan significance tests (Waller and Duncan, 1969) were calculated at K=100 which is analogous to a Type I significance level of P =0.05.

Preference percentiles were calculated for each dietary component. The preference percentile represents the ranking of a component relative to the total number of components present and is inversely related to the order of ranking of each component e.g., a component ranked number 1 of 10 components would be in the 90th preference percentile.

Care must be exercised in interpreting rank data. The rank data indicate only that dietary preference exists based upon the usage of the diet item as a function of its availability to the turtle. A high preference ranking does not necessarily imply a high level of importance to the diet. A diet item may rank number one in preference but last in its contribution to the volume of the pooled diet. For example, *Gelidiella* ranked number one in preference in the diet in November, 1988 but contributed <2.0% to the pooled diet of turtles feeding in monogeneric stands. Contrastingly in July, 1989, *Enteromorpha* ranked only 5 out of 10 genera but represented 90% of the pooled diet volume for turtles feeding in monogeneric stands.

The hypothesis that all diet items consumed were equally preferred by animals feeding amongst monogeneric stands of algae was tested for all sampling sessions except March, 1988 (no substrate cover information was available for that date). When the same turtle was captured more than once during the same sampling session, only the first lavage sample was used for this data set. As the composition of the algal turf could

not be quantified (see Chapter 5), turtles feeding on algal turf were eliminated from these analyses. Therefore the diet preference analysis was limited to turtles that had most recently fed amongst monogeneric stands of algae. I initially considered lavage samples to have originated from turtles feeding amongst monogeneric stands if upon macroscopic examination of the sample, no more than a single genus could be readily detected. As the individual pieces of algae present in the sample were relatively large (1-10mm), the primary genus was easily identified. This initial visual analysis was conducted on 507 samples prior to their microscopic examination and quantification (see Section 6.2.3). Following quantification of the lavage samples under the microscope, I found that those samples classified as originating from turtles feeding amongst monogeneric stands of algae had a single genus account for ≥75% of their volume. Samples that I harvested from monogeneric stands of algae across the reef showed a similar contribution from the primary genus. Those genera comprising the balance of the harvested samples included epiphytic algae and thalli from other genera interspersed in the otherwise monogeneric stands of the primary genus. This would also be true for the lavage samples. Therefore, lavage samples containing ≥75% of one genus were considered to have originated from monogeneric stands of algae.

6.2.5.2 Contribution of Algal Genera to Diet

The mean and ranges of values for the volume of each dietary component for individual diets were calculated across those samples containing that component. This was done for all turtles irrespective of whether they were feeding in monogeneric or algal turf stands. This procedure provided an indication of the relative importance of each dietary item to those turtles consuming it whereas the pooled diet values were calculated across all samples to provide an indication of the relative importance of each dietary item to the population of green turtles on Heron Reef. Since some turtles consumed one species exclusively while other turtles were quite diverse in their diet,

measurements of central tendency were of limited value. Therefore, the number of turtles in which a genus contributed to ≥5%, ≥25% and ≥50% of the volume of an individual's diet was also calculated to provide information on the importance of the item in the diet.

As almost 80% (78.4%) of the algal genera consumed by turtles feeding in monogeneric and or algal turf stands never exceeded 5% of the volume of the pooled diet, dietary components comprising <5.0% of the pooled or individual diet volumes were considered trace or incidental components of the diet whereas those accounting for ≥5.0% were considered primary components. Using 5% as the demarcation for incidental components also allowed comparison with Garnett *et al.* 's (1985) diet study results from northern Queensland.

6.2.5.3 Variation in Diet Across Individuals and Over Time

In addressing the question of variation in the diet, the data were analysed to determine if there was a significant difference in diet between: 1) individuals, sexes, age classes and sampling occasions; 2) repeated captures of the same individual. The percent contribution of each dietary component to the volume of a lavage sample was used as the response. Only the data from the first capture of each animal during a sampling occasion was used ("first capture data set") in the analyses except in the data set of repeatedly captured individuals. In this data set, data from all captures of an individual were used to compare with the "first capture data set". Before assessing differences between individuals in these analyses, the factors in this model were fitted using a sequential sums of squares in order to take into account any possible trip and age class effects.

Initial exploratory analyses of the data using boxplots and descriptive statistics indicated extremely skewed distributions due to the dominance of zero values for the 48 diet components examined across all individual diets (n=384 turtles). Further exploration indicated that 13 of the original 48 diet components contained the majority of the information relating to variation in the diet. All subsequent analyses were performed on these components. The data were log transformed ($\log_{10}$+0.1) to improve distributions and satisfy the assumptions of parametric statistics. Principal component analysis was used to explore any multivariate relationships that may exist in the data for the three factors of interest: Sampling $Occasion_7$ (Mar. 88, Nov. 88, Jan. 89, Mar. 89, May, 89, Jul. 89, Mar. 90), Age $Class_3$ (juvenile, subadult, adult) and Sex_3 (male, female, indeterminate). Biplots were produced to explore the spatial relationships between these factors with the variables (algal genera) represented by vectors and the observational units (individual turtles) displayed as points coded to represent either sampling occasion or age class. Correlation between variables is indicated by the angles between their respective vectors with correlation increasing as the angles between the vectors decrease. Right angles between vectors indicate no correlation while opposing vectors show negative correlations. The distributions of the observational units around each vector represent the relative weighting of each unit upon that variable. Groups of observational units clustered around a vector suggest that multivariate relationships may exist. Possible multivariate relationships indicated by the principal component biplots were investigated using both multivariate and univariate analyses of variance. Tests of significance were assessed at α=0.05.

The data for the individuals captured on multiple occasions (n=60 turtles) could not be treated in a repeated measures analysis as the recapture of individual turtles was irregular in both the number of recaptures and recapture of individuals in sequential sampling occasions. Therefore the data were analysed using multivariate and

univariate analyses of variances tests with factors fitted using a sequential sums of squares in order to take into account the occasion or seasonal effect before assessing the differences between individuals. Tests of significance were assessed at α=0.05.

6.2.5.4 Variation in Diet Strategy

To investigate the possibility of a change in the diet strategy (monogeneric vs. algal turf feeders) of green turtles as a function of their age classes (juvenile, subadult , adult) or sampling occasion, analyses were conducted using a loglinear modelling technique and analysis of deviance to assess changes in deviance between models using likelihood ratio Chi-square tests. The optimal model was selected when a significant increase in the deviance was detected between models. The optimal model was: count ~ constant + sampling occasion + age class + diet strategy + (sampling occasion * age class) + (sampling occasion * diet strategy) + ε.

6.3 Results

6.3.1 Diet Components

A total of 507 lavage samples was analysed from green turtles captured within the study site and peripheral areas with 435 samples originating from the study site. A total of 340,704 individual identifications of diet items was made from the lavage samples. Forty-one genera and at least 66 species from 15 orders of the Chlorophyta, Phaeophyta and Rhodophyta were identified from the samples including ~19 species of Chlorophyta from 5 orders and nine genera, nine species of Phaeophyta from 3 orders and 9 genera and ~38 species of Rhodophyta from 6 orders and 23 genera (Table 6.3). Twenty-nine genera of algae that are known to occur on Heron Reef (see Chapter 5) were never found in the lavage samples. These species were most commonly algal turf species with very small thalli.

Genera from each of the three algal divisions were present in the lavage samples from the study site and peripheral areas during all sampling sessions. The relative contribution (rank order) to the volume of the individual and pooled diets by each algal division was dynamic and changed during each sampling session (Table 6.4). Overall, the Rhodophyta ranked as the most important contributor to diet volume followed by the Phaeophyta and Chlorophyta. Most green turtles ($\overline{X}$ =70.4%, s.e.=1.05, range=40.3-74.5%) concentrated their foraging activity in the algal turf assemblage but opportunistically exploited preferred monogeneric stands when available as was the case in July, 1989 when a bloom of the chlorophyte *Enteromorpha* occurred (Table 6.2). At this time, only 40.3% of the turtles continued to feed in the algal turf even though there was no reason to assume that their access to the *Enteromorpha* areas was restricted.

Lavage samples were successfully retrieved from animals of both sexes and all age classes. Five females captured during this study were confirmed to be nesting on Heron Island within two weeks of their capture. Although lavage samples were obtained from each of these animals, the volume was less than 200 ml even after repeated efforts at obtaining additional sample. Animals of breeding size normally produced in excess of 1-2 litres of sample. The low volume of digesta retrieved from nesting females suggested that they were not feeding actively.

During this study, only 12 genera ever exceeded incidental amounts (≥5%) in the pooled diet of the study site turtles (Table 6.5). The phaeophyte *Turbinaria* was the greatest contributor to the pooled diet volume during four of the seven sampling periods (Nov. '88, Jan. '89, May '89, March '90). In three of these sampling periods (Nov. '88, Jan. '89, May '89) *Turbinaria* contributed more to the diet volume than did all of: (a) the combined chlorophytan genera, or (b) the combined rhodophytan genera. In the

remaining session (March, 1989), the volume of *Turbinaria* was greater than that of the Chlorophyta and Rhodophyta genera combined. The rhodophyte *Laurencia* was the greatest contributor to the pooled diet volume in two of the sampling periods (March 1988 & 1989). In March 1989, *Laurencia* contributed more to the diet volume than did all of the combined chlorophytan genera and in March 1988, *Laurencia* contributed more than the combined phaeophytan genera. In the remaining sampling session, the chlorophyte *Enteromorpha* was the greatest contributor to the pooled diet volume with more than four times the contribution of the rhodophytan and 38 times the contribution of the phaeophytan genera.

An average of 23 genera (s.e.=1.83) and 34 species (s.e.=2.5) of algae were present in all of the lavage samples collected from the study site during each sampling occasion (Table 6.6). On average, less than one quarter (21.6%, s.e.=0.80) of the genera in the diet of turtles from this area ever exceeded incidental contributions whereas in individual diets, 62.3% (s.e.=1.54) of the genera exceeded incidental amounts. Less than 1% (0.6%, s.e.=0.14) of the genera present ever contributed ≥50% to the pooled diet of all animals sampled at the study site and only a quarter (25.9%, s.e.=0.87) of the genera ever contributed ≥50% to an individual's diet. These results suggest that Heron Reef green turtles do not concentrate their foraging in monogeneric stands of algae but instead concentrate their efforts in the algal turf.

In addition to algae, incidental amounts of two species of macroscopic filamentous cyanobacteria were identified from two genera (*Lyngbya*, *Microcoleus* , Order Oscillatoriales). In May 1989, incidental amounts (several leaves) of two seagrasses species (*Halophila decipiens*, *H. ovalis*) were found in three samples while *H. ovalis* occurred in excess of incidental amounts (15.2%) in a single sample.

Animal material was present in some lavage samples in incidental amounts. Animal matter averaged 1.6% (s.e.=0.5) of the pooled diet from the animals sampled at the study site. The only whole-bodied animals identified from the lavage samples were the hydrozoan *Physalia*, sponges, polychaete worms, amphipods and polyps of octocorals. Additional animal matter included mollusc eggs, mollusc eggs casings (post hatch), polychaete worm tubes, mollusc shell fragments and arthropod exoskeleton fragments. Sand and coral skeleton fragments were found in incidental amounts in limited number of samples. Anthropogenic material in the diet was absent except for a small piece of plastic in a single sample.

Appendix Tables 6.1-6.21 indicate the contribution of each diet component to the pooled and individual diets during each sampling occasion.

6.3.2 Diet Preference

Rank orders of preference for diet items were produced for all sampling sessions (Table 6.7) as were significant differences in preference between individual diet items (Appendix Tables 6.31-6.36). The preference ranking of the algal diet items varied between sampling sessions (Table 6.8).

The rhodophyte *Gelidiella* had the highest mean preference percentile value ($\overline{X}$=83.0, s.d.=7.53) followed by the phaeophyte *Sargassum* ($\overline{X}$=70.3, s.d.=7.67). The lowest mean preference percentile value was found in the chlorophytes *Halimeda* (9.6, s.d.=6.45) and *Chlorodesmis* ($\overline{X}$=5.0, s.d.=10.00). Although *Gelidiella* and *Sargassum* had high preference percentile values, their contribution to the pooled diets of turtles feeding in monogeneric stands was only 4.7% and 4.8% respectively, with most of the contribution originating from few individuals.

Not all algal species occurring in monogeneric stands were consumed even though some species were locally abundant e.g., *Plocamium*. However, none of these genera ever represented more than 0.5% of the total reef algal cover (Tables 5.3 & 6.8). Contrastingly, the rhodophyte *Gelidiella* was never found in monogeneric stands during the benthic surveys but was present in the diet of monogeneric feeders during each sampling session. Due to their prostrate coralline thallus form, the crustose algae are unavailable to green turtles and therefore never occurred in the diet despite their relative abundance in monogeneric stands. Green turtles rarely fed upon monogeneric stands of the chlorophytes *Chlorodesmis* (0-20th preference percentile) and *Halimeda* (0-18th preference percentile) or the phaeophyte *Hydroclathrus* (0-40th preference percentile) regardless of their availability. On those occasions when these species were consumed, a few animals ingested only incidental amounts.

Juvenile and subadult green turtles also exhibited a preference for the hydrozoan *Physalia*. On three occasions (3/88,1/89, 3/90) *Physalia* were swept across the reef flat over a period of 1-2 days. During each such event, *Physalia* would immediately appear in the diet (with a relative frequency of 15.7%, 30.8%,6.7% respectively, in the diet of juveniles and 13.3%, 26.7%, 0.0% respectively, in the diet of subadults). Ingestion of *Physalia* was not incidental to algal feeding as *Physalia* float at the surface and it was common to see juvenile and subadult turtles at the surface gulping at the *Physalia*.. Adults were not observed taking *Physalia* at the surface and only one adult was ever found to have consumed *Physalia* compared with 9 juveniles and 10 subadults.

6.3.3 Individual, Age Class and Temporal Variation in Diet

Principal components analysis did not suggest any differences in diet between the sexes and this was later confirmed with multivariate analysis of variance for the 13 diet

components investigated. However, exploratory data analysis did suggest the possibility of differences and multivariate relationships for Sampling $Occasion_7$ and Age $Class_3$. The principal components plots (Figure 6.1 & 6.2), error bar graphs (Appendix Figure 6. 1) and boxplots (Appendix Figure 6.2) suggest that the age class effects observed may be a result of the differences found between the juveniles and the adults rather than the subadults. These relationships were examined using multivariate and univariate analyses of variance.

A multivariate analysis of variance performed on this data set with the 13 diet components as dependent variables and $Occasion_7$ and Age $Class_3$ as independent variables showed that the multivariate Occasion * Age Class interaction was significant (Appendix Table 6.22). However as can be seen by the small F ratio, the relationship in this interaction is weak. In an attempt to identify those genera that may have contributed to this interaction, univariate analyses of variance for each genus were performed. The univariate results indicated that interactions between Occasion and Age Class for *Enteromorpha*, *Turbinaria*, *Gelidiella*, *Laurencia* and *Polysiphonia* may have been responsible for the interaction identified in the multivariate analysis (Appendix Table 6.22). However, these main effect contrasts are confounded by the weak but significant multivariate interaction. Examination of the principal components plots (Figures 6.1 & 6.2) and boxplots (Appendix Figures 6.3-6.5) did not reveal any apparent patterns of change across these or other components. The identification of patterns across the genera is made even more difficult by the absence of many of the species over several sampling occasions and also by the skewed distribution of a genera within a sampling occasion (Appendix Figure 6.6). Although the contrasts also failed to identify any such patterns, a strong correlation between *Enteromorpha*, *Polysiphonia* and the July, 1989 sampling occasion is shown in the principal components plot whereas all other sampling occasions are spread around the biplot

indicating that strong correlations are not present between the other genera and individual sampling sessions.

Multivariate analysis showed that the main effects of Age Class and Occasion were also significant (Appendix Tables 6.23 & 6.24). Univariate tests showed a significant Age Class effect for all components except *Codium*, *Sargassum* and *Champia* and a significant Occasion effect for all diet components. Principal component analysis indicated that the diet of turtles from the July, 1989 sampling occasion could be discriminated from all other occasions (Figure 6.1). Removing the July, 1989 data from the data set did not reveal any additional groupings.

The principal components plots (Figure 6.2) and error bar graphs (Appendix Figure 6.1) suggest that the age class effects observed may be a result of the differences found between the juveniles and the adults, however, there was no consistent pattern across the diet components. The age class main effects contrasts indicate that juveniles differ significantly from adults in their consumption of *Halimeda*, *Turbinaria*, *Coelothrix*, *Enteromorpha*, *Lobophora* and *Gelidiella*. (Appendix Figure 6.1). Subadults differ from adults for *Enteromorpha*, *Lobophora, Caulerpa*, *Hypnea*, and *Polysiphonia*. and *Gelidiella*. There are no age class differences in the consumption of *Codium*, *Sargassum*, *Champia* or *Laurencia*. The main effect contrasts described above for the genera *Enteromorpha, Turbinaria, Coelothrix, Gelidiella*, *Laurencia, Polysiphonia* should be interpreted carefully as significant interactions between Occasion and Age Class confound the main effect contrasts for these genera.

The principal component analysis biplot (Figure 6.2) shows that adults cluster around the vectors for *Turbinaria*, *Enteromorpha* and *Polysiphonia* indicating that these genera are important components of the adult diet. Similarly, juveniles cluster around

the vectors for *Gelidiella*, *Laurencia*, *Champia*, *Sargassum*, *Coelothrix*, *Halimeda*, *Caulerpa*, *Hypnea* and *Lobophora*.. Subadults are distributed throughout the biplot.

The data for those individuals captured repeatedly (n=60) showed patterns similar to but weaker than the single capture data (Appendix Table 6.25). The Occasion (Appendix Table 6.26) and Age Class (Appendix Table 6.27) main effects were both significant. Further, there was a significant difference in the diet between individuals although univariate tests show these differences exist only for *Lobophora variegata* (Appendix Table 6.28) and the means output attributes this to few individuals. Although the inconsistent nature of the repeat capture data set precluded a repeated measures analysis of the data, an examination of the diet data from these animals does indicate that considerable shifts in diet appear to be occurring in some animals while others remain consistent (Appendix Table 6.29). As an example, animal #T1085 had a maximum contribution of 33% from a single alga species (*Pterocladia caerulescens*) and 13 genera in its diet when captured (23 March '89). When recaptured just 10 days later, the maximum contribution on one species was 92% (*Laurencia intricata*) and only 6 genera were present. Animal # T38076 had a maximum contribution of 91% from a single species (*Enteromorpha sp.*) and 8 genera (23 July '89) and just three days later, a maximum of contribution of 50% (*Enteromorpha sp.*) and 3 genera. Such shifts in diet were not uncommon.

Analysis of variance indicated that the total amount of animal matter occurring in the diet was significantly different between trips (Appendix Table 6.30). Most of this variation is attributable to the January and March 1989 sampling occasion (Figure 6.3) when mollusc egg cases and *Physalia* were ingested (Appendix Tables 6.6 & 6.9).

6.3.4 Variation in Diet Strategy

There was no significant difference in the diet strategy (monogeneric or algal turf feeders) between the age classes although the overall diet strategy of the green turtles (all age classes combined) on Heron Reef did change significantly between sampling occasions (Table 6.9 & Figure 6.4).

6.4 Discussion

The analysis of the 507 lavage samples collected during this study indicates that algae is the most important and almost exclusive diet item of green turtles on Heron Reef during all seasons and for all age classes and both sexes. Most green turtles at Heron Reef (70.4%) were concentrating their foraging activity in the heterogenous algal turf assemblage when sampled; a minority were grazing upon monogeneric stands of algae. There were significant temporal changes in the composition of the diet amongst turtles grazing in the algal turf and monogeneric stands and amongst turtles captured once or repeatedly and there appeared to be no discernible continuity or pattern to this change.

6.4.1 Diet and Sex

No significant differences in the diets of males and females were observed in this study. In her study of Nicaraguan green turtles, Mortimer (1981) also failed to identify any differences in diet between the sexes. Mortimer states that she found "...no significant trends or differences in the food preferences of the two sexes". However, Mortimer does not indicate her method of analysis. Similarly, Garnett *et al.* (1985) state that no differences between the sexes nor trends over time could be detected in the diet of green turtles from Torres Strait, Australia. However, Garnett *et al.* recognise that their findings may be influenced by the small number of males in their sample (4 of 38 turtles) and the fact that the pooled diet was generated from animals from two geographically distinct habitats with unquantified forage. Working in Moreton Bay, Queensland, Read

(1991) found a significant difference in the relative volumes of a single seagrass species (*Halophila spinulosa*) consumed by juvenile males and females. However, Read's analysis only demonstrated a difference for one seagrass species from a mixed diet of more than a dozen species and the results of his ANOVA indicated a significant difference whereas a Student-Newman-Keuls means comparison test of the same data set did not show a significant difference. Additionally, his animals were captured from two distinct locations and the data were combined.

6.4.2 Diet and Age Class

The results of this study indicate that there were significant differences between the diets of adults and juveniles although these differences were not consistent across all genera of algae (Section 6.3.3). Although there were differences in the consumption of various genera between the age classes, no differences in the diet strategy (monogeneric versus algal turf feeders) between age classes were detected. When a desirable diet item became available as did *Enteromorpha* in July of 1989, all age classes may shift to this item thereby eliminating any demarcation in diets between age classes.

Post hatchling green turtles are considered to be carnivorous for the first several years of their life and at approximately 25 cm (SCL), the juvenile turtles move to inshore benthic feeding areas and switch to an herbivorous diet (Bjorndal, 1985). Because young sea turtles have high mass-specific energy requirements, there has been speculation as to how they meet their energetic requirements once they switch to an herbivorous diet. Bjorndal (1996) suggests that small herbivorous reptiles may meet their higher energy requirements by: 1) feeding selectively on the parts of plants that can be more easily fermented, 2) ingesting smaller pieces of food which would result in

higher fermentation rates, 3) increasing body temperature which may increase the rate of digestive processing.

Bjorndal's first point suggests that fermentation rates in young herbivorous reptiles may be increased by their selection of the more digestible parts of a plant. Upon the macroscopic and microscopic examination of the lavage samples, I was unable to detect any age class based differences in the regions of the thalli consumed in those species that appeared in the diets across age classes. Bjorndal's second suggestion cannot be directly addressed as the particle size of digesta was not quantified for each sample. However, upon visual inspection, there did not appear to be a difference in particle size between the age classes with almost all food particles being ≤1 cm in length. The green turtle's ability to harvest such small pieces is facilitated by its serrated beak or rhamphotheca. The third strategy suggested by Bjorndal, increased body temperature, cannot be addressed as body temperatures were not taken and furthermore, the effects of body temperature upon the digestive efficiency of reptiles are poorly known and those studies completed to date have yielded conflicting results (Bjorndal, 1996). The apparent failure of juvenile green turtles to select specific plant parts and to decrease their bite size may be an result of their algal diet. The unique cell wall chemistry of algae (Chapter 7) may present less of a challenge to the enteric microflora than would a diet of vascular plant matter such as seagrasses or mangrove leaves and therefore such selection adaptations may not be necessary.

Although the green turtles on Heron Reef may not show differences in the region of the thallus they select or in their bite size, there is still a significant difference in the diet between the age classes. There are species of algae that are frequently consumed by juveniles that are infrequently consumed by adults and vice versa (Section 6.3.3, Figure 6.2). The selection of these species may be a result of the ability of young turtles to

select the smaller or more inconspicuous species as a result of their smaller beaks or there may be nutritive or energetic reasons for their selection. The opposite may be true for the adults which because of their larger beaks, may be able to collect and process species such as *Turbinaria* which possess tough thalli and may present more of a harvesting challenge to juveniles. However, thallus size alone cannot be the sole selection criterion as both juvenile and adults feed across the spectrum although only juveniles feed upon the species with very small thalli e.g., *Gelidiella*, *Coelothrix* and young *Lobophora*.

Whether the detected differences in diet are a result of the turtle's harvesting or assimilative abilities, there appears to be an ontogenetic factor involved as the subadults fed upon those species frequently consumed by the juveniles and also upon species frequently consumed by the adults. The diet of the subadults may represent a transitional diet. Additional study of the assimilation efficiencies of different species of algae across the age classes will be required before conclusions can be drawn.

Differences in diet between age classes have been identified in two other studies. In her study of green turtles feeding amongst *Thalassia testudinum*, Bjorndal (1979a) found that smallest subadult turtles consumed significantly more sponges than did the larger subadult turltes. Garnett *et al.* (1985) found a significant difference in diet composition between immature and mature animals feeding in mixed seagrass and algal communities. However Garnett *et al.* state that the difference that they detected is most likely a result of the different localities of capture of their animals rather than an absolute difference in preference. Although these findings are not directly comparable to those of this study, they do provide support.

6.4.3 Diet and Nesting

There has been speculation that green turtles either do not feed or feed very little while on their nesting grounds (Hirth, 1971; Carr *et al.*, 1974; Carr, 1975; Bjorndal, 1982). In part, this suggestion is based upon the fact that, unlike Heron Island, many green turtle nesting beaches are often physically displaced from suitable feeding grounds. Carr *et al.* (1974) found that green turtles nesting on Ascension Island in the Atlantic have no access to food during the internesting period as the island is bordered by deep water close inshore. Balazs (1980b) states that adult Hawaiian green turtles of both sexes fed from the locally available forage while on their breeding grounds. However, Balazs did not quantify the intensity of this feeding (pers. comm.). The low volume of ingesta retrieved from the five nesting females lavaged during this study suggests that females feed little while near the nesting beaches even though suitable forage is locally abundant. A larger number of animals captured throughout the nesting season is required to substantiate these conclusions.

6.4.4 Diet Selection

This study found evidence of preference in the diet of green turtles feeding upon monogeneric stands of algae and also for turtles feeding within the algal turf. Of the 70 genera and over 115 species of algae identified from Heron Reef, only 41 genera were selected and consumed and only 12 genera and ~10 species ever represented more than 5% of the pooled diet volume.

Balazs (1980b) found that subadult Hawaiian green turtles preferred to feed upon only 56 of the approximately 400 species of algae available within the archipelago and that only 7 genera and 9 species were considered "major food items". Balazs also found that algae species readily consumed by turtles living around one island were avoided by green turtles on nearby islands although the algal species was locally abundant.

Garnett *et al.* (1985) concluded that based upon a subjective assessment of the substrate near one of their sampling sites that "...some selectivity of certain food types was observed". Read (1991) found that immature green turtles in southern Queensland were selecting against the seagrasses *Halophila ovalis* and *H. uninervis* rather than consuming them in proportion to their abundance. Working with the same group of turtles, Brand (1995) found that juvenile green turtles showed preference for red algae over seagrasses that were in greater abundance. Bjorndal (1980) found that green turtles feeding in beds of the seagrass *Thalassia testudinum* not only selected for blades low in epiphytic algae, but also selected for young blades of *Thalassia testudinum* that are low in lignin and high in nitrogen. It is therefore clear that green turtles are selective in their diet choices.

6.4.5 Diet Fidelity

In addition to the significant changes observed in the pooled diet over time, changes were also seen in individual diets over time. Individual diet change may be a response to changing availability, nutrient or energy content of the forage or may be part of the normal feeding strategy in which a diet change take place as "bouts" of dietary preference over a period of hours or days. C. J. Limpus (pers. comm.) observed changes in the diet of green turtles feeding in Shoalwater Bay, Queensland as a function of tides and access to different food items. Upon examining necropsied green turtles, Ross (1985) and Brand (1995) also found spatial separation of diet items along the digestive tract suggesting dynamic changes in dietary preference. Data from the animals captured repeatedly in this study support the conclusion that at least some individuals change their diet significantly over short periods of time (several days). However, on average, green turtles on Heron Reef show fidelity to feeding in the algal turf as over 70% of the lavage samples were of algal turf origin. This suggests that

although dynamic changes may occur over short periods of time, there is a "common base diet".

6.4.6 Animal Matter Content

Animal matter represented only 1.6% (s.e.=0.5) of the pooled diet volume across all sampling occasions. Similar low contributions by animal matter to the mean pooled diet volume of green turtles were found by Read (1991) (1.2%), Mortimer (1981) (1.4%), Brand (1995) (~2%) and Garnett *et al.* (1985) (0.9%). Bjorndal (1979) found animal matter to account for 4.6% of the pooled diet but states that this is most likely an overestimation of the actual contribution as a result of her sampling protocol. Animal matter appears to be ingested both incidentally and intentionally by Heron Reef turtles. The amphipods identified in the diet were the same species that live in the buccal cavity of the green turtle and were most likely dislodged from that area during feeding. The hydrozoan *Physalia*, mollusc eggs and egg casings appear to be ingested intentionally as *Physalia* must be taken from the surface and the mollusc eggs and casings were too large to be inadvertently ingested while grazing on benthic algae. Read (1991) also found that immature green turtles intentionally fed upon the jellyfish *Catostylus mosaicus* which is only available in the water column. Balazs (1980b) found that immature Hawaiian green turtles also readily consumed the hydrozoans *Physalia* and *Velella* at the surface when available. Of the 20 turtles that consumed *Physalia* in this study, only one was an adult, the remaining were subadults (n=10) and juveniles (n=9). The frequent occurrence of animal matter in the diets of immature turtles in contrast to its almost complete absence from the diet of adults may be a response to: 1) the relatively greater nitrogen demands of immature turtles which may be more easily met by consuming animal matter rather than plant matter, 2) other beneficial associative effects that nitrogen may have upon microflora activity and digestibility (Chapter 8) or 3) the meeting of non-nitrogen based nutritive requirements of juvenile and subadult

turtles. Additional work on the benefits of animal matter in the diet of immature green turtles is required to adequately address this topic.

6. 5 Conclusions

1. Algae are the most important and almost the exclusive diet item of green turtles on Heron Reef during all seasons and for all age classes and both sexes.
2. Green turtles on Heron Reef concentrate their foraging effort in the algal turf and opportunistically exploit preferred monogeneric stands of algae.
3. Green turtles on Heron Reef that feed upon monogeneric stands of algae prefer some genera of algae e.g., *Laurencia* , *Enteromorpha* , while other genera e.g., *Chlorodesmis* , *Hydroclathrus* , are avoided. Diet selection is demonstrated in turtles grazing on both algal turf and monogeneric stands of algae.
4. The diet of the green turtle varies significantly temporally and between age classes although there is no continuity or discernible pattern to these changes. The differences observed between age classes may disappear when desirable diet components become available e.g., *Enteromorpha* . There are no discernible differences in diet between the sexes.
5. There was no significant difference in the diet strategy (algal turf vs. monogeneric stand) between age classes although the diet strategy of green turtles on Heron Reef did change between sampling occasions.
6. The diet of individual green turtles captured on repeat occasions varied over time although there is no continuity or discernible pattern to this change. Some individuals exhibited considerable shifts in diet while others remained rather constant in their dietary choices.
7. During their nesting season, females appear to feed at a greatly reduced rate.
8. The amount of animal matter consumed varies significantly over time. When available, the hydrozoan *Physalia* is intentionally consumed by immature turtles.

9. The dynamics of the green sea turtle diet require diet studies to be conducted over a period of time sufficient to identify the changes cited above. The variation in diet between individuals and age classes identified in this study suggest that diet studies that are restricted to samples from a few individuals or do not include all age classes, are of limited value in drawing inferences about the diet of the population.

Table 6.1- Description of sample populations and their utilisation in the analyses.

Sample Population	Composition	Analyses in which sample population is used
Study site animals or samples	Animals or samples from sectors 0-9	Description of study site diet, diet preference.
Peripheral animals or samples	Animals or samples from sectors other than 0-9	Combined with study site samples for pooled diet analyses
Pooled animals or samples	Animals or samples from all sectors	Description of pooled diet, variability in diet as a function of age class, sex or occasion
Single capture animals	Study site or peripheral animals captured only once during a sampling occasion or when captured repeatedly during a sampling occasion, only the lavage sample from the first capture was used.	Description of study site and pooled diets, diet preference, variability in diet as a function of age class, sex or occasion
Repeatedly captured animals	Animals captured repeatedly during the study. All lavage samples were used.	Individual and temporal variation in diet

Table 6.2. Grazing strategies of green turtles captured within the study area, Heron Reef. Values represent the number of turtles in each category. Values in parentheses are percentages.

Feeding Strategy	Nov-88 n=33	Jan-89 n=51	Mar-89 n=63	May-89 n=51	Jul-89 n=67	Mar-90 n=68	Overall n=333	Overall Minus July 1989 n=266
Monogeneric[1]	10 (30.3)	13 (25.5)	19 (30.1)	16 (31.4)	40 (59.7)	21 (30.9)	119 (34.7, s.e.=5.08)	79 (29.6, s.e.=1.06)
Algal Turf[2]	23 (69.7)	38 (74.5)	44 (69.8)	35 (68.7)	27 (40.3)	47 (69.1)	214 (65.4, s.e.=5.08)	187 (70.4, s.e.=1.05)

Data include animals of all age classes and both sexes. When individuals were recaptured with a sampling session, only the data from the first capture were used. Summary data are presented that both include and exclude the July data as turtles switched to a monogeneric diet in July.

[1] Lavage samples with ≥75% of the composition contributed by a single genus of algae
2 Lavage samples with <75% of the composition contributed by a single genus of algae

Table 6.3- Diet items present in lavage samples of Heron Reef green turtles captured at the study site and peripheral areas during study. The diet items listed are from the pooled diets of all age classes and both sexes and from turtles feeding in either monogeneric stands or in the algal turf. (n=507)

D. Chlorophyta

O. Caulerpales
Caulerpa brachypus
C. cupressoides
C. lentillifera
C. nummularia
C. racemosa
C. sertularioides
C. webbiana
C. sp.
Chlorodesmis fastigiata
Halimeda cylindracea
H. tuna
H. sp.

O. Cladophorales
Cladophora sp.
Rhizoclonium sp.

O. Codiales
Codium spp.

O. Siphonocladales
Dictyosphaeria sp.
Valonia sp.

O. Ulvales
Enteromorpha sp.

Unidentifiable Chlorophyta

D. Phaeophyta

O. Dictyotales
Dictyota bartayressi
Lobophora variegata
Padina sp.

O. Fucales
Cystoseira trinoides
Hormophysa triquetra
Sargassum spp.
Turbinaria ornata

O. Scytosiphonales
Chnoospora implexa
Hydroclathrus clathratus

Unidentifiable Phaeophyta

D. Rhodophyta

O. Ceramiales
Acanthophora specifera
Amansia glomerata
Centroceras apiculatum
C. clavulatum
C. sp.
Ceramium species
Chondria minutula
C. species
Hypoglossum spathulatum
Laurencia carolinensis
L. intricata
L. parvipapillata
L. majusculata
L. succisa
L. sp.
Leveillea jungermannioides
Polysiphonia infestans
P. sp.
Spyridia filamentosa
Tolypoicladia glomerulata

O. Corallinaceae
Amphiroa sp.

O. Cryptonemiales
Chondrococcus hornemannii

O. Gelidiales
Gelidiella acerosa
G. pannosa
G. sp.
Pterocladia caerulescens
P. spp.

D. Rhodophyta (cont.)

O. Gigartinales
Eucheuma denticulatum
Hypnea pannosa
H. spinella
H. sp.
Plocamium hamatum

O. Nemaliales
Galaxaura subfruticulosa

O. Rhodymeniales
Champia parvula
C. sp.
Coelarthrum boergesenii
Coelothrix irregularis
Lomentaria corallicola

Unidentifiable Rhodophyta

Cyanophyta

O. Oscillatoriales
Lyngbya sp.
Microcoleus lyngbyaceus

TRACHEOPHYTA

O. Hydrocharitaceae
Halophila decipiens
Halophila ovalis
Halophila sp.

Miscellaneous

Algae, unidentifiable
Amphipod
Animal flesh, unidentifiable
Arthropod fragments
Bivalve
Bryozoan
Foraminiferan
Mollusk eggs
Mollusk egg casing
Mollusk fragments
Octocoral
Osteichthyes scales
Physalia sp.
Plastics
Polychaete worm
Polychaete worm tube
Porifera
Sand
Sand & rubble

Table 6.4-Rank order of volume contribution to the diet of green turtles captured in the study site, Heron Reef. n=408. Data include animals feeding in either the algal turf or in monogeneric stands of algae.

	Mar-88 n=75	Nov-88 n=33	Jan-89 n=51	Mar-89 n=63	May-89 n=51	Jul-89 n=67	Mar-90 n=68	Total #1 Rankings 1	Total #2 Rankings 2	Total #3 Rankings 4
Chlorophyta	2	3	3	3	3	1	2	1	2	4
Phaeophyta	3	2	1	2	1	3	1	3	2	2
Rhodophyta	1	1	2	1	2	2	3	3	3	1

When individuals were recaptured within a sampling session, only the data from the first capture were used in the data set. Data includes animals of both sexes and all age classes. Rank order was the same for both individual and pooled diets.

Table 6.5- Diet composition of green turtles captured within the study site, Heron Reef. Data include animals feeding in either the algal turf or in monogeneric stands of algae. C=Chlorophyta, P=Phaeophyta, R=Rhodophyta, CB=cyanobacteria, AM=animal matter, SG=seagrass, PR=protozoan, S=substrate.

	Division	March 1988	Division	November 1988	Division	January 1989	Division	March 1989
Number of lavage samples:		n=75		n=33		n=51		n=63
Number of algal:								
Divisions		3		3		3		3
Genera		28		28		28		20
Chlorophyta		9		7		8		5
Phaeophyta		3		6		5		3
Rhodophyta		16		15		15		12
Species		≥42		≥40		≥38		≥31
Chlorophyta		15		12		12		12
Phaeophyta		2		6		5		3
Rhodophyta		25		22		21		16
Animal Matter (%)		0.91		0.70		4.06		1.83
Greatest contribution to pooled diet								
Division		Rhodophyta		Rhodophyta[1]		Phaeophyta		Rhodophyta
Genus	R	*Laurencia* (18.0% contrib.)	P	*Turbinaria* (19.3% contrib.)	P	*Turbinaria* (31.2% contrib.)	R	*Laurencia* (24.4 contrib.)
Species		*spp.*		*ornata*		*ornata*		*spp.*
% Contribution to vol. of pooled diet								
Chlorophyta		21.1		11.7		15.3		20.9
Phaeophyta		15.8		32.0		51.0		29.8
Rhodophyta		62.0		55.3		28.4		47.4
Number of primary genera	Total	8	Total	7	Total	6	Total	5
(≥5.0% of vol.)	C	2 (25.0)	C	1 (14.3)	C	1 (16.7)	C	1 (20.0)
No. in parentheses =	P	1 (12.5)	P	2 (28.6)	P	3 (50.0)	P	2 (40.0)
% of primary genera	R	5 (62.5)	R	4 (57.1)	R	2 (33.3)	R	2 (40.0)
% of genera present contrib. ≥5% vol. to pooled diet		28.6		25.0		21.4		25.0
Primary components	R	*Laurencia spp.*	P	*Turbinaria ornata*	P	*Turbinaria ornata*	R	*Laurencia spp.*
(≥5.0% of vol.) Listed in	R	*Polysiphonia spp.*	R	*Chondria spp.*	R	*Gelidiella spp.*	P	*Turbinaria ornata*
order of decreasing	P	*Turbinaria ornata*	R	*Laurencia spp.*	P	*Lobophora variegata*	R	*Gelidiella spp.*
contribution.	R	*Gelidiella spp.*	R	*Polysiphonia spp.*	R	*Laurencia spp.*	C	*Codium spp.*
	C	*Codium spp.*	C	*Caulerpa spp.*	P	*Sargassum spp.*	R	*Gelidiella acerosa*
	C	*Caulerpa spp.*	C	*Caulerpa cupressoides*	R	*Gelidiella acerosa*	P	*Lobophora variegata*
	R	*Chondria spp.*	P	*Sargassum spp.*	C	*Codium spp.*		
	C	*Caulerpa cupressoides*	R	*Spyridia filamentosa*				
	R	*Hypnea spp.*						
	R	*Gelidiella acerosa*						

Table 6. 5 (cont.)

Trace components (≥5.0% of vol.) Listed in order of decreasing contribution.

C	*Enteromorpha spp.*	P	*Lobophora variegata*	R	*Laurencia intricata*	C	*Caulerpa spp.*
R	*Toypolcladia glomerulata*	R	*Hypnea spp.*	C	*Caulerpa spp.*	R	*Laurencia intricata*
R	*Hypnea pannosa*	P	*Hydroclathrus clathratus*	C	*Halimeda spp.*	R	*Gelidiella sp.*
R	*Hypnea sp.*	R	*Gelidiella spp.*	C	*Enteromorpha spp.*	C	*Caulerpa cupressoides*
P	*Lobophora variegata*	R	*Gelidiella sp.*	C	*Halimeda sp.*	R	*Coelothrix irregularis*
R	*Coelothrix irregularis*	R	*Hypnea pannosa*	C	*Caulerpa racemosa*	C	*Caulerpa racemosa*
R	*Laurencia intricata*	R	*Coelothrix irregularis*	AM	Scyphozoa	R	*Hypnea spp.*
R	*Laurencia majusculata*	C	*Enteromorpha spp.*	C	*Caulerpa cupressoides*	AM	Mollusk Eggs
P	*Sargassum spp.*	R	*Hypnea sp.*	S	Sand	P	*Sargassum spp.*
R	*Hypnea spinella*	C	*Codium spp.*	R	*Hypnea spp.*	R	*Hypnea pannosa*
AM	*Physalia sp.*	C	*Dictyosphaeria sp.*	R	*Coelothrix irregularis*	R	*Laurencia parvipapillata*
C	*Caulerpa racemosa*	C	*Chlorodesmis fastigiata*	AM	Mollusk Egg Casing	R	*Toypolcladia glomerulata*
R	*Champia parvula*	C	*Halimeda spp.*	AM	*Physalia sp.*	R	*Hypnea spinella*
AM	Polychaete Worm Tube	C	*Halimeda sp.*	R	*Amphiroa spp.*	C	*Caulerpa nummularia*
C	*Halimeda spp.*	R	*Champia parvula*	R	*Hypnea pannosa*	C	*Halimeda spp.*
C	*Dictyosphaeria sp.*	AM	Polychaete Worm Tube	R	*Acanthophora specifera*	C	*Dictyosphaeria sp.*
C	*Caulerpa nummularia*	P	*Chnoospora implexa*	R	*Toypolcladia glomerulata*	C	*Halimeda sp.*
C	*Halimeda sp.*	R	*Amphiroa spp.*	R	*Hypnea sp.*	AM	Mollusk Egg Casing
C	*Caulerpa sp.*	R	*Tolypiolcladia glomerulata*	R	*Gelidiella pannosa*	C	*Caulerpa sp.*
S	Sand-Rubble	S	Sand-Rubble	R	*Lomentaria corallicola*	S	Sand-Rubble
R	*Acanthophora specifera*	R	*Laurencia succisa*	C	*Dictyosphaeria sp.*	R	*Eucheuma denticulatum*
R	*Ceramium sp.*	C	*Caulerpa sp.*	R	*Chondria sp.*	R	*Champia parvula*
R	*Laurencia succisa*	R	*Gelidiella acerosa*	R	*Champia parvula*	R	*Amansia glomerata*
PR	Foraminiferan	P	*Dictyota bartayressi*	P	*Padina sp.*	AM	Mollusk Fragments
AM	Polychaete Worm	C	*Caulerpa nummularia*	AM	Mollusk Fragments	C	*Halimeda cylindracea*
R	*Centroceras spp.*	AM	Mollusk Fragments	R	*Spyridia filamentosa*	R	*Amphiroa spp.*
AM	Mollusk Egg Casing	R	*Centroceras spp.*	C	*Caulerpa sp.*	AM	Animal Flesh
AM	Mollusk Eggs	R	*Eucheuma denticulatum*	R	*Galaxaura subfruticulosa*	C	*Caulerpa webbiana*
C	*Caulerpa brachypus*	R	*Laurencia carolinensis*	R	*Polysiphonia spp.*	R	*Polysiphonia spp.*
R	*Rhizoclonium sp.*	R	*Hypoglossum spathulatum*	AM	Animal Flesh	C	*Chlorodesmis fastigiata*
R	*Centroceras apiculatum*	C	*Caulerpa racemosa*	AM	Mollusk Eggs	R	*Chondrococcus hornemannii*
AM	Mollusk Fragments	AM	Polychaete Worm	C	*Caulerpa nummularia*	PR	Foraminiferan
R	*Spyridia filamentosa*	R	*Centroceras clavulatum*	AM	Octocoral	AM	Amphipod
R	*Centroceras clavulatum*	C	*Caulerpa brachypus*	R	*Laurecnia succisa*	AM	Polychaete Worm Tube
C	*Cladophora spp.*	R	*Ceramium sp.*	C	*Valonia sp.*	C	*Caulerpa sertularioides*
R	*Amphiroa spp.*	R	*Laurencia parvipapillata*	C	*Cladophora sp.*	R	*Hypoglossum spathulatum*
C	*Halimeda tuna*	AM	Arthropod fragments	R	*Laurencia parvipapillata*		
R	Rhodophyta Unknown	AM	Amphipod	P	*Dictyota bartayressi*		
R	*Leveillea jungermannioides*	PR	Foraminiferan	R	*Centroceras sp.*		
AM	Porifera	AM	Mollusk Eggs	C	*Caulerpa lentillifera*		
AM	Animal flesh	R	*Laurencia intricata*	AM	Polychaete WormTube		
R	*Centroceras sp.*	AM	Porifera	AM	Amphipod		
R	*Plocamium hamatum*	R	*Coelarthrum boergesenii*	S	Sand-Rubble		
R	*Gelidiella pannosa*	CB	*Microcoleus lyngbyaceus*	R	*Ceramium sp.*		
C	*Chlorodesmis fastigiata*	C	*Cladophora spp.*	AM	Porifera		
C	*Valonia sp.*			C	*Chlorodesmis fastigiata*		
R	*Pterocladia caerulescens*			AM	Osteichthyes Scale		

Table 6.5 (cont.)

	Division	May 1989	Division	July 1989	Division	March 1990	Study Total (Mean; s.e.)
n=		51		67		68	408
Number of algal:							
Divisions		3		3		3	3 (3; 0.00)
Genera		19		19		20	41 (22.9; 1.83)
Chlorophyta		7		4		5	
Phaeophyta		3		5		4	
Rhodophyta		9		10		11	
Species		≥32		≥22		≥31	62 (33.9; 2.52)
Chlorophyta		12		5		12	
Phaeophyta		3		5		4	
Rhodophyta		17		12		17	
Animal Matter (%)		2.16		0.11		1.48	(1.6; 0.5)
Greatest contribution to pooled diet							
Division		Phaeophyta		Chlorophyta		Phaeophyta	
Genus	P	*Turbinaria* (41.2% contrib.)	C	*Enteromorpha*	P	*Turbinaria* (35.2% contrib.)	
Species		*ornata*		*spp.* (79.7% contrib.)		*ornata*	
% Contribution to vol. of pooled diet							
Chlorophyta		9.6		80.8		33.5	
Phaeophyta		46.4		2.1		41.4	
Rhodophyta		41.4		16.9		23.6	
Number of primary genera	Total	3	Total	2	Total	5	12 (5.1; 0.8)
(≥5.0% of vol.)	C	0 (0.0)	C	1 (50.0)	C	2 (40.0)	(1.1; 0.26)
No. in parentheses =	P	1 (33.3)	P	0 (0.0)	P	1 (20.0)	(1.4; 0.37)
% of primary genera	R	2 (66.7)	R	1 (50.0)	R	2 (40.0)	(2.3; 0.53)
% of genera present contrib. ≥5% vol. to pooled diet		15.8		10.5		25.0	(21.6; 2.39)
Primary components (≥5.0% of vol.) Listed in order of decreasing contribution.	P	*Turbinaria ornata*	C	*Enteromorpha spp.*	P	*Turbinaria ornata*	
	R	*Polysiphonia spp.*	R	*Polysiphonia spp.*	C	*Caulerpa spp.*	
	R	*Polysiphonia infestans*			C	*Codium spp.*	
	R	*Laurencia spp.*			C	*Caulerpa racemosa*	
Table 6.4 (cont.)					R	*Gelidiella spp.*	
					R	*Gelidiella acerosa*	
					R	*Laurencia spp.*	
Trace components (≥5.0% of vol.) Listed in order of decreasing contribution.	C	*Codium spp.*	P	*Turbinaria ornata*	P	*Sargassum spp.*	
	R	*Gelidiella spp.*	R	*Laurencia spp.*	R	*Laurencia intricata*	
	P	*Lobophora variegata*	R	*Chondria sp.*	C	*Caulerpa lentillifera*	
	C	*Caulerpa spp.*	C	*Chlorodesmis fastigiata*	P	*Lobophora variegata*	
	R	*Gelidiella acerosa*	R	*Hypnea spp.*	AM	Mollusk Egg Casing	

Table 6. 5 (cont.)

R	*Laurencia intricata*
C	*Caulerpa cupressoides*
R	*Hypnea spp.*
R	*Hypnea sp.*
C	*Caulerpa racemosa*
AM	*Animal flesh*
R	*Chondria spp.*
R	*Chondria minutula*
AM	Polychaete Worm Tube
P	*Sargassum spp.*
C	*Chlorodesmis fastigiata*
R	*Gelidiella sp.*
SG	*Halophila spp.*
C	*Enteromorpha spp.*
SG	*Halophila sp.*
R	*Hypnea pannosa*
R	*Polysiphonia sp.*
C	*Caulerpa lentillifera*
AM	Mollusk Fragments
AM	Octocoral
R	*Galaxaura subfruticulosa*
C	*Halimeda spp.*
S	Sand
SG	*Halophila ovalis*
C	*Caulerpa nummularia*
R	*Toypolcladia glomerulata*
C	*Halimeda sp.*
R	*Gelidiella pannosa*
C	*Cladophora spp.*
R	*Champia spp.*
R	*Champia parvula*
R	*Chondria sp.*
C	*Caulerpa brachypus*
R	*Centroceras apiculatum*
C	*Caulerpa sp.*
R	*Hypnea spinella*
R	*Champia sp.*
AM	Arthropod fragments
C	*Dictyosphaeria sp.*
R	*Hypnea sp.*
R	*Hypnea spinella*
P	*Lobophora variegata*
R	*Toypolcladia glomerulata*
R	*Spyridia filamentosa*
R	*Gelidiella acerosa*
R	*Hypnea pannosa*
R	*Coelothrix irregularis*
P	*Hydroclathrus clathratus*
R	*Champia parvula*
S	Sand-Rubble
AM	Polychaete Worm Tube
R	*Ceramium sp.*
S	Sand
P	*Sargassum sp.*
C	*Halimeda spp.*
C	*Caulerpa sertularioides*
P	*Dictyota bartayressi*
P	Phaeophyta Unknown
AM	Mollusk Fragments
C	*Halimeda sp.*
R	*Coelothrix irregularis*
R	*Gelidiella sp.*
R	*Hypnea spp.*
C	*Halimeda spp.*
R	*Hypnea pannosa*
R	*Laurencia majusculata*
C	*Halimeda sp.*
AM	Animal flesh
C	*Caulerpa cupressoides*
C	*Caulerpa nummularia*
S	Sand-Rubble
AM	Octocoral
R	*Hypnea sp.*
R	*Galaxaura subfruticulosa*
AM	Mollusk Fragments
R	*Laurencia parvipapillata*
C	*Caulerpa brachypus*
R	*Champia parvula*
R	*Amphiroa spp.*
AM	Arthropod fragments
R	*Leveillea jungermannioides*
PR	Foraminiferan
R	*Plocamium hamatum*
AM	Bryozoan
C	*Caulerpa sertularioides*
S	Sand
AM	Porifera
C	*Caulerpa sp.*
AM	Amphipod
R	*Acanthophora specifera*
AM	*Physalia sp.*
AM	Mollusk Eggs
P	*Dictyota bartayressi*
R	*Laurencia succisa*
AM	Holothuroidea
R	*Toypolcladia glomerulata*
SG	*Halophila ovalis*

Data are from animals of all age classes and both sexes. When individuals were recaptured within a sampling session, only the data from the first capture were used. Data are based upon the volume contribution of the item to the pooled diet. All diet items identified are listed even though they may represent <1% of the pooled diet. See Appendices 6.2-6.22 for specific values. Genus names followed by "spp" represent values for all members of that genus.

1 Note that the division with the greatest contribution to the pooled diet volume (Rhodophyta) is different than the division of the genus with the greatest contribution (P. Phaeophyta, G. *Turbinaria*).

Table 6.6-Number of algal genera in the diet comprising ≥5%, ≥25% and ≥50% of the volume of the individual and pooled diets of green turtles captured within the study site, Heron Reef. Values in parentheses are the percentage of genera in that category. Data include animals feeding in either the algal turf or in monogeneric stands of algae. n=408

	Sampling Session								
	Mar-88 n=75	Nov-88 n=33	Jan-89 n=51	Mar-89 n=63	May-89 n=51	Jul-89 n=67	Mar-90 n=68	Study n=408 mean	s.e
Total number of genera present-	28	28	28	20	19	19	20	23.1	1.83
Individual Diets									
Number of genera composing:									
≥5% of diet volume	15 (53.4)	20 (71.4)	20 (71.4)	11 (55.0)	13 (68.4)	11 (57.9)	11 (55.0)	14.4 (62.3)	1.54
≥25% of diet volume	11 (39.3)	10 (35.7)	10 (35.7)	7 (35.0)	9 (47.4)	5 (26.3)	7 (35.0)	8.4 (36.4)	0.81
≥50% of diet volume	4 (14.3)	10 (35.7)	8 (28.6)	6 (30.0)	4 (21.1)	4 (21.1)	6 (30.0)	6 (25.9)	0.87
Pooled Diet									
Number of genera composing:									
≥5% of diet volume	8 (28.6)	7 (25.0)	6 (21.4)	5 (25.0)	3 (15.8)	2 (10.5)	5 (25.0)	5.1 (21.6)	0.80
≥25% of diet volume	0	0	1 (3.6)	0	2 (10.5)	1 (5.3)	1 (5.0)	0.7 (3.1)	0.29
≥50% of diet volume	0	0	0	0	0	1 (5.3)	0	0.1 (0.6)	0.14

Data include animals of all age classes and both sexes. When animals were recaptured during a sampling session, only data from the capture was used.

Table 6.7- Rank order of feeding preference in green sea turtles feeding in monogeneric stands of algae within the study site, Heron Reef, Queensland. Only those algae growing in monogeneric stands are listed. NP=Algae not present in substrate sampling. P=Algae present in substrate sampling but not consumed by turtles in that data set. Preference data was calculated using the diet preference program Prefer (Johnson, 1980) v. 5.1 (1995).

		Nov-88 (n=10)		Jan-89 (n=13)		Mar-89 (n=19)		May-89 (n=16)		Jul-89 (n=40)		Mar-90 (n=21)		Study n=119	
		Rank	Percentile	Rank	Percentile	Rank	Percentile	Rank	Percentile	Rank	Percentile	Rank	Percentile	Percentile Mean	Std. Dev.
	No. Genera Ranked	8		10		9		11		10		10			
Chlorophyta	*Caulerpa spp.*	5	37.5	7	30.0	6	33.3	6	45.5	P		1 (NP)	90.0	47.3	24.58
	Chlorodesmis fastigiata	P		10	0.0	P		11	0.0	8	20.0	10	0.0	5.0	10.00
	Codium spp.	NP		2 (NP)	80.0	2 (NP)	77.8	7	36.4	NP		6	40.0	58.5	23.57
	Enteromorpha spp.	NP		NP		NP		4	63.6	5	50.0	NP		56.8	9.64
	Halimeda spp.	P		9	10.0	9	0.0	9	18.2	9	10.0	9	10.0	9.6	6.45
	Valonia ventricosa	NP		NP		P		NP		NP		NP			
Phaeophyta	*Chnoospora implexa*	NP		NP		P		NP		NP		NP			
	Hydroclathrus clathratus	8	0.0	NP		NP		NP		6	40.0	P			
	Lobophora variegata	7	12.5	5	50.0	8	11.1	1 (NP)	90.9	P		7	30.0	38.9	33.08
	Sargassum spp.	2 (NP)	75.0	4 (NP)	60.0	3 (NP)	66.7	NP		2 (NP)	80.0	3 (NP)	70.0	70.3	7.67
	Turbinaria ornata	4	50.0	3	70.0	5	44.4	3	72.7	7	30.0	4	60.0	54.5	16.27
Rhodophyta	*Amphiroa spp.*	NP		NP		P		P		P		P			
	Gelidiella spp.	1 (NP)	87.5	1 (NP)	90.0	1 (NP)	88.9	2 (NP)	81.8	3 (NP)	70.0	2 (NP)	80.0	83.0	7.53
	Hypnea spp.	3	62.5	6	40.0	4 (NP)	55.6	5	54.5	4	60.0	5	50.0	53.8	8.03
	Laurencia spp.	6	25.0	8	20.0	7	22.2	10	9.1	10	0.0	8	20.0	16.1	9.54
	Plocamium hamatum	NP		NP		P		P		P		NP			
	Polysiphonia spp.	NP		NP		NP		8	27.3	1	90.0	NP		58.6	44.35

Data include animals of all age classes and both sexes. When animals were recaptured during the sampling session, only the data from the first capture were used in the calculations below. Genus names followed by "spp" represent values for all species of that genus.

Table 6.8-Diet preference of green turtles captured in the study site, Heron Reef. The data set excludes those animals feeding amongst the algal turf.
Test of Ho: All items consumed are equally preferred.

	Nov-88 n=10	Jan-89 n=13	Mar-89 n=19	May-89 n=16	Jul-89 n=40	Mar-90 n=21
	F(7,3)=31.47 0.005<*P* <0.01	F(9,4)=67.73 *P* <0.001	F(8,11)=19.20 *P* <0.001	F(10,6)=40.39 *P* <0.001	F(9,31)=see note *P* =see note	F(9,12)=139.05 *P* <0.001
Rank Order of Preference						
1	*Gelidiella spp.*	*Gelidiella spp.*	*Polysiphonia spp.*	*Lobophora variegata*	*Polysiphonia spp.*	*Caulerpa spp.*
2	*Sargassum spp.*	*Codium spp.*	*Sargassum spp.*	*Gelidiella spp.*	*Sargassum spp.*	*Gelidiella spp.*
3	*Hypnea spp.*	*Turbinaria ornata*	*Gelidiella spp.*	*Turbinaria ornata*	*Gelidiella spp.*	*Sargassum spp.*
4	*Turbinaria ornata*	*Sargassum spp.*	*Hypnea spp.*	*Enteromorpha spp.*	*Hypnea spp.*	*Turbinaria ornata*
5	*Caulerpa spp.*	*Lobophora variegata*	*Enteromorpha spp.*	*Hypnea spp.*	*Enteromorpha spp.*	*Hypnea spp.*
6	*Laurencia spp.*	*Hypnea spp.*	*Hydroclathrus clathratus*	*Caulerpa spp.*	*Hydroclathrus clathratus*	*Codium spp.*
7	*Lobophora variegata*	*Caulerpa spp.*	*Turbinaria ornata*	*Codium spp.*	*Turbinaria ornata*	*Lobophora variegata*
8	*Hydroclathrus clathratus*	*Laurencia spp.*	*Chlorodesmis fastigiata*	*Polysiphonia spp.*	*Chlorodesmis fastigiata*	*Laurencia spp.*
9		*Halimeda spp.*	*Halimeda spp.*	*Halimeda spp.*	*Halimeda spp.*	*Halimeda spp.*
10		*Chlorodesmis fastigiata*	*Laurencia spp.*	*Laurencia spp.*	*Laurencia spp.*	*Chlorodesmis fastigiata*
11				*Chlorodesmis fastigiata*		

Note: As many of the July diets had the same rank order of preference, the matrix could not be inverted and therefore calculation of the sigma inverse and F values was not possible. Data include animals of all age classes and both sexes. When animals were recaptured during the sampling session, only data from the first capture were used.

Table 6.9- Results of the analysis of deviance tests that investigated the relationship between feeding strategy (monogeneric vs. algal turf feeders), age class and sampling occasion. The number of individuals was used as the response.

	Residual Dev.	Test[1]	ΔDF	ΔDeviance	Pr(Chi)	Significance
1	0.0000					
2	11.0458	-trip:age:type	-12	-11.0458	0.5250	
3	16.3573	-age:type	-2	-5.3116	0.0702	
4	11.0458	+age:type	2	5.3116	0.0702	
5	91.6403	-trip:age	-12	-80.5945	0.0000	Sig.
6	11.0458	+trip:age	12	80.5945	0.0000	Sig.
7	52.6647	-trip:type	-6	-41.619	0.0000	Sig.
8	16.3573	7 vs. 8	4	36.3074	0.0000	Sig.
9	60.0368	-trip:type	-6	-43.6794	0.0000	Sig.
10	16.3573	+trip:type	6	43.6794	0.0000	Sig.
11	99.0123	-trip:age	-12	-82.655	0.0000	Sig.
12	272.5806		-15	-173.5683	0.0000	Sig.

[1]Trip= sampling occasion, age= age class, type= feeding strategy.
The optimal model used in this analysis was: count ~ constant + trip + age + type + type (trip * age) + (trip * type) + ε

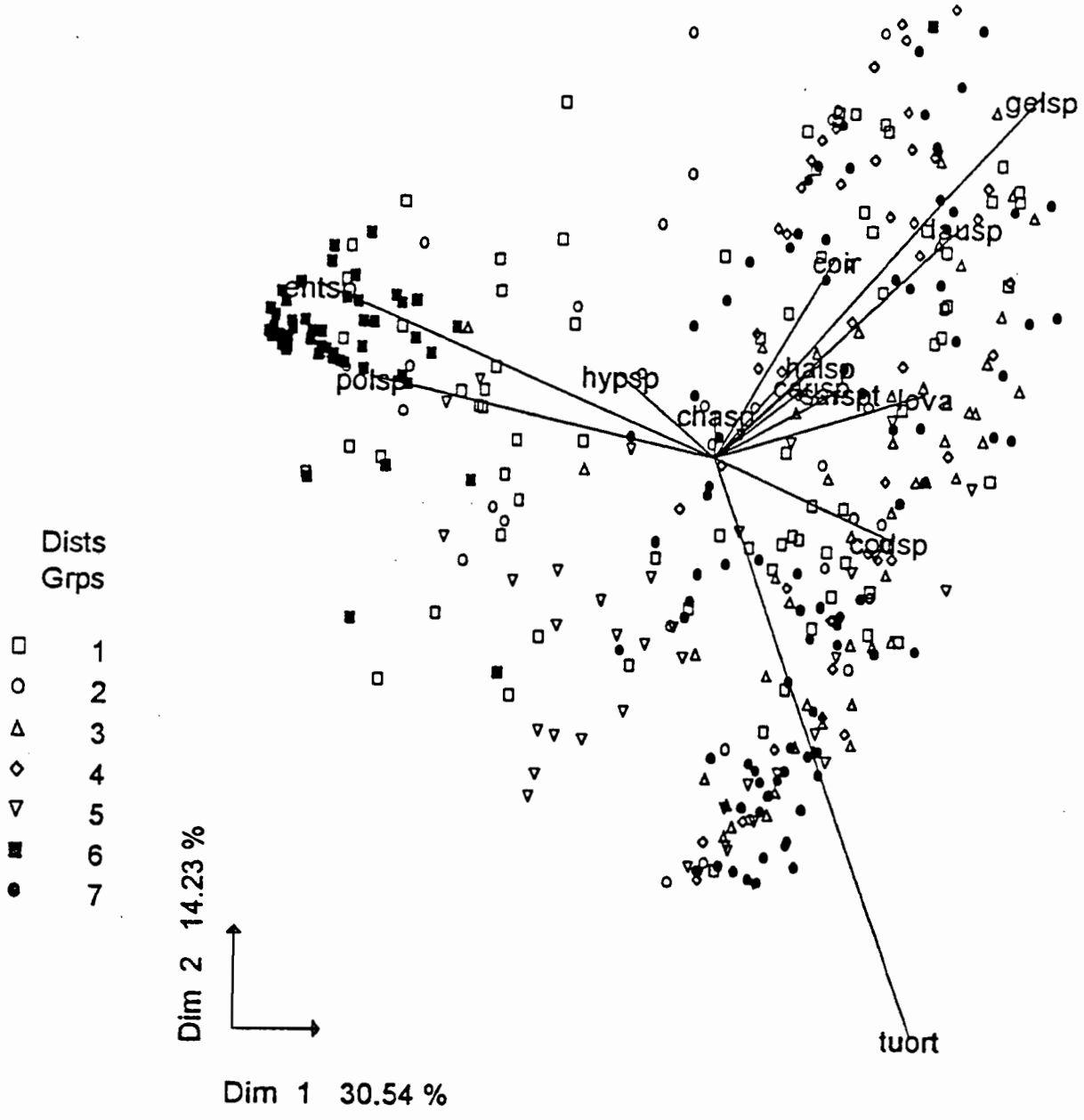


Figure 6.1-Principal components biplot with distribution groupings by occasion. (Dist. groups: 1=3/88, 2=11/88, 3=1/89, 4=3/89, 5=5/89, 6=7/89, 7=3/90) (causp=*Caulerpa spp.*, chasp=*Champia spp.*, codsp=*Codium spp.*, coir=*Coelothrix irregularis*, entsp=*Enteromorpha spp.*, gelsp=*Gelidiella spp.*, halsp=*Halimeda sp.*, hypsp=*Hypnea spp.*, lausp=*Laurencia spp.*, lova=*Lobophora spp.*, polsp=*Polysiphonia spp.*, sarspt=*Sargassum spp.*, tuort=*Turbinaria ornata*,)

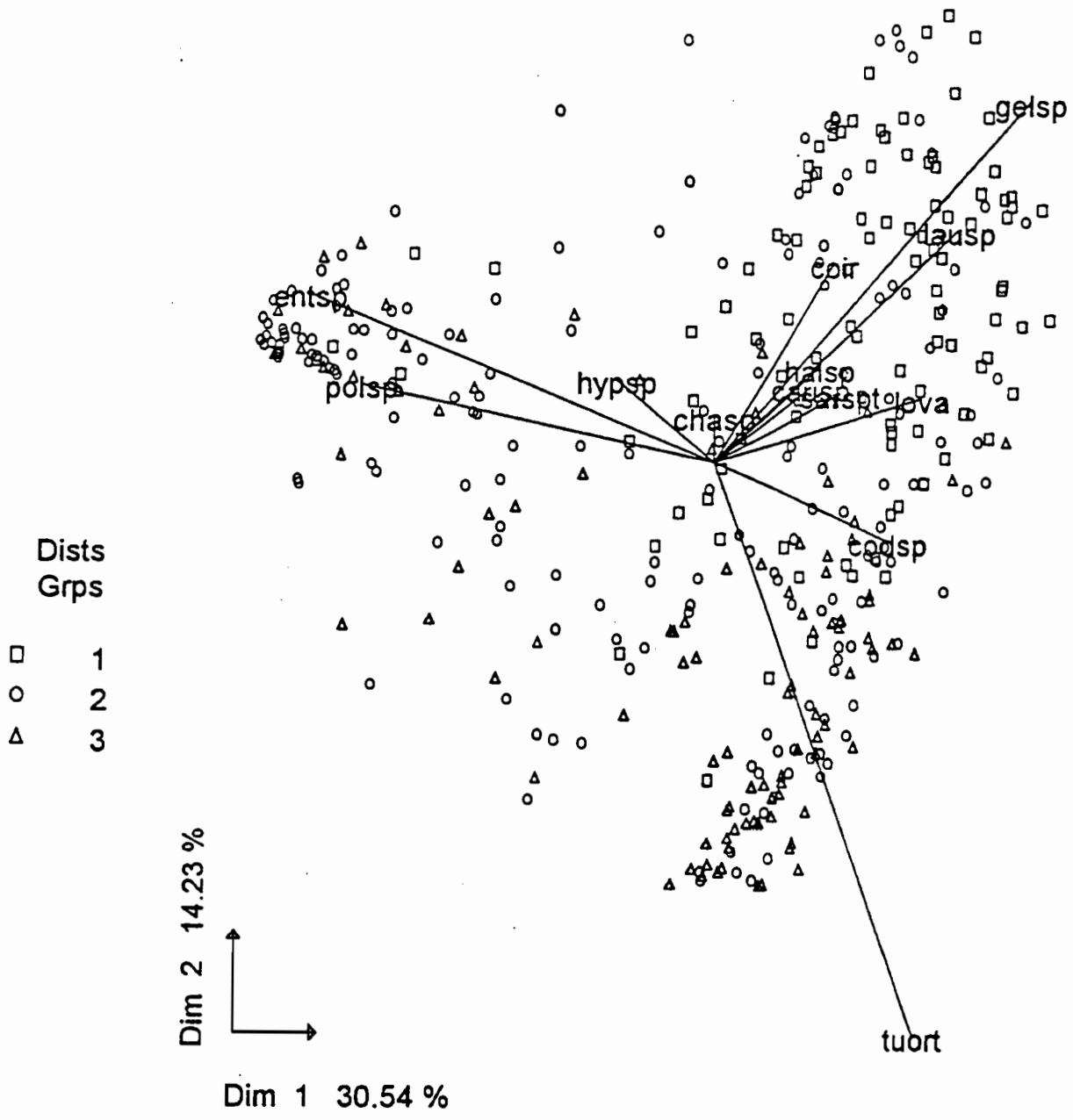


Figure 6.2- Principal components biplot with distribution groupings by age class. (Dist. groups: 1=juvenile, 2=subadult, 3=adult) (causp=*Caulerpa spp.*, chasp=*Champia spp.*, codsp=*Codium spp.*, coir=*Coelothrix irregularis*, entsp=*Enteromorpha spp.*, gelsp=*Gelidiella spp.*, halsp=*Halimeda sp.*, hypsp=*Hypnea spp.*, lausp=*Laurencia spp.*, lova=*Lobophora spp.*, polsp=*Polysiphonia spp.*, sarspt=*Sargassum spp.*, tuort=*Turbinaria ornata*)

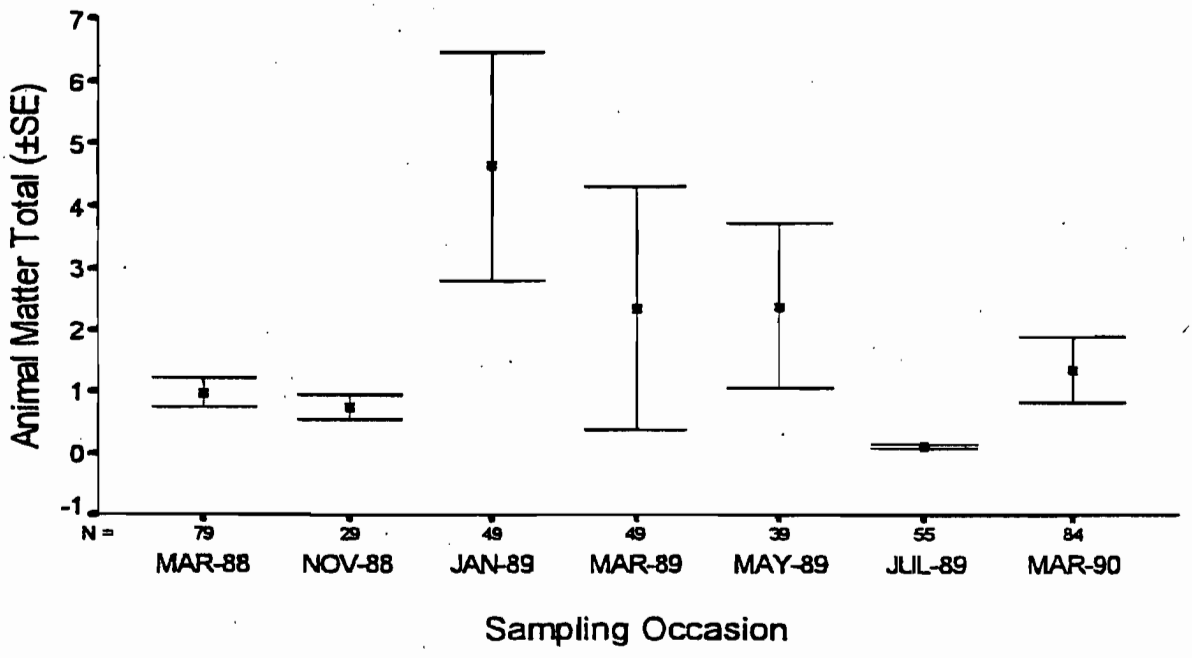


Figure 6.3- Change in total animal matter content in pooled diet over time (n=384).

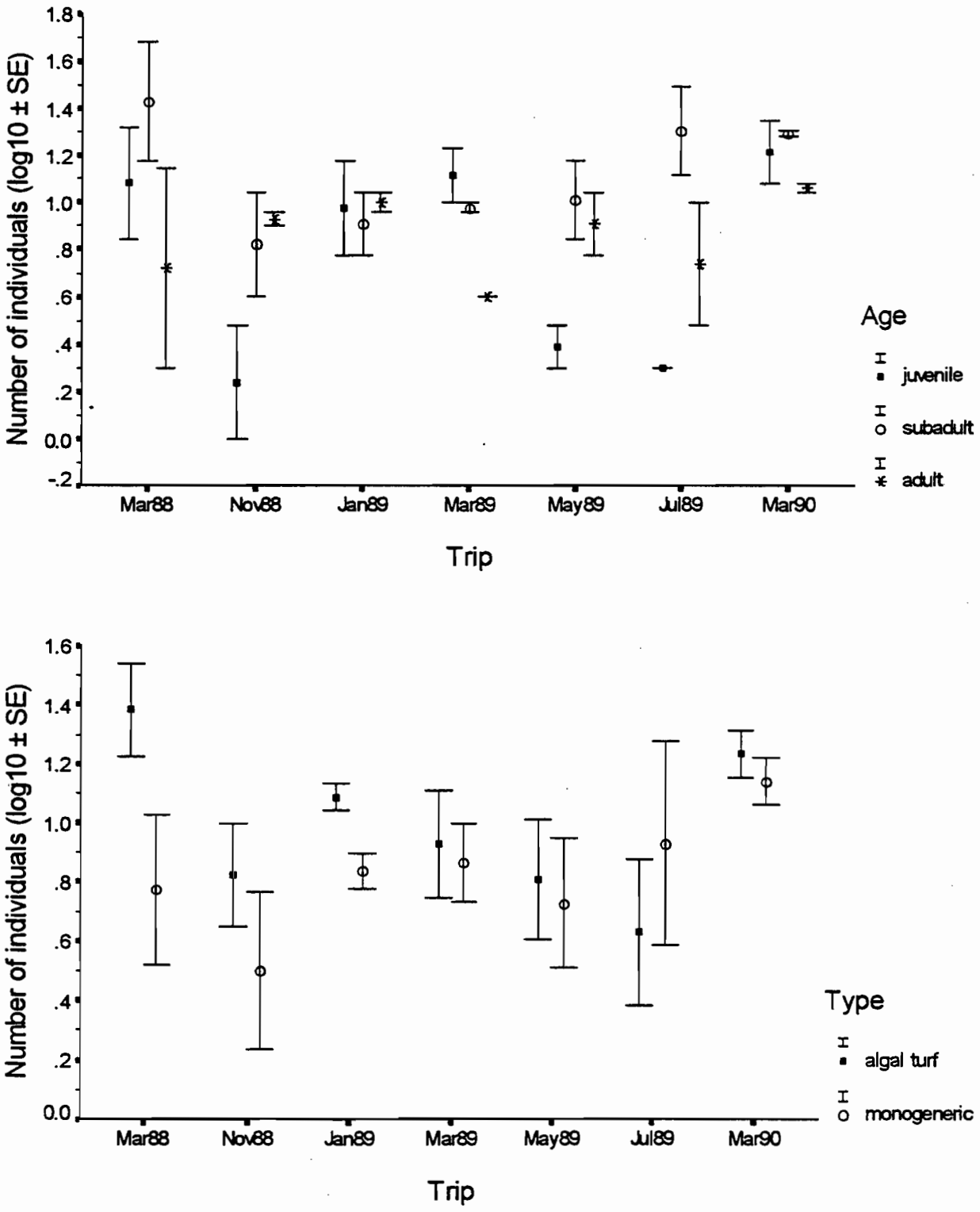


Figure 6.4- Error bar graphs with standard error for the model interaction terms of age (age class), trip (sampling occasion) and type (diet strategy; monogeneric or algal turf feeder).

Chapter 7

Nutritive Potential of Reef Algae

7.1 Introduction

To be considered a nutrient, a dietary constituent must supply either energy or a specific nutrient requirement to the consumer (Jones and Wilson, 1987). However, the same dietary item may not provide the same types or amounts of nutrients and energy to all organisms feeding upon it. Herbivores with enteric fermenting microflora are able extract more nutrients and energy from a given dietary component than nonruminants feeding upon the same item (Van Soest, 1967, 1982; Bjorndal, 1980,1985; Jones and Wilson, 1987; Bjorndal *et al.*, 1990a,b, 1991). Enteric microflora are capable of breaking down complex cellulose and hemicellulose (Van Soest, 1969; Bjorndal, 1979a,b, 1982) and in the process produce volatile fatty acids, vitamins, and amino acids which may be absorbed and utilised by the herbivore (Jones and Wilson, 1987; Bjorndal, 1979b; 1990a,b). As a result of such differential digestibilities, individual dietary components (nutrients and energy) may be of differing value to different species.

In consideration of the benefits of any dietary item, the question of the "value" of that item must be addressed. In attempting to place a value upon a dietary item, the difficulty rests not in the determination of the absolute levels of energy and nutrients, but in the ability to determine the efficiency at which the consumer can extract and absorb nutrients and energy from the various chemical and structural fractions of the plant cell.

The chemical fractions of forage items are typically placed into one of two broad categories based upon their origin in the cell (Van Soest, 1965,1967; Van Soest and Moore, 1965; Jones and Wilson, 1987): cellular components and cell wall (total fibre)

fraction. The cellular components of vascular and algal plants are quite similar in that both contain sugars, reserve carbohydrates, nonprotein nitrogen, protein, lipids, pigments, organic acids, and soluble minerals (Van Soest, 1965,1967; Van Soest and Moore, 1965; Bold and Wynne, 1985; Jones and Wilson, 1987). The cell wall fraction of vascular plants, such as seagrasses, is comprised almost entirely of cellulose, hemicellulose, lignin and cutin (Van Soest, 1965,1967; Van Soest and Moore, 1965; Jones and Wilson, 1987; Bjorndal *et al.*, 1990a,b). However, the cell wall chemistry of algae is much more complex than that of vascular plants and contains a much broader array of complex structural carbohydrates and even proteins (Table 7.1). Reviews of algal cell wall chemistry are presented by Siegel and Siegel (1973), Mackie and Preston (1974) and Bold and Wynne (1985). Algal intracellular components are reviewed by Bold and Wynne (1985).

Cell walls that are composed primarily of cellulose and or hemicellulose are generally nutritionally available only to those herbivores such as the green turtle that possess a fermenting enteric microflora (Van Soest, 1967, 1982; Jones and Wilson, 1987; Bjorndal, 1979b). However, due to the complexity and diversity of the cell wall components of algae, the nutritional availability of the cell wall components remains unclear and poorly studied although it is likely that an enteric microflora should be capable of breaking down these substrates successfully. However, in the absence of studies dealing with the capabilities of green turtle enteric microfloras to act upon these cell wall structural components, it would be premature to assume that they are nutritionally available. Intracellular components are generally considered to be nutritionally available to all herbivores (Van Soest and Moore, 1965; Van Soest, 1969; Jones and Wilson, 1987). The nutritional availability of the cell wall components of marine algae requires further investigation as there are many structural carbohydrates other than cellulose and hemicellulose present in some algal taxa.

Assigning values to the dietary items of domestic livestock is commonly done with empirical knowledge of both their digestive and assimilative efficiencies within the context of the animal's health and dietary regime. When discussing the benefit of a food item in the diet of a wild animal, the value question is difficult to address as the digestive and assimilative efficiencies of the animal with respect to a particular food item are frequently unknown. In euryphagous species, such as the green turtle, this issue is further complicated by the nonadditive or associative effects resulting from the interaction of dietary items (Church, 1977; Martin and Martin, 1978; Kukor *et al.*, 1988; McDonald, *et al.*, 1988; Bjorndal, 1991) (Section 8.2.6).

An objective of my study (Chapter 1) was to determine if the nutritive or energy potential of a dietary component may influence the overall dietary selection strategy of the green turtle. In the absence of known assimilation efficiencies, I investigated the nutrient and energy values of marine algae as indices of their potential value to green turtles appreciating that I could not empirically demonstrate their actual availabilities and importance to the diet.

My investigations on Heron Reef showed that green turtles are confronted with algae whose nutrient and energy levels vary significantly both between species and, in the case of nitrogen, over time. Algal species that were frequently consumed had significantly lower levels of both lipids and nitrogen than did those species infrequently consumed. This suggests that the factors influencing diet selection in the green turtle are complex. Given that many algae contain secondary compounds as defenses against herbivory, it is plausible that they play a major role in the diet choice. This is a hypothesis that requires further investigation. However, it is certain that in making its

dietary decisions, the green turtle must discriminate between a matrix of plant attributes including levels of nutrients, energy and secondary compounds.

7.2 Materials and Methods

I assayed seven algal species which were frequently consumed by green turtles and seven species of algae and one species of macroscopic Cyanobacteria which were infrequently or never consumed (Table 7.2). Those species that were frequently consumed were primary components of the diet at some point during the study and they always appeared in the pooled diet when they were present on the reef. The species that were infrequently or never consumed were spatially available to the turtles and their thalli did not possess any structural deterrents against grazing by turtles. Due to the costs associated with the assays, only seven species from each of the two categories were investigated. All samples were assayed in replicate for total Kjeldahl nitrogen, acid soluble carbohydrates, energy, total lipid, organics, ash content and proximate crude protein using methods detailed in Sections 7.2.2-7.2.7. These nutrients were chosen for assay as they are commonly cited in the literature as being of importance in herbivore diets. To test for temporal influences on these parameters, samples of each of the species were collected from each of the twelve sampling locations on Heron Reef during each sampling trip if they were available.

7.2.1 Collection and Processing of Algae

During each sampling session (excluding March 1988), samples of reef algae were collected from each of the reef habitats along two of the permanent transect lines (Transects #3 & #6). Sampling areas were located near the base of each of the sector marker posts (Section 5.2.2). Representative specimens of the macroscopic noncrustose algal species were collected by hand while snorkelling or while on scuba. Holdfasts and chlorotic specimens were not collected. Specimens were placed into

labelled mesh bags and placed into buckets of fresh seawater for transport back to Heron Island. During transport, the algae were covered and kept cool with constant changes of seawater.

Upon return to Heron Island Research Station, the algae specimens were placed into shaded aquaria supplied with a steady exchange of seawater until they could be processed (< 6 hours). Each thallus was rinsed to remove sand and then cleaned by hand to remove epiphytic growths of algae, foraminiferans and animals. Every effort was made to reduce the rinsing and out of water handling of the fresh algae in order to prevent the removal of the mucilaginous covering of the thallus. This mucilaginous covering is an amorphous matrix of the cell wall which contains large quantities of polysaccharides (Price, 1981; Bold and Wynne, 1985). Damage to this layer may result in the underestimation of the energy content of the plant. Following rinsing, the algae were placed into plastic bags, sealed and stored in a -20°C deep freeze until they could be freeze-dried.

Lyophilization (freeze-drying) of samples is preferred to heat drying (Van Soest, 1982; Short, 1990; Dawes and Kenworthy, 1990) which has been shown to alter the measurable levels of sugar, soluble carbohydrates, in vitro cellulose digestion, acid-detergent fibre, available lysine, crude fibre and protein, lignin, lipids, volatile organics and energy values (Van Soest, 1964, 1965, 1969) and cause amino nitrogen to bind with carbohydrates and result in the formation of Maillard complexes (Van Soest, 1982). Specimens were dried to constant weight in a Dynavac© model FDA/3RH freeze dry unit. Following drying, the algae were ground in a Culatti© mill until the sample could pass through the mill's 1 mm screen. Care was taken not to heat the specimens during milling. The mill and screens were completely disassembled and cleaned between each milling. The powdered specimens were placed into labelled, air tight, screw top

plastic vials and stored in a frost-free deep freeze at -20°C until analysed for nutrient, energy and ash content.

7.2.2 Total Organic Nitrogen Determination

Total organic nitrogen was determined at the Laboratory of Biomedical and Environmental Sciences at the University of California, Los Angeles. Analysis was conducted using 100 mg of lyophilised sample digested using the micro-Kjeldahl digestion technique with the salicylic acid modification of Allen *et al.* (1979). Salicylic acid and $Na_2S_2O_3$ were used to remove NO_x groups that may be present in algae. Failing to remove the NO_x groups would have resulted in artificially high organic nitrogen levels. Digested samples were assayed using a Technicon® continuous flow analyser and expressed as percent total nitrogen of the dry weight sample. Data were then converted to an ash-free dry weight basis. Replicates were accepted if their values were within 0.5% of each other.

7.2.3 Acid Soluble Carbohydrates Determination

The total amount of acid soluble carbohydrates was determined utilising the Dubois phenol-sulfuric acid technique as described by Dawes and Kenworthy (1990). Another commonly used technique for CHO determination utilises anthrone. However, anthrone reagent is expensive and unstable when mixed with H_2SO_4. Anthrone is also of limited value in assaying for methylated sugars and pentoses (Kochert, 1978). In contrast, the phenol-sulfuric acid technique of Dubois is rapid, stable, highly sensitive and inexpensive (Kochert, 1978). The phenol-sulfuric acid technique quantifies only acid soluble carbohydrates such as simple sugars, oligosaccharides, polysaccharides and derivatives having free or potentially free reducing groups (Dawes and Kenworthy, 1990). The percentage of insoluble carbohydrates can be calculated by the subtraction

of the values for acid soluble carbohydrates, protein and lipids from the percentage of organic material in the sample.

The Dubois technique was modified by refluxing 30 mg of lyophilised sample in 15 ml of 15% trichloro-acetic acid for 3 hours in a water bath at 85° C to denature the proteins present. Following refluxing, the sample was cooled to ambient temperature and centrifuged in an International® Clinical Centrifuge, model #CL, at maximum RPM for 10 minutes to precipitate the proteins and particulates present. A 0.2 ml aliquot of the sample was mixed in a cuvette with 1.0 ml of 5% phenol and then 5 ml of concentrated sulfuric acid was then added rapidly to facilitate a colour change to amber. The sample was cooled to ambient (30 min.) and absorbence was read at 490 nm in a Milton Roy® Spectronic 21 spectrophotometer. Sample absorbence was plotted against a glycogen generated standard curve to determine percent acid soluble carbohydrate on a dry weight basis. Glycogen was the standard because glycogen is a polysaccharide and polysaccharides are the primary carbohydrate components in algal walls and storage products (Bold and Wynne, 1985). Data were then converted to an ash-free dry weight basis. Replicates were accepted if their values were within 2.0% of each other.

7.2.4 Total Lipids Determination

The total lipid content of the sample was determined using the chloroform-methanol technique described by Dawes and Kenworthy (1990). This technique was chosen because the very limited work that has been done on lipid levels in algae and seagrasses has been conducted using this technique and therefore comparisons could be made. This technique is also a standard technique for determining lipid levels in other ecological materials.

The total lipid content was determined gravimetrically from 100 mg of lyophilised sample. The technique of Dawes and Kenworthy (1990) was modified by mixing 100 mg of sample with 20 ml of a 2:1 (vol/vol) mixture of chloroform-methanol and refluxed for 15 minutes in a water bath at 60° C. Following refluxing, the sample was cooled to ambient and then filtered through Whatman® #541 filter paper and collected in a shell vial. A 10 ml aliquot of the filtrate was taken and placed into a preweighed centrifuge tube to which 2.0 ml of distilled water was added to extract hydrophilic carbohydrates, minerals and nonprotein nitrogen compounds. The sample was then placed in a VWR® mechanical shaker at low speed for 15 minutes and then centrifuged at maximum RPM for 10 minutes in an International® Clinical Centrifuge, model #CL. Following centrifuging, the upper phase was micropipetted off and the remaining sample was placed uncovered in a water bath at 60° C under a high flow volume fume hood to evaporate off the chloroform-methanol solvent. The sample was then placed in a desiccator for 12 hours and then into a vacuum chamber for 30 minutes to ensure that any residual moisture had been removed. The percent lipid content of the sample was determined gravimetrically by difference and expressed on a percentage of dry weight basis and converted to an ash-free dry weight basis. Replicates were accepted if their values were within 2.0% of each other.

7.2.5 Energy Determination

Energy content was determined at the Laboratory of Biomedical and Environmental Sciences at the University of California, Los Angeles. A 20-30 mg of lyophilised sample was ignited in a Phillipson microbomb calorimeter (Gentry Instruments Inc., Aiken, South Carolina, USA) according to the procedure described by Gentry Inst. Inc. (1989). Samples with high ash contents were mixed with benzoic acid to ensure complete combustion. Corrections for endothermy were made according to Paine (1966, 1971). The residual ash was not used in the determination of total ash as this procedure is not

considered an accurate measurement of ash content (Paine, 1971) as the residual ash will rehydrate after combustion and many salts will decompose during combustion (Paine, 1966). In addition, elements such as sodium and potassium may be swept out on colloidal particles or by the volatilisation of salts during combustion (Grove *et al.*, 1961). Results were expressed as Kj/g on a dry weight basis and converted to Kj/g on an ash-free dry weight basis.

7.2.6 Ash and Organic Matter Determination

Ash content was determined by ashing 50 mg of lyophilised sample in preweighed porcelain crucibles in a muffle furnace for 3 hours at 500° C. Higher temperatures and longer ashing periods were avoided in order to prevent the loss of carbonates from the sample (Paine, 1971). Samples were placed in a desiccator until ambient temperature was reached. The percent ash content was determined by difference. Organic matter was calculated by subtracting the ash weight from dry matter weight. Replicates were accepted if their values were within 2.0% of each other.

7.2.7 Crude Protein Determination

Crude protein levels were determined by multiplying the total nitrogen content by 6.25. Although this conversion factor is cited extensively in the literature (Mortimer, 1976; Wood and Wood, 1977a,b; Bjorndal, 1980) it has been well documented that this procedure may result in a significant over estimation of the actual protein levels as not all the nitrogen analysed will be protein bound (Van Soest and Robertson, 1980; Milton and Dintzis, 1981; Garnett *et al.*, 1985). The crude protein conversion values provided here are for comparison with other studies only and are not intended to represent actual protein levels. Since crude protein levels are only approximations of actual protein levels, the use of these values in the calculation of acid insoluble carbohydrates must

be made with caution (Section 7.2.3). Protein levels were expressed on a dry weight and ash-free dry weight basis.

7.2.8 Statistical Analysis

In order to determine whether each species changed in nutrient and energy content over time, it was desirable to sample the same species from the same locations repeatedly over time. However, due to the ephemeral distribution of the algal flora, specimens of most species were not available during most sampling sessions resulting in many missing data points and unbalanced data. Therefore, the analyses were limited to the treatment of mean values. Of the 15 species that were sampled, the nutrient and energy content of seven species were analysed across four sampling occasions in an analysis of variance. The remaining species were assayed but these data were not included in the analysis of variance due to their irregular occurrence on the reef. Species_7 (*Caulerpa racemosa, Chlorodesmis fastigiata, Codium sp., Halimeda sp., Halimeda tuna, Laurencia intricata, Turbinaria ornata*) were treated as fixed factors and occasion_4 (Nov, 88; Jan 89; May 89; Jul 89) as random factors. The response had to be the mean value for each nutrient for each species for each occasion because of the unbalanced and incomplete data set. Thus it was impossible to test the species by occasion interaction.

Analysis of variance using sequential sums of squares was used to determine if the nutrient and energy levels were significantly different between those species frequently consumed (*Caulerpa racemosa, Codium sp., Laurencia intricata, Turbinaria ornata*) and those species infrequently consumed (*Chlorodesmis fastigiata, Halimeda sp., Halimeda tuna, Lobophora variegata, Plocamium hamatum*). The values for nitrogen and lipid were l_n transformed to stabilise variance. "Consumption status" was treated as a fixed factor while "species" was nested within "consumption status" and treated as

a random factor as was "occasion". As in the previous analysis, the mean value for each nutrient for each species for each occasion was used as the response due to the unbalanced and incomplete data set.

Prior to analysis of the data sets, the assumptions of normality and homoscedasticity of residuals were examined. The data were examined for normality of errors by assessing q-q plots and equality of variance was evaluated using plots of residual vs. predicted values. The assumptions of normality and homoscedasticity were met for all of the analyses. Tests of significance were assessed at α=0.05.

7.3 Results

7.3.1 Nutrient and Energy Values for Nine Species Studied Over Time

The nine algal species analysed differed significantly from each other in their mean content of energy (p =0.001), carbohydrates (p <0.001), ash (p <0.0001), lipid (p =0.02) and nitrogen (p <0.001) (Table 7.3, Figure. 7.1). The levels of energy and nutrients did not change significantly across the sampling times with the exception of nitrogen (p =0.024) (Table 7.3, Figures 7.1 & 7.2). There was no apparent pattern to the changes observed in the levels of nutrients or energy over time for each species (Figure 7.3). For example, lipid levels were highest in May, 1989 for *Laurencia* and *Plocamium* , the time when *Chlorodesmis* had its lowest levels. Lipid levels were highest in November, 1988 for *Halimeda* when *Chlorodesmis* and *Laurencia* were at their lowest levels. Contrastingly, *Lobophora* and *Turbinaria* remained relatively unchanged throughout the sampling period. Similar results were found for the other nutrient and energy assays. Not only did the nutrient and energy levels vary between species but there was also considerable variation within a species during the same sampling occasion.

7.3.2 Nutrient and Energy Values Across All Species

7.3.2.1 Nitrogen

Of the species assayed, nitrogen levels ranged from a low of 0.8% (dry weight, ash-free basis) to a high of 5.8 % (Table7.4.a). There was a significant change in nitrogen levels when averaged across the 9 species followed throughout the study (p =0.024) Table 7.3, Figure 7.1 & 7.2). The greatest change in a single species occurred in the rhodophyte *Plocamium* (range: 3.1-5.4%). Of the species examined, the highest mean nitrogen levels averaged across the study were found in both the Chlorophyta ($\overline{X}$=3.6%, s.e.=0.3) and the Rhodophyta ($\overline{X}$=3.6%, s.e.=0.3). In addition to having the highest nitrogen levels averaged over the study, the Chlorophyta (*Chlorodesmis fastigiata*) also possessed the highest nitrogen levels during each sampling occasion (Table 7.4b). However the cyanophyte *Lyngbya,* which was sampled only during July, 1989, had nitrogen levels (4.5%) in excess of the mean levels of all three algal divisions.

The highest nitrogen levels averaged across all three algal divisions and the same six species occurred during May, 1989 ($\overline{X}$=3.2%, s.e.=0.7) although overall nitrogen levels were comparable across all sampling occasions (range: 2.6-3.2%) (Table 7.5).

7.3.2.2 Energy

Of the species assayed, energy levels ranged from a low of 2.48 Kcal/g (dry weight, ash free basis) to a high of 5.32 Kcal/g (Table 7.4a). There was no significant change in energy levels when averaged across the 9 species followed throughout the study (p =0.733) (Table 7.3). The greatest change in a single species occurred in the chlorophyte *Halimeda* (range: 2.48-4.28 Kcal/g). The highest mean energy levels averaged across the study were found in the Chlorophyta ($\overline{X}$=4.1 Kcal/g, s.e.=0.2) followed by the Rhodophyta ($\overline{X}$=3.9 Kcal/g, s.e.=0.1) and the Phaeophyta ($\overline{X}$=3.6 Kcal/g, s.e.=0.1). In addition to having the highest energy levels averaged over the

study, the Chlorophyta (*Chlorodesmis fastigiata*) also possessed the highest energy levels during each sampling occasion (Table 7.4).

The highest energy levels averaged across all three algal divisions and the same six species occurred during May, 1989 although overall energy levels were comparable across all sampling occasions (range: 3.8-4.1 Kcal/g) (Table 7.5).

7.3.2.3 Lipids

Lipid levels ranged from a low of 0.8% (dry weight, ash-free basis) across all species to a high of 18.5%[1] (Table 7.4a). There was no significant change in lipid levels when averaged across the 9 species followed throughout the study (p =0.563) (Table 7.3). The greatest change in a single species occurred in the rhodophyte *Laurencia* (range: 4.1-11.8%). Of the species examined, the highest mean lipid levels averaged across the study were found in the Chlorophyta ($\overline{X}$=10.2%, s.e.=0.5 or 7.5%, s.e.=1.1 w/o *Halimeda*[1]) followed by the Rhodophyta ($\overline{X}$=6.1%, s.e.=1.0) and the Phaeophyta ($\overline{X}$=3.0%, s.e.=0.5). In addition to having the highest lipid levels averaged over the study, chlorophytes also possessed the highest lipid levels during each sampling occasion with the exception of May, 1989 in which *Laurencia* had slightly higher levels (11.8%) than the next highest chlorophyte, *Chlorodesmis* (10.1%) (Table 7.4). However the cyanophyte *Lyngbya,* which was sampled only during July, 1989, had lipids levels (16.5%) in excess of even the Chlorophyta.

The highest lipid levels averaged across all three algal divisions and the same six species occurred during November, 1988 ($\overline{X}$=11.1%, s.e.=6.8) (Table 7.5). However,

[1] The November measurements of lipid levels in *Halimeda* were excluded from this data set as although the measurements were supported by replicate analyses, the levels are double that of the next highest levels detected in this study and are much higher than other published levels of lipids for *Halimeda* or other algal species.

as previously discussed, a very high lipid content (37.8%) in *Halimeda* was responsible for this ranking. When *Halimeda* was removed from each of the four sampling session's data set, the highest lipid levels occurred in May of 1989 ($\overline{X}$=6.6, s.e.=1.9) and the lowest in November of 1988 ($\overline{X}$=4.5, s.e.=1.8).

7.3.2.4 Carbohydrates

Carbohydrate levels ranged from a low of 6.0% (dry weight, ash-free basis) to a high of 29.8% (Table 7.4a) in those species that were assayed. There was no significant change in carbohydrate levels when averaged across the 9 species followed throughout the study (p = 0.926) (Table 7.3). The greatest change in a single species occurred in the chlorophyte *Caulerpa* (range: 8.6-18.5%). Of the species examined, the highest mean carbohydrate levels averaged across the study were found in the Rhodophyta ($\overline{X}$=23.4%, s.e.=1.0) followed by the Chlorophyta ($\overline{X}$=17.1%, s.e.=1.4) and the Phaeophyta ($\overline{X}$=10.0%, s.e.=0.8). In addition to having the highest carbohydrate levels averaged over the study, rhodophytes (*Laurencia*) also possessed the highest carbohydrate levels during each sampling session (Table 7.4b). The carbohydrate levels in the cyanophyte *Lyngbya* were at 14.8% in July, 1989, the only time sampled. This level exceeded the overall levels found in the Phaeophyta.

The highest carbohydrate levels averaged across all three algal divisions and the same six species occurred during July, 1989 ($\overline{X}$=16.9%, s.e.=2.5) although the carbohydrate levels found during the other sampling occasions were comparable (range: 14.5-16.9%) (Table 7.5).

7.3.2.5 Ash

Of the species assayed, ash levels ranged from a low of 11.6% (dry weight basis) to a high of 87.8% (Table 7.4a). There was no significant change in ash levels when

averaged across the 9 species followed throughout the study (p =0.885) (Table 7.3). The greatest change in a single species occurred in the chlorophyte *Halimeda* (range: 58.8-87.8%). Of the species examined, the highest mean ash levels averaged across the study were found in the Chlorophyta ($\overline{X}$=45.6, s.e.=6.6) although levels in the Rhodophyta were similar ($\overline{X}$=45.4, s.e.=5.0). The Phaeophyta averaged 35.1% (s.e.=5.3) ash. In addition to having the highest ash levels averaged over the study, chlorophytes also had the highest ash levels during each sampling occasion with the exception of July, 1989 in which the phaeophyte *Hydroclathrus* was 1.3 % higher than the next highest chlorophyte (Table 7.4b). However, the high ash level in *Hydroclathrus* was mostly likely an artefact of substrate contaminants that accumulate in *Hydroclathrus* as it tumbles across the lagoon floor. Substrate contaminates were also a problem in the chlorophyte *Enteromorpha*. Although every effort was made to remove these contaminants prior to analysis, some still remained.

The highest ash levels averaged across all three algal divisions and the same six species occurred during January, 1989 ($\overline{X}$=39.6, s.e.=10.8) although overall ash levels were comparable across all sampling occasions (range; 34.8-39.6%) (Table 7.5).

7.3.3 Nutrient and Energy Content of Frequently vs. Infrequently Consumed Species.

Those species of algae that were identified as frequently consumed were found to have significantly lower levels of lipids and nitrogen than did those species that were infrequently consumed (Table 7.6). The levels of the remaining nutrients and energy were not found to differ between the two consumption categories (Figures 7.4 & 7.5). There were significant differences in the levels of nutrients and energy between the species within each category which supports the findings from other analyses cited above (Section 7.3.1, Table 7.3).

7.4 Discussion

Of the species analysed, the Chlorophyta and the Rhodophyta contained the highest and comparable levels of nitrogen, energy and ash while the Chlorophyta had higher lipid and lower carbohydrate levels than the Rhodophyta. All nutrient and energy levels were considerably lower in the Phaeophyta. Horn and Neighbors (1984) also found nitrogen and protein levels comparable in the Chlorophyta and Rhodophyta while Edwards and Horn (1982) found variable levels of protein, carbohydrate, lipids and ash between the two divisions (Table 7.7). In contrast to the findings in this study, Montgomery and Gerking (1980) found that the Phaeophyta exceeded the Rhodophyta in protein, carbohydrate, lipid and energy and exceeded the Chlorophyta in lipids. In their extensive survey of energy levels in marine algae, Paine and Vadas (1969) found the energy levels in the three divisions to be comparable while Larkum *et al.*, (1967) found levels in the Chlorophyta to be higher than in the Phaeophyta.

The apparently inconsistent relationships between the divisions found amongst these studies may be a result of several factors: 1) actual variation within the divisions, 2) variable analytical techniques, 3) samples from different geographical locales, 4) single versus multiple sampling period data sets, 5) the species and number of species selected for study, 6) the season of sampling, 7) sample size. Therefore care should be exercised in making generalisations about the value of one division over another in the absence of a longitudinal study of the algae in the habitat of interest. If generalisations are to be made, they may be best made at a taxon below the Division. The results of this study and others (Dawes *et al.*, 1979; Hay *et al*, 1988) show that nutrient content varies widely over time at the division, genus and species level. Additionally, it has been demonstrated that there is variation in algal chemistry on a 24 hr. basis (Hay *et al.*, 1988).

The nitrogen levels found in marine macroalgae in this and other studies (≤4% dm) fall within the range for seagrasses (~1.5-3.5% dm) (Bjorndal, 1982; Lanyon, 1991), terrestrial monocots (~1-4% dm) (Stobbs, 1973; Mattson, 1980; McDonald *et al.*, 1988) and in the low range for terrestrial dicots (McArthur, 1988).

The levels of ash found in the leaves of the seagrass genera studied by Lanyon (1991) (*Halophila, Halodule, Cymodocea, Zostera*) were substantially lower (~7-10% dm) than those found for macroalgae in this study (Table 7.4) while the ash content in the leaves of *Thalassia* was comparable (~35%dm) (Dawes, *et al.*, 1979; Bjorndal, 1982) to the noncalcareous macroalgae.

Carbohydrate levels in the leaves of seagrasses are substantially lower (~3-12% dm) (Dawes, *et al.* 1979; Lanyon, 1991) than in macroalgae (Table 7.4) although the rhizomes of seagrasses contain comparable levels (~11-26% dm) (Lanyon, 1991). Contrastingly, Dawes *et al.* (1979) found very low levels of carbohydrates (6-10% dm) in the algal species they examined.

Lipid levels in macroalgae are also comparable to those found in seagrasses (~0.1-8% dm) (Nichols *et al.*, 1982; Anderson, 1986; Dawes, *et al*, 1987) while energy levels of macroalgae from this study were also comparable to those in seagrasses (Wake, 1975; Dawes *et al*,. 1979; Bjorndal, 1982).

It is clear from the diet literature (Chapter 2) that many factors influence the nutritive potential of a dietary item. These factors will certainly include the absolute levels of nutrients and energy, but will also take into account the physiological uptake of these nutrients by the animal as a function of the animal's digestive efficiency and nonadditive

or associative effects of the various dietary components (Chapter 8). Additionally, negative impacts from secondary metabolites must also be taken into account for an algae species high in a desirable nutrient may also be well defended with herbivore deterrents (Sections 2.3.2.8 & 8.3.2). This may be the situation with those species of algae that were infrequently consumed by green turtles on Heron Reef but yet had significantly higher levels of lipids and nitrogen than did those species that were frequently consumed. Those species that were infrequently consumed and grow in monogeneric stands e.g, *Plocamium* , *Chlorodesmis*, *Halimeda* , are known to possess rich secondary compound profiles which may act as deterrents against herbivory (De Nys, 1991; pers. comm. R. De Nys). However, some species e.g., *Laurencia* , are known to possess a rich secondary metabolite profile yet they were common in the diet and even accounted for some of the primary diet species. It is therefore apparent that further investigation is required to understand the relationship between secondary compounds and diet selection in green turtles. The possible influences of secondary compounds on diet selection in green turtles is discussed in Sections 2.3.2.8 & 8.3.2.

The nomination of a single nutrient parameter of importance in this study would have led to variable results depending on the parameter selected. If carbohydrate was chosen, *Laurencia* would have been the most important species in each session whereas the use of nitrogen would place *Chlorodesmis* in the forefront of importance. Mattson (1980) suggests that levels of available nitrogen play a critical role in dietary selection by herbivores which are limited in their nitrogen intake as a result of their plant diet. Total lipid levels would place *Halimeda* as the most important forage in the majority of sampling sessions. If energy were selected, *Chlorodesmis* would have been the most important dietary item in each sampling occasion. The use of energy as the sole criterion is further complicated by the fact that absolute energy content does not equate to the nutritive value of that energy. In the absence of empirical knowledge of

the selection criteria by which green turtles choose their diet, use of a single nutrient parameter to evaluate potential dietary items may be inappropriate.

The goal of this study was not to identify those species that would provide the optimal forage for the green turtle, but to determine if there was variation within and between species that would influence dietary selection choices by green turtles. For the 14 algae and 1 cyanobacterian species analysed, there were significant differences in the levels of energy and the nutrients assayed between species. This wide variation shows that certain species are of greater energy and nutrient potential than others and that this variation is temporally influenced. In addition to the significant variation in nutrient and energy content between species, there was also considerable variation in these levels within a species during the same sampling occasion. As the value of a food item to the diet will vary with the food's nutrient or energy value to the consumer, there is an advantage for the green turtle to attempt to optimise its intake of those species providing the greatest nutrient and energy benefit while decreasing the intake of undesirable secondary compounds. However, the green turtle is faced with an algal flora that varies in its nutrient, energy and secondary metabolite content temporally and between and within species. Such variation presents challenges to the green turtle in selecting an optimal diet. The environmental and physiological influences acting upon this diet selection process are discussed in Chapter 8.

7.5 Conclusions

1. The gross nutrient (carbohydrate, nitrogen, lipid, ash) and energy contents of macroalgae species on Heron Reef vary significantly among species and show considerable variation within a species during the same sampling occasion.
2. Carbohydrate, lipid, ash and energy levels in algae from Heron Reef do not change significantly over time whereas nitrogen levels do show significant changes.

3. There is substantial variation in nutrient and energy content between species within the same division.
4. Those species frequently consumed by green turtles on Heron Reef have significantly lower lipid and nitrogen levels than those infrequently consumed. This suggests that the more nutritionally valuable species may be protected with secondary compounds that deter green turtle grazing. The relationship between secondary compounds and dietary selection in green turtles requires further investigation before causative relationships can be determined.
5. In the face of a nutritionally and energetically diverse and dynamic algal flora, optimal foraging theory would suggest that the green turtle on Heron Reef should develop a foraging strategy that will optimise its intake of nutrients and energy while minimising its intake of deleterious compounds.

Table 7.1- Diversity of algal and cyanobacteria cell wall structural components and storage products. Listings represent the diversity found within each division. Information from Bold and Wynne (1985).

Division	Cell Wall Components	Storage Products	Calcification
Chlorophyta	Protein, cellulose, hemicellulose, polymers of mannose and xylose, sulphated mucopolysaccharides.	Starch (amylose or amylopectin), glucan, fructan, oil.	Aragonite in the Udoteaceae
Phaeophyta	Cellulose, sulfated mucopoly-saccharides, alginic acid, alginates.	Laminarian (glucan), mannitol.	Only in *Padina* spp.
Rhodophyta	Protein, cellulose, mannans, xylans, alginates, sulphated mucopoly-saccharides.	Starch (amylopectin), glucan, sucrose.	Aragonite or calcite in 15% of species.
Cyanophyta	Mucopolymer layers of peptido-glycans, murein, lipopolysaccharides,	Starch (amylopectin or glycogen-like), glucan, cyanophycin granules, polyglucose, aspartic acid, arginine	None

Table 7.2- Algae and cyanobacteria assayed for nutrient and energy content. Species are grouped by the frequency by which they appeared in the diet of green turtles from Heron Reef.

	Chlorophyta	Phaeophyta	Rhodophyta	Cyanobacteria
Frequently Consumed	*Caulerpa racemosa* *Codium sp.* *Enteromorpha sp.*	*Lobophora variegata* *Turbinaria ornata*	*Laurencia intricata* *Polysiphonia sp.*	
Infrequently Consumed	*Chlorodesmis fastigiata* *Halimeda sp* *Halimeda tuna*	*Padina sp.* *Sargassum sp.* *Hydroclathrus clathratus*	*Plocamium hamatum*	*Lyngbya sp.*

Table 7.3-Specific and temporal variation in the nutrient and energy content of nine species of algae from Heron Reef. Species was treated as fixed factor and occasion as a random factor. Nutrient type was the response variable.

Nitrogen content (%, ash free basis)

Source of Variation	SS	DF	MS	F	Sig. of F
Within + Residual	3.80	17	0.22		
Occasion	2.73	3	0.91	4.06	0.024
Species	53.08	8	6.64	29.66	0.000
(Model)	55.33	11	5.03	22.49	0.000
(Total)	59.13	28	2.11		
R-Squared	0.936				
Adj. R-Squared	0.894				

Energy content (Kj/g, ash free basis)

Source of Variation	SS	DF	MS	F	Sig. of F
Within + Residual	2.58	17	0.15		
Occasion	0.2	3	0.07	0.43	0.733
Species	7.55	8	0.94	6.23	0.001
(Model)	7.72	11	0.7	4.63	0.002
(Total)	10.3	28	0.37		
R-Squared	0.75				
Adj. R-Squared	0.588				

Lipid content (%, ash free basis)

Source of Variation	SS	DF	MS	F	Sig. of F
Within + Residual	524.58	17	30.86		
Occasion	65.18	3	21.73	0.7	0.563
Species	799.39	8	99.92	3.24	0.02
(Model)	897.23	11	81.57	2.64	0.035
(Total)	1421.81	28	50.78		
R-Squared	0.631				
Adj. R-Squared	0.392				

Carbohydrate content (%, ash free basis)

Source of Variation	SS	DF	MS	F	Sig. of F
Within + Residual	159.73	18	8.87		
Occasion	4.07	3	1.36	0.15	0.926
Species	972.43	8	121.55	13.7	0.000
(Model)	992.97	11	90.27	10.17	0.000
(Total)	1152.7	29	39.75		
R-Squared	0.861				
Adj. R-Squared	0.777				

Ash content (%)

Source of Variation	SS	DF	MS	F	Sig. of F
Within + Residual	966.12	17	56.83		
Occasion	36.65	3	12.22	0.21	0.885
Species	10493.53	8	1311.69	23.08	0.000
(Model)	10589.23	11	962.66	16.94	0.000
(Total)	11555.34	28	412.69		
R-Squared	0.916				
Adj. R-Squared	0.862				

Due to the many missing data points and therefore unbalanced data, analyses addressing the interaction between Occasion and Species were not possible and mean values for each species were used in the analyses.

Table 7.4 -Nutrient and energy profiles for all species of algae collected on Heron Reef. Data are arranged in Table 7.4a by division, then alphabetically and by each sampling occasion with overall means for each species and each division. Data are arranged in Table 7.4b by sampling occasion and then alphabetically within each sampling occasion. Lipid, carbohydrate, energy, nitrogen and protein values are based upon an ash free, dry weight basis.

Table 7.4a	Sampling Occasion	Mean % Lipid (Ash-Free)	Mean % Acid Sol. CHO[1] (Ash-Free)	Mean Energy (KCal/g)[6] (Ash-Free)	Mean % Nitrogen (Ash-Free)	Mean % Crude Protein[2] (Ash-Free)	Mean % Ash	Mean % Organic Content[5]
Chlorophyta								
Caulerpa racemosa	Nov-88	-	8.6	-	-	-	-	-
	Jan-89	5.6	18.0	4.15	2.2	13.9	35.3	64.7
	Mar-89	-	12.6	-	-	-	-	-
	May-89	5.6	18.4	4.72	2.9	18.1	27.2	72.8
	Jul-89	5.2	18.5	3.86	2.8	17.4	38.2	61.9
	Overall (s.e.)	5.5 (0.16)	15.2 (1.98)	4.20 (0.25)	2.6 (0.21)	16.5 (1.32)	33.6 (3.3)	66.5 (3.3)
Chlorodesmis fastigiata	Nov-88	9.5	21.6	5.32	5.0	31.0	14.1	86.0
	Jan-89	12.7	17.0	5.18	3.9	24.5	15.1	85.0
	May-89	10.1	14.4	5.03	5.8	36.5	11.6	88.4
	Jul-89	12.3	15.9	4.46	5.3	33.3	14.7	85.4
	Overall (s.e.)	11.2 (0.8)	17.2 (1.5)	5.04 (0.2)	5.0 (0.4)	31.3 (2.5)	13.8 (0.8)	86.2 (0.8)
Codium sp.	May-89	5.6	29.8	3.97	2.7	16.8	57.9	42.1
	Jul-89	4.7	28.8	3.65	2.4	14.7	50.5	49.5
	Overall (s.e.)	5.2 (0.5)	29.3 (0.5)	3.83 (0.2)	2.5 (0.2)	15.8 (1.1)	54.2 (1.1)	45.8 (3.7)
Enteromorpha sp.	Jul-89	3.7	18.4	3.00	1.7	10.8	69.0[4]	31.0
Halimeda sp.	Nov-88	37.8[3]	13.0	3.23	4.1	25.4	87.8	12.2
	Jan-89	18.5	14.5	2.48	3.8	23.8	86.1	13.9
	May-89	8.1	13.8	4.28	4.0	24.8	58.8	41.2
	Jul-89	5.0	18.4	4.14	3.3	20.7	61.2	38.8
	Overall (s.e.)	17.4 (7.4)	14.9 (1.2)	3.5 (0.4)	3.8 (0.2)	23.7 (1.0)	73.5 (7.8)	26.5 (7.8)
Halimeda tuna	Jul-89	9.1	9.5	4.20	3.5	22.0	56.7	43.3
Chlorophyta Total		10.2 (2.2)	17.1 (1.4)	4.1 (0.2)	3.6 (0.3)	22.2 (1.9)	45.6 (6.6)	54.4 (6.6)
Phaeophyta								
Padina sp.	Jul-89	7.4	6.6	3.97	2.1	13.4	63.5	36.5
Sargassum sp.	Jul-89	3.3	6.0	2.90	1.3	8.3	43.6	56.4
Turbinaria ornata	Nov-88	3.4	9.6	3.43	0.8	4.7	21.2	78.8
	Jan-89	3.1	8.0	3.50	1.0	5.9	29.3	70.7
	May-89	3.2	7.8	3.53	1.2	7.3	24.3	75.7
	Jul-89	2.5	9.8	3.35	0.8	5.0	31.4	68.7
	Overall (s.e.)	3.1 (0.2)	8.8 (0.5)	3.54 (0.04)	0.9 (0.1)	5.7 (0.6)	26.5 (2.3)	73.5 (2.3)
Hydroclathrus clathratus	Jul-89	4.2	11.5	3.64	2.8	17.6	70.3[4]	29.7
Lobophora variegata	Nov-88	0.8	15.5	3.83	1.3	7.9	16.2	83.8
	Jan-89	1.3	12.0	3.94	1.6	9.7	18.9	81.2
	May-89	2.2	12.1	3.68	1.7	10.6	31.6	68.4
	Jul-89	1.3	11.5	3.61	1.5	9.4	35.8	64.3
	Overall (s.e.)	1.4 (0.3)	12.8 (0.9)	3.76 (0.07)	1.5 (0.1)	9.4 (0.5)	25.6 (4.8)	74.4 (4.8)
Phaeophyta Total		3.0 (0.5)	10.0 (0.8)	3.6 (0.1)	1.5 (0.2)	9.1 (1.1)	35.1 (5.3)	64.9 (5.3)
Rhodophyta								
Laurencia intricata	Nov-88	4.1	26.5	4.30	3.1	19.4	45.4	54.7
	Jan-89	6.3	23.8	3.80	3.3	20.8	53.2	46.8
	May-89	11.8	20.7	3.38	3.8	23.7	55.1	45.0
	Jul-89	7.7	27.1	3.82	2.6	16.0	50.1	49.9
	Overall (s.e.)	7.5 (1.6)	24.5 (1.4)	3.825 (0.2)	3.2 (0.3)	20.0 (1.6)	50.9 (2.1)	49.1 (2.1)
Plocamium hamatum	Jan-89	3.5	20.4	4.24	3.1	19.4	23.9	76.1
	May-89	6.4	21.1	4.10	5.4	33.7	34.7	65.3
	Jul-89	4.1	21.6	4.23	4.9	30.4	33.0	67.0
	Overall (s.e.)	4.7 (0.9)	21.0 (0.4)	4.19 (0.04)	4.5 (0.7)	27.9 (4.3)	30.5 (3.3)	69.5 (3.3)
Polysiphonia sp.	Jul-89	4.6	26.4	3.25	3.0	18.9	68.2	31.8
Rhodophyta Total		6.1 (1.0)	23.4 (1.0)	3.9 (0.1)	3.6 (0.3)	22.8 (2.2)	45.4 (5.0)	54.6 (5.0)
Cyanophyta								
Lyngbya sp.	Jul-89	16.5	14.8	-	4.5	28.0	57.3	42.7

Table 7.4b

	Sampling Occasion	Mean % Lipid (Ash-Free)	Mean % Acid Sol. CHO[1] (Ash-Free)	Mean Energy (KCal/g)[6] (Ash Free)	Mean % N (Ash Free)	Mean % Crude Protein[2] (Ash-Free)	Mean % Ash	Mean % Organic Content[5]
Caulerpa racemosa	Nov-88	-	8.6	-	-	-	-	
Chlorodesmis fastigiata	Nov-88	9.5	21.6	5.32	5.0	31.0	14.1	86.0
Halimeda sp.	Nov-88	37.8 [3]	13.0	3.23	4.1	25.4	87.8	12.2
Laurencia intricata	Nov-88	4.1	26.5	4.30	3.1	19.4	45.4	54.7
Lobophora variegata	Nov-88	0.8	15.5	3.83	1.3	7.9	16.2	83.8
Turbinaria ornata	Nov-88	3.4	9.6	3.43	0.8	4.7	21.2	78.8
Nov-88 Mean(s.e.)		11.1 (6.8)	15.7 (2.9)	4.0 (0.4)	2.8 (0.8)	17.6 (5.0)	36.9 (13.9)	
Caulerpa racemosa	Jan-89	5.6	18.0	4.15	2.2	13.9	35.3	64.7
Chlorodesmis fastigiata	Jan-89	12.7	17.0	5.18	3.9	24.5	15.1	85.0
Halimeda sp.	Jan-89	18.5	14.5	2.48	3.8	23.8	86.1	13.9
Laurencia intricata	Jan-89	6.3	23.8	3.80	3.3	20.8	53.2	46.8
Lobophora variegata	Jan-89	1.3	12.0	3.94	1.6	9.7	18.9	81.2
Plocamium hamatum	Jan-89	3.5	20.4	4.24	3.1	19.4	23.9	76.1
Turbinaria ornata	Jan-89	3.1	8.0	3.50	1.0	5.9	29.3	70.7
Jan-89 Mean (s.e.)		7.3 (2.3)	16.2 (2.0)	3.9 (0.3)	2.7 (0.4)	16.8 (2.7)	37.4 (9.4)	
Caulerpa racemosa	May-89	5.6	18.4	4.72	2.9	18.1	27.2	72.8
Chlorodesmis fastigiata	May-89	10.1	14.4	5.03	5.8	36.5	11.6	88.4
Codium sp.	May-89	5.6	29.8	3.97	2.7	16.8	57.9	42.1
Halimeda sp.	May-89	8.1	13.8	4.28	4.0	24.8	58.8	41.2
Laurencia intricata	May-89	11.8	20.7	3.38	3.8	23.7	55.1	45.0
Lobophora variegata	May-89	2.2	12.1	3.68	1.7	10.6	31.6	68.4
Plocamium hamatum	May-89	6.4	21.1	4.10	5.4	33.7	34.7	65.3
Turbinaria ornata	May-89	3.2	7.8	3.53	1.2	7.3	24.3	75.7
May-89 Mean (s.e.)		6.6 (1.2)	17.3 (2.4)	4.1 (0.2)	3.4 (0.6)	21.4 (3.6)	37.6 (6.2)	
Caulerpa racemosa	Jul-89	5.2	18.5	3.86	2.8	17.4	38.2	61.9
Chlorodesmis fastigiata	Jul-89	12.3	15.9	4.46	5.3	33.3	14.7	85.4
Codium sp.	Jul-89	4.7	28.8	3.65	2.4	14.7	50.5	49.5
Enteromorpha sp.	Jul-89	3.7	18.4	3.00	1.7	10.8	69.0 [4]	31.0
Halimeda sp.	Jul-89	5.0	18.4	4.14	3.3	20.7	61.2	38.8
Halimeda tuna	Jul-89	9.1	9.5	4.20	3.5	22.0	56.7	43.3
Hydroclathrus clathratus	Jul-89	4.2	11.5	3.64	2.8	17.6	70.3 [4]	29.7
Laurencia intricata	Jul-89	7.7	27.1	3.82	2.6	16.0	50.1	49.9
Lobophora variegata	Jul-89	1.3	11.5	3.61	1.5	9.4	35.8	64.3
Padina sp.	Jul-89	7.4	6.6	3.97	2.1	13.4	63.5	36.5
Plocamium hamatum	Jul-89	4.1	21.6	4.23	4.9	30.4	33.0	67.0
Polysiphonia sp.	Jul-89	4.6	26.4	3.25	3.0	18.9	68.2	31.8
Sargassum sp.	Jul-89	3.3	6.0	2.90	1.3	8.3	43.6	56.4
Turbinaria ornata	Jul-89	2.5	9.8	3.35	0.8	5.0	31.4	68.7
Jul-89 Mean (s.e.)		5.4 (0.8)	16.4 (2.0)	3.7 (0.1)	2.7 (0.3)	17.0 (2.1)	49.0 (4.5)	
Lyngbya sp.	Jul-89	16.5	14.8	-	4.5	28.0	57.3	42.7

[1]Mean percent carbohydrate levels include only those carbohydrates that are soluble in acid (Section 7.2.3). Insoluble carbohydrate levels can be calculated by subtracting the values for acid soluble carbohydrates, lipid, protein and ash from 100 percent.

[2] Crude protein levels are calculated by multiplying N x 6.25. The resultant protein content values are not intended to reflect actual protein levels (Section 7.2.7) but are provided only for comparisons with other studies. Since crude protein levels are only approximations of actual protein levels, the use of these values in the calculation of acid insoluble carbohydrates must be made with caution (Section 7.2.3).

[3] Although supported by replicate samples, this lipid value may be in error as it is more than twice the level of lipids at any other time of the year or for any species.

[4]High ash levels in this species may be an artefact of contamination from the substrate.

[5]The sum of all of the organic components (lipids, carbohydrates and protein) may not equal the percentage of organic material in the sample as the acid insoluble carbohydrates (Section 7.2.7) are not included in the data above. Additionally the protein values listed are crude protein values (see footnote #2 and Section 7.2.7).

[6] Kcal/g can be converted to Kj/g by multiplying Kcal x 4.1840.

Table 7.5-Nutrient and energy profiles for those algae species that were present on Heron Reef in November, January, May and July. See Table 7.2a &b for additional species. Lipid, carbohydrate, energy, nitrogen and protein values are based upon an ash free, dry weight basis. C=Chlorophyta, P=Phaeophyta, R=Rhodophyta

	Sampling Occasion	Mean % Lipid	Mean % CHO	Mean Energy (KCal/g)	Mean % N	Mean % Crude Protein	Mean % Ash	Mean % Organic Content
Caulerpa racemosa (C)	Nov-88	-	8.6	-	-	-	-	-
Chlorodesmis fastigiata (C)	Nov-88	9.5	21.6	5.32	5.0	31.0	14.1	86.0
Halimeda sp. (C)	Nov-88	37.8 [2]	13.0	3.23	4.1	25.4	87.8	12.2
Laurencia intricata (R)	Nov-88	4.1	26.5	4.30	3.1	19.4	45.4	54.7
Lobophora variegata (P)	Nov-88	0.8	15.5	3.83	1.3	7.9	16.2	83.8
Turbinaria ornata (P)	Nov-88	3.4	9.6	3.43	0.8	4.7	21.2	78.8
Nov-88 Mean(s.e.)		11.1 (6.8)	15.8 (2.9)	4.0 (0.4)	2.8 (0.8)	17.7 (5.0)	36.9 (13.9)	63.0 (13.9)
Caulerpa racemosa (C)	Jan-89	5.6	18.0	4.15	2.2	13.9	35.3	64.7
Chlorodesmis fastigiata (C)	Jan-89	12.7	17.0	5.18	3.9	24.5	15.1	85.0
Halimeda sp. (C)	Jan-89	18.5	14.5	2.48	3.8	23.8	86.1	13.9
Laurencia intricata (R)	Jan-89	6.3	23.8	3.80	3.3	20.8	53.2	46.8
Lobophora variegata (P)	Jan-89	1.3	12.0	3.94	1.6	9.7	18.9	81.2
Turbinaria ornata (P)	Jan-89	3.1	8.0	3.50	1.0	5.9	29.3	70.7
Jan-89 Mean (s.e.)		7.9 (2.6)	15.5 (2.2)	3.8 (0.4)	2.6 (0.5)	16.4 (3.2)	39.6 (10.8)	60.4 (10.8)
Caulerpa racemosa (C)	May-89	5.6	18.4	4.72	2.9	18.1	27.2	72.8
Chlorodesmis fastigiata (C)	May-89	10.1	14.4	5.03	5.8	36.5	11.6	88.4
Halimeda sp. (C)	May-89	8.1	13.8	4.28	4.0	24.8	58.8	41.2
Laurencia intricata (R)	May-89	11.8	20.7	3.38	3.8	23.7	55.1	45.0
Lobophora variegata (P)	May-89	2.2	12.1	3.68	1.7	10.6	31.6	68.4
Turbinaria ornata (P)	May-89	3.2	7.8	3.53	1.2	7.3	24.3	75.7
May-89 Mean (s.e.)		6.8 (1.6)	14.5 (1.9)	4.1 (0.3)	3.2 (0.7)	20.1 (4.3)	34.8 (7.5)	65.2 (7.5)
Caulerpa racemosa (C)	Jul-89	5.2	18.5	3.86	2.8	17.4	38.2	61.9
Chlorodesmis fastigiata (C)	Jul-89	12.3	15.9	4.46	5.3	33.3	14.7	85.4
Halimeda sp. (C)	Jul-89	5.0	18.4	4.14	3.3	20.7	61.2	38.8
Laurencia intricata (R)	Jul-89	7.7	27.1	3.82	2.6	16.0	50.1	49.9
Lobophora variegata (P)	Jul-89	1.3	11.5	3.61	1.5	9.4	35.8	64.3
Turbinaria ornata (P)	Jul-89	2.5	9.8	3.35	0.8	5.0	31.4	68.7
Jul-89 Mean (s.e.)		5.7 (1.6)	16.9 (2.5)	3.9 (0.2)	2.7 (0.6)	17.0 (4.0)	38.5 (6.5)	61.5 (6.5)

[1] Crude protein levels are calculated by multiplying N x 6.25. The resultant protein content values are not intended to reflect actual protein levels (see text) but are provided only for comparisons with other studies.

[2] Although supported by replicate samples, this lipid value may be in error as it is more than twice the level of lipids at any other time of the year or for any species.

Table 7.6- Nutrient and energy content of species of algae that were frequently consumed (4 spp.) compared with those that were not frequently consumed (5 spp.). Consumption status was treated as a fixed factor while "species" was nested in consumption rate and treated as a random factor as was "occasion".

Nitrogen content (%, ash free basis)

Source of Variation	SS	DF	MS	F	Sig. of F
Within + Residual	0.21	14	0.01		
Consumption Status (Error 1)	4.13	7	0.59	39.99	0.000
Occasion	0.27	3	0.09	6.11	0.007
Consumption Status Occasion	0.1	3	0.03	2.24	0.129
Error 1	4.13	7	0.59		
Consumption Status	4.83	1	4.83	8.19	0.024

Energy content (Kj/g, ash free basis)

Source of Variation	SS	DF	MS	F	Sig. of F
Within + Residual	2.35	14	0.17		
Consumption Status (Error 1)	6.13	7	0.88	5.21	0.004
Occasion	0.2	3	0.07	0.39	0.723
Consumption Status Occasion	0.23	3	0.08	0.45	0.723
Error 1	6.13	7	0.88		
Consumption Status	1.4	1	1.4	1.6	0.247

Lipid content (%, ash free basis)

Source of Variation	SS	DF	MS	F	Sig. of F
Within + Residual	2.27	14	0.16		
Species Freq. Consumed (Error 1)	9.11	7	1.3	8.02	0.001
Occasion	0.45	3	0.15	0.91	0.459
Consumption Status Occasion	0.81	3	0.27	1.67	0.218
Error 1	9.11	7	1.3		
Consumption Status	6.26	1	6.26	4.81	0.064

Carbohydrate content (%, ash free basis)

Source of Variation	SS	DF	MS	F	Sig. of F
Within + Residual	154.11	15	10.27		
Species Freq. Consumed (Error 1)	988.39	7	141.2	13.74	0.000
Occasion	4.07	3	1.36	0.13	0.939
Consumption Status Occasion	5.62	3	1.87	0.18	0.907
Error 1	988.39	7	141.2		
Consumption Status	0.51	1	0.51	0.00	0.954

Table 7.6 (cont.)

Ash content (%)

Source of Variation	SS	DF	MS	F	Sig. of F
Within + Residual	675.08	14	48.22		
Consumption Status (Error 1)	10382.59	7	1483.23	30.76	0.000
Occasion	36.65	3	12.22	0.25	0.858
Consumption Status Occasion	291.04	3	97.01	2.01	0.159
Error 1	10382.59	7	1483.23		
Consumption Status	169.98	1	169.98	0.11	0.745

Due to the many missing data points and therefore unbalanced data, analyses addressing the interaction between Occasion and Species were not possible and mean values for each species were used in the analyses.

Table 7.7-Nutrient and energy values of marine macroalgae. Values in parentheses indicate number of species sampled.
C=Chlorophyta, R=Rhodophyta, P=Phaeophyta

	No. of Sampling Periods	Nitrogen[1] (% dry wt.)			Protein[1] (% dry wt.)			Carbohydrate[1] (% dry wt.)		
		C	R	P	C	R	P	C	R	P
This study[2]	5	3.6 (6)	3.6 (3)	1.5 (5)	22.2 (6)[3]	22.8 (3)[3]	9.1 (5)[3]	17.1 (6)	23.4 (3)	10.0 (5)
Horn & Neighbors, 1984	12	2.8 (2)	2.9 (6)	-	3.3 (2)	3.6 (6)	-	-	-	-
Dawes, *et al* ., 1974	1	-	-	-	-	4.5 (2)	-	-	59.5 (2)	-
Edwards & Horn, 1982	1	-	-	-	9.6 (2)	11.9 (2)	-	56.0 (2)	62.3 (2)	-
Montgomery & Gerking, 1980	1	-	-	-	10.2 (1)	7.7 (6)	8.3 (3)	59.9 (1)	51.9 (6)	55.7 (3)
		Ash (% dry wt.)			Lipid[1] (% dry wt.)			Energy[1] (Kcal/g)		
		C	R	P	C	R	P	C	R	P
This study[2]	5	45.6 (6)[4]	45.4 (3)[4]	35.1 (5)[4]	10.2 (6)	6.1 (3)	3.0 (5)	4.1 (6)	3.9 (3)	3.6 (5)
Himmelman & Carefoot, 1975	9	27.4 (2)	21.0 (2)	-	7.2 (2)	4.8 (2)	-	-	-	-
Montgomery & Gerking, 1980	1	-	24-28 (2)	16-38(2)	-	-	-	-	2.7-3.1 (	2.6-3.5 (2)
Larkum, *et al* ., 1967	1	25.4 (1)	38.3 (6)	31.3(3)	4.5 (1)	2.1 (6)	4.8 (3)	3.3 (1)	2.5 (6)	2.8 (3)
Paine and Vadas, 1969	>1[5]	44.5 (2)[4]	48.5 (2)	31.6 (5)	-	-	-	3.7 (2)	2.8 (2)	3.3 (5)
Dawes, *et al* ., 1979	3	28.3 (9)	32.1 (39)	32.4 (25)	-	-	-	3.5 (9)	3.2 (39)	3.1 (25)

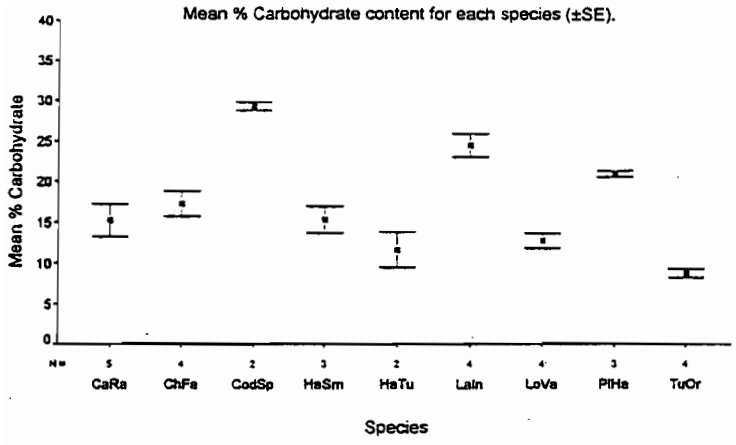
[1] Nutrient and energy levels may not be directly comparable due to different analysis techniques employed by each author.

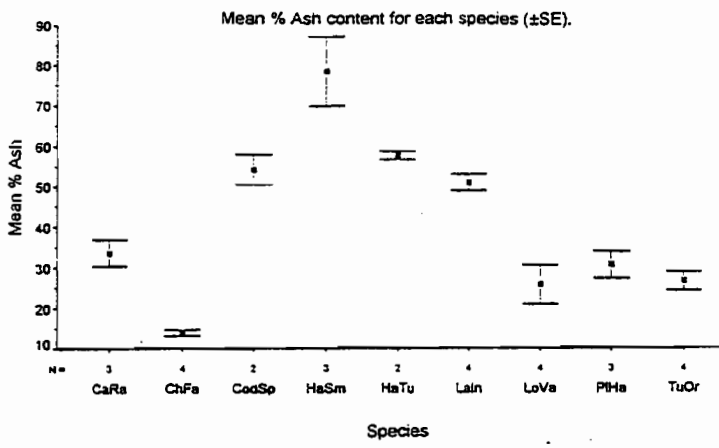
[2] The values for nitrogen, protein, carbohydrate, lipid and energy for this study are based upon an ash-free, dry-weight basis.

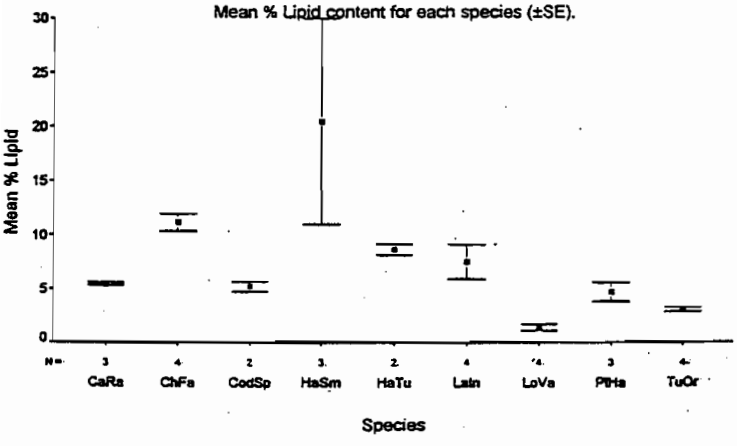
[3] Crude protein levels were calculated by multiplying N x 6.25. The resultant protein content values are not intended to reflect actual protein levels (Section 7.2.7) but are provided only for comparisons with other studies.

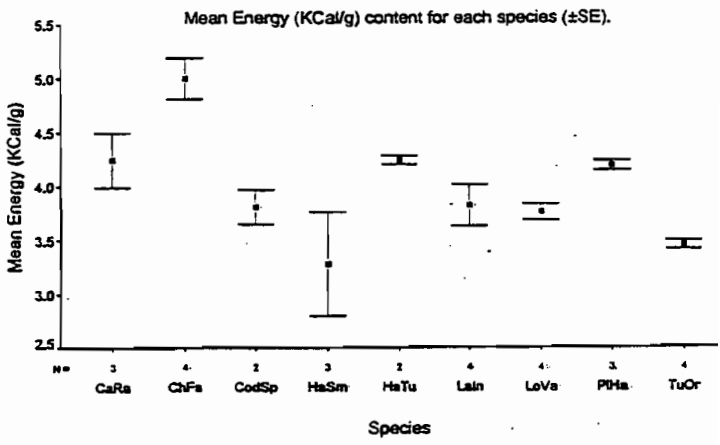
[4] *Halimeda,* a calcium bearing species was sampled in this group, therefore the mean ash levels for the Chlorophyta are unusually high.

[5] The number of sampling sessions is not stated for each species but reference to "scattered" sampling periods is made.









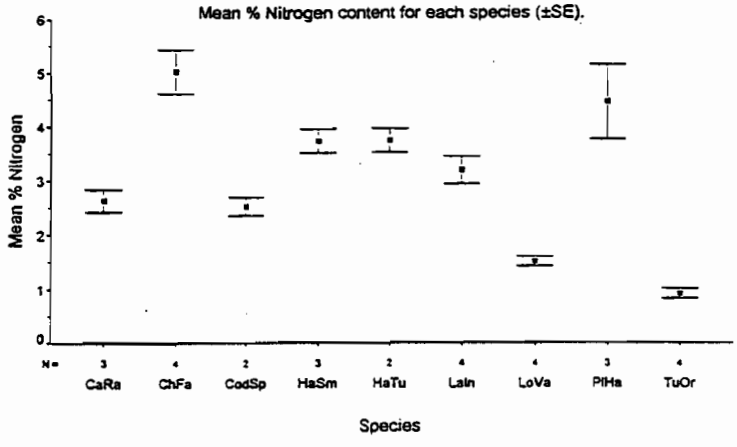


Figure 7.1-Nutrient and energy content (±s.e.) of Heron Reef algae expressed as percentage of ash-free dry matter. Nutrients are listed on graph "Y" axes. CaRa=*Caulerpa racemosa,* ChFa=*Chlorodesmis fastigiata,* CodSp=*Codium sp* ., HaSm=*Halimeda sp* ., HaTu=Halimeda tuna, LaIn=Laurencia intricata, LoVa=Lobophora variegata, PlHa= Plocamium hamatum, TuOr=*Turbinaria ornata* .

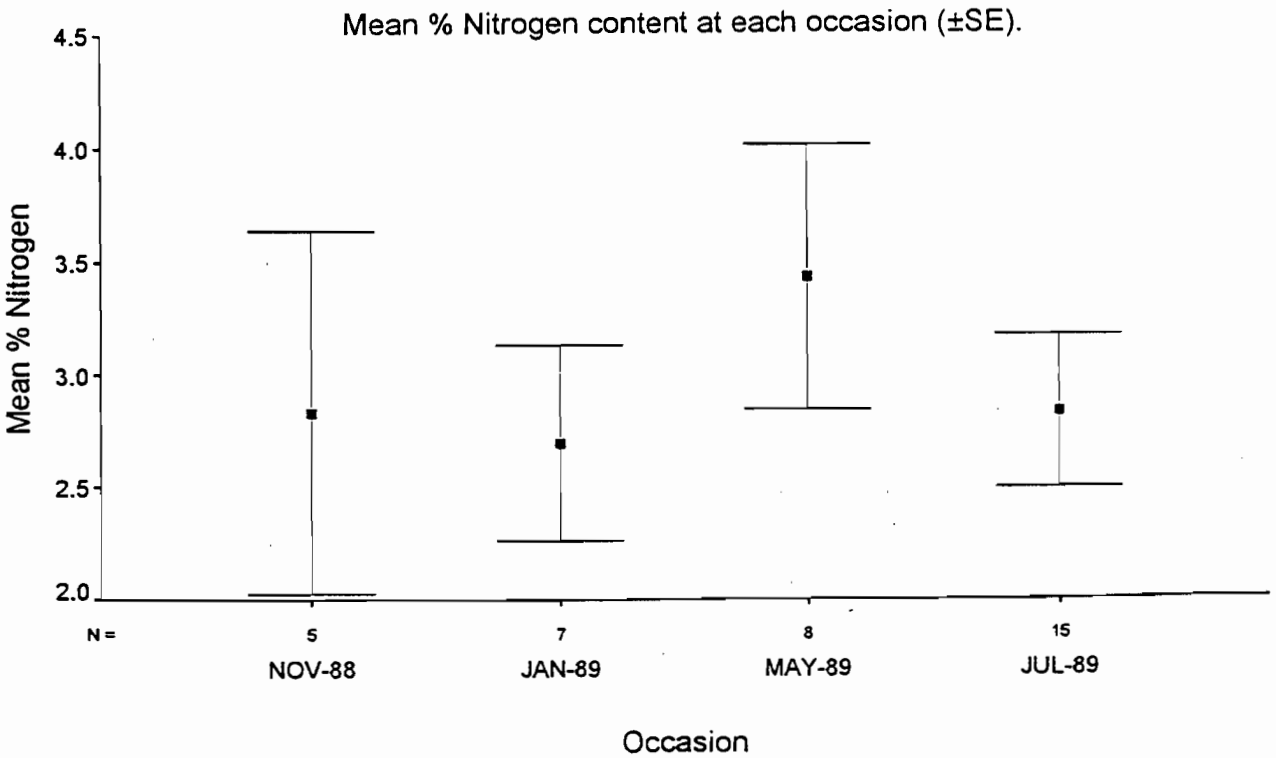


Figure 7.2-Mean nitrogen content (±s.e.) of Heron Reef algae (9 spp.) at each occasion expressed as a percentage of ash-free dry matter.

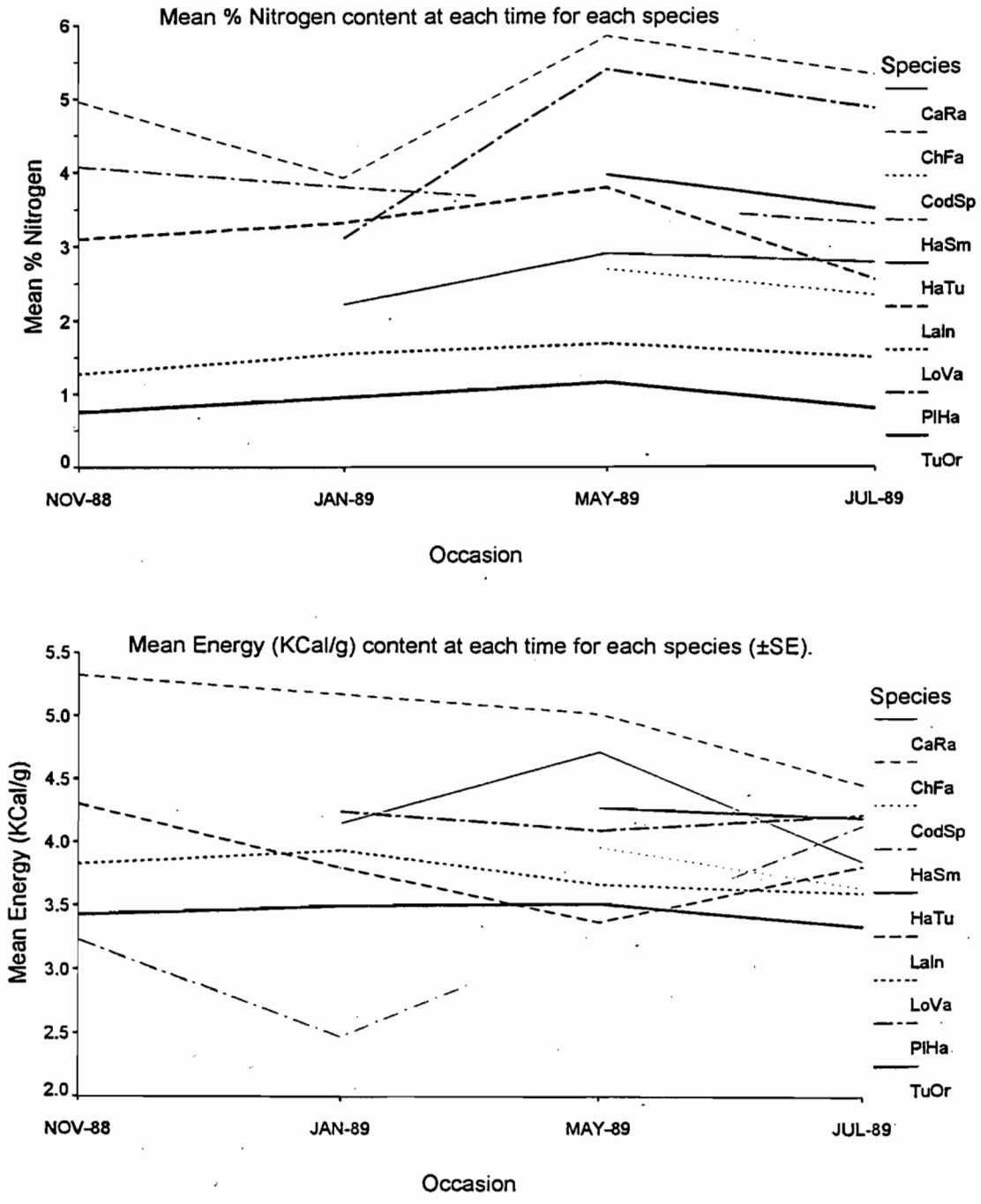
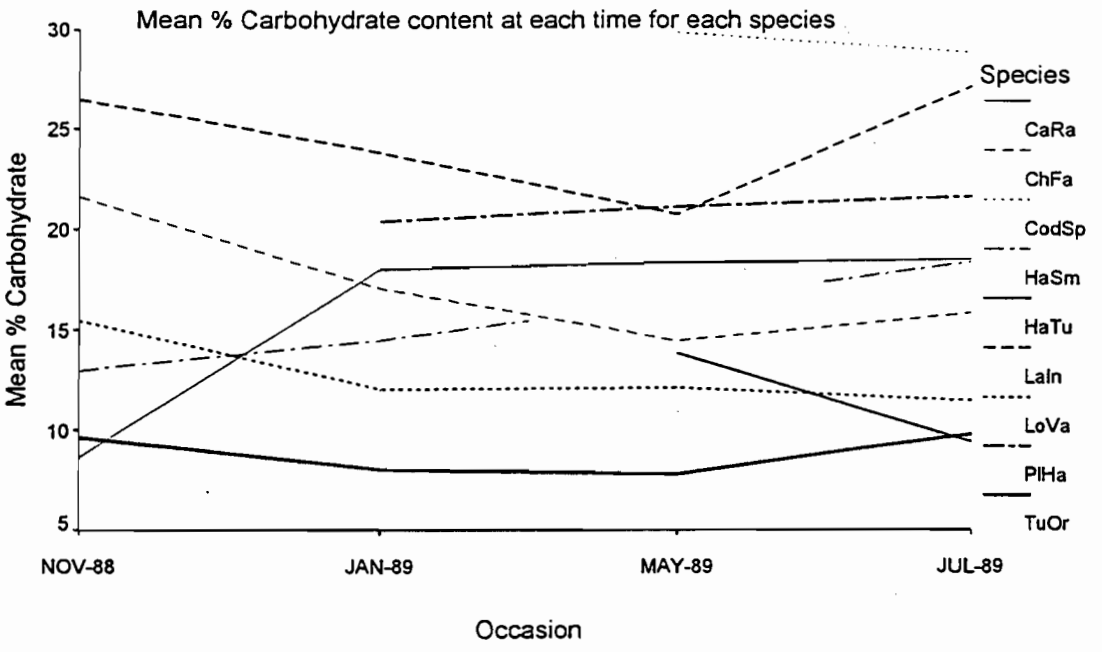
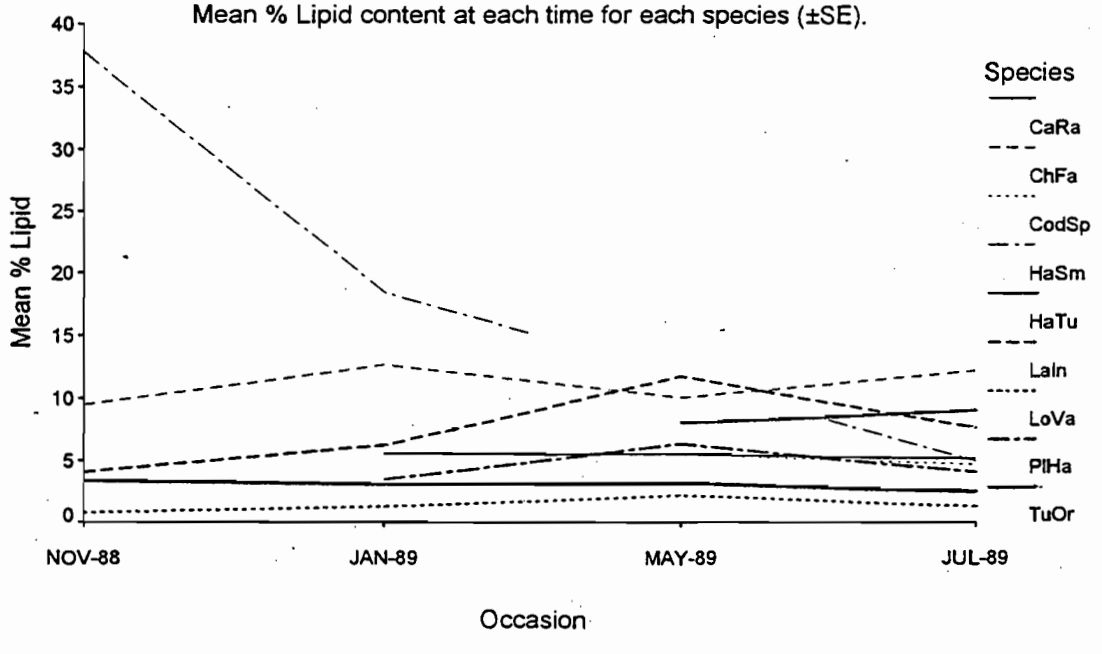
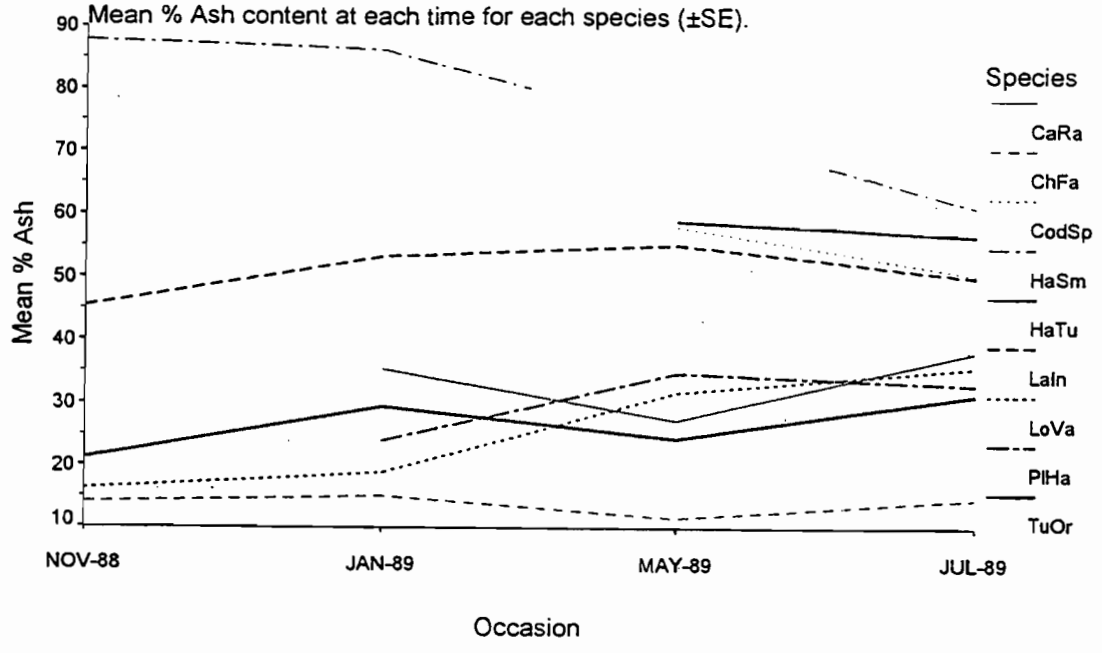


Figure 7.3-Mean nutrient and energy content of Heron Reef algae at each occasion expressed as a percentage of ash-free dry matter. Nutrients are shown on "Y" axis of each graph. CaRa=*Caulerpa racemosa,* ChFa=*Chlorodesmis fastigiata,* Cod Sp=*Codium sp* ., HaSm=*Halimeda sp* ., LaIn=*Laurencia* intricata, LoVa=Lobophora variegata, PlHa=*Plocamium hamatum* , TuOr=*Turbinaria ornata* .


Mean % Carbohydrate content at each time for each species
Mean % Carbohydrate
30
25
20
15
10
5
NOV-88
JAN-89
MAY-89
JUL-89
Occasion
Species
CaRa
ChFa
CodSp
HaSm
HaTu
LaIn
LoVa
PlHa
TuOr


Mean % Lipid content at each time for each species (±SE).
Mean % Lipid
40
35
30
25
20
15
10
5
0
NOV-88
JAN-89
MAY-89
JUL-89
Occasion
Species
CaRa
ChFa
CodSp
HaSm
HaTu
LaIn
LoVa
PlHa
TuOr


Mean % Ash content at each time for each species (±SE).
Mean % Ash
90
80
70
60
50
40
30
20
10
NOV-88
JAN-89
MAY-89
JUL-89
Occasion
Species
CaRa
ChFa
CodSp
HaSm
HaTu
LaIn
LoVa
PlHa
TuOr

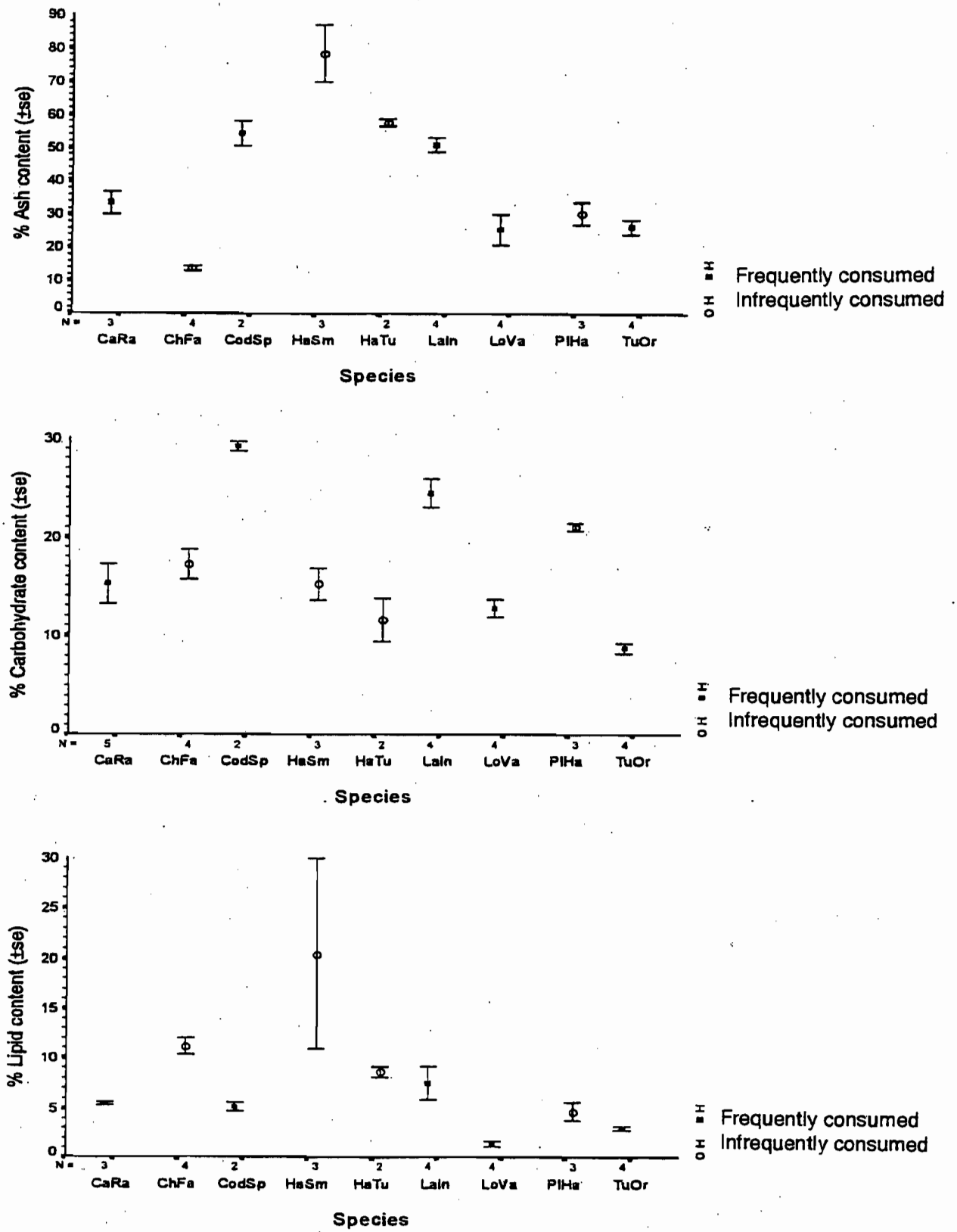
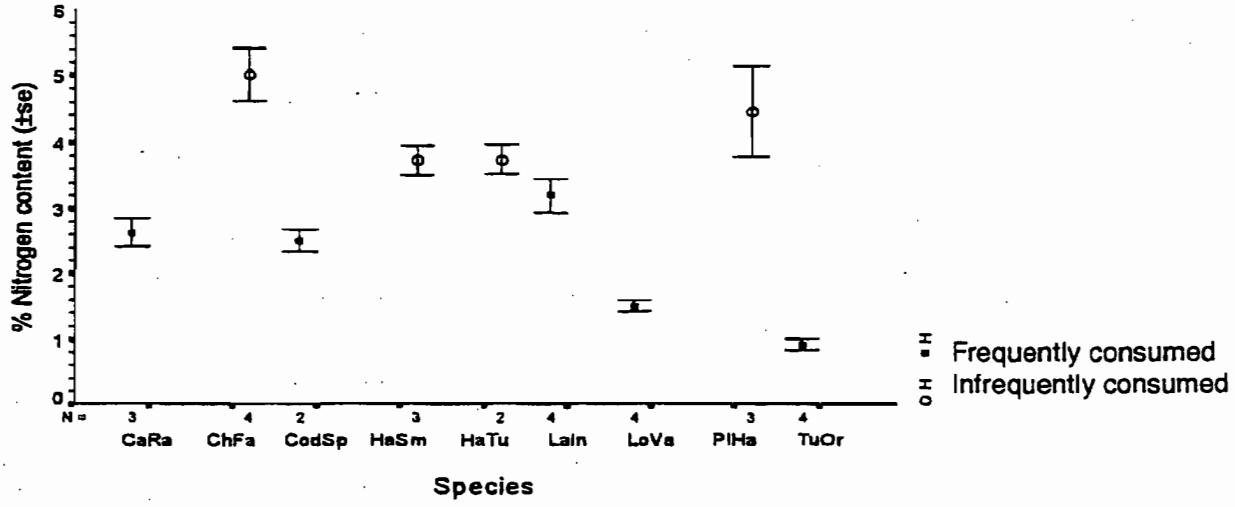
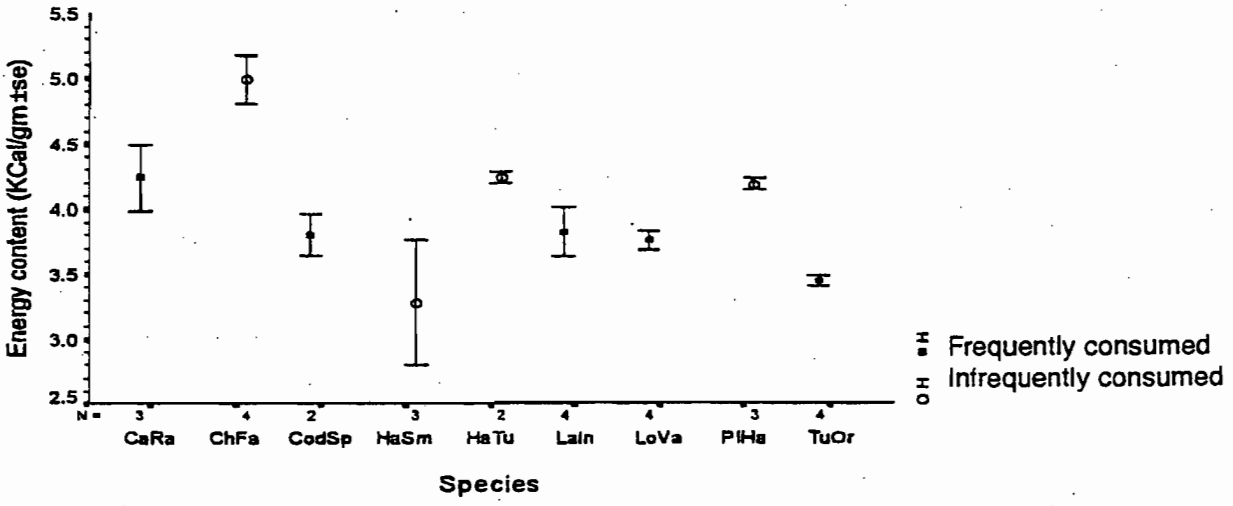


Figure 7.4-Error bar graphs with s.e. for nutrient and energy content of frequently and infrequently consumed algae from Heron Reef. Nutrients are listed on the "Y" axis of each graph. CaRa=*Caulerpa, racemosa,* ChFa=*Chlorodesmis fastigiata,* CodSp=*Codium sp.,* HaSm=*Halimeda sp* ., HaTu=*Halimeda tuna* , LaIn=*Laurencia intricata* , LoVa=*Lobophora variegata* , PlHa=*Plocamium hamatum* , TuOr=*Turbinaria ornata* .


% Nitrogen content (±se)
6
5
4
3
2
1
0
N =
3
4
2
3
2
4
4
3
4
CaRa
ChFa
CodSp
HaSm
HaTu
LaIn
LoVa
PlHa
TuOr
Species
H
O
Frequently consumed
Infrequently consumed


Energy content (KCal/gm±se)
5.5
5.0
4.5
4.0
3.5
3.0
2.5
N =
3
4
2
3
2
4
4
3
4
CaRa
ChFa
CodSp
HaSm
HaTu
LaIn
LoVa
PlHa
TuOr
Species
H
O
Frequently consumed
Infrequently consumed

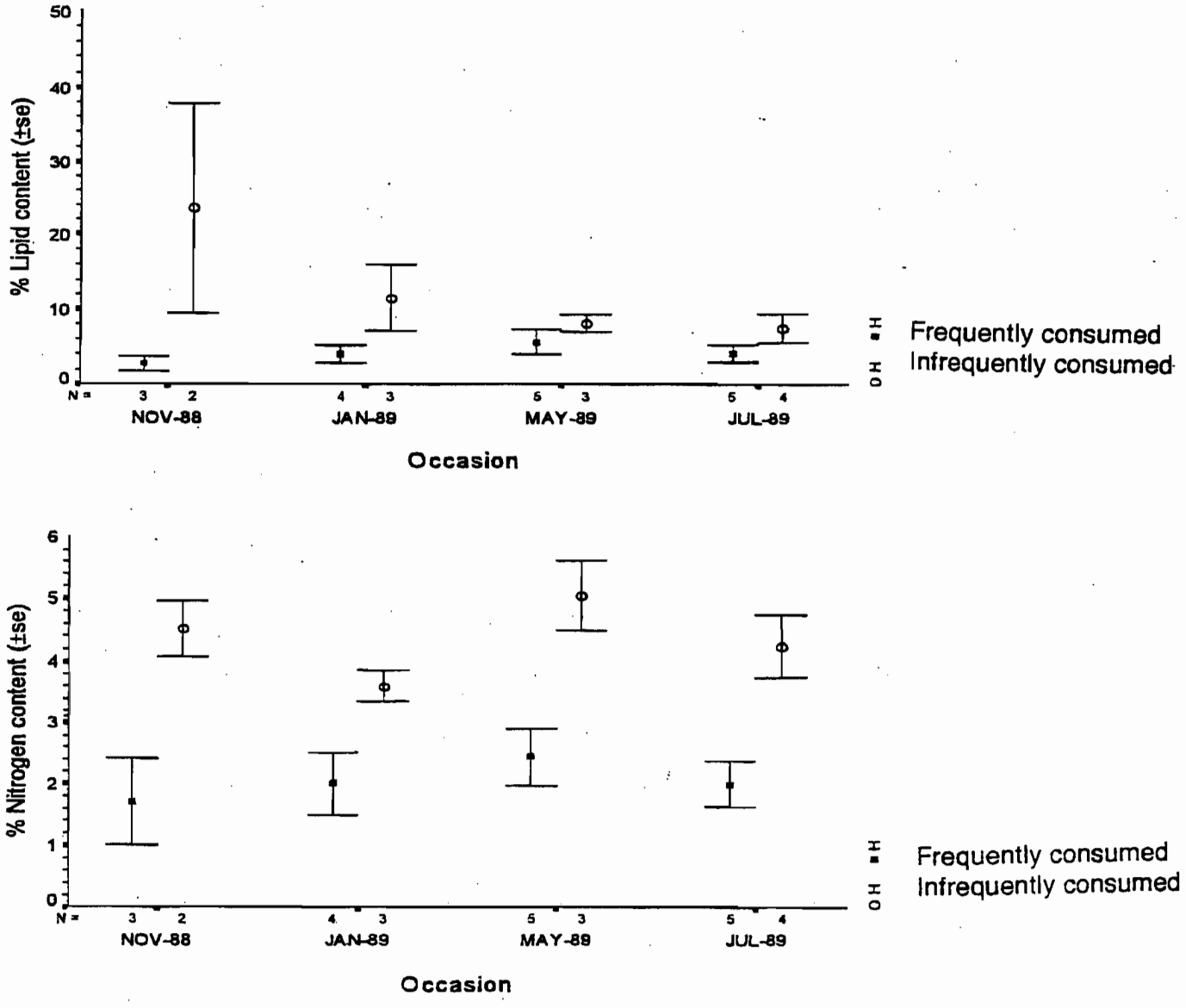


Figure 7.5-Error bar graphs with s.e. for nitrogen and lipid content of nine species of frequently and infrequently consumed Heron Reef algae. Nutrients are listed on the "Y" axis of each graph.

Chapter 8

General Discussion

8.1 Introduction

On Heron Reef, green turtles foraged within an algal community that experienced significant spatial and temporal variation in composition, abundance and quality (Section 5.3.3). Nutrient and energy levels were significantly different between various species of algae with wide temporal and spatial variation within a species. Nitrogen levels varied significantly over time between and within species (Section 7.3 & Tables 7.3 &7.4). In response to this changing environment, the green turtle has evolved a diet strategy that provides a dependable base diet of algal turf (Section 6.3) while exploiting other desirable species when they become available. The findings of this study indicate that green turtles of both sexes and all age classes on Heron Reef fed almost exclusively upon algae. Animal matter was rarely consumed and this was limited to juveniles and subadults (Section 6.3).

The algal community on Heron Reef is composed of a heterogenous turf interspersed with monogeneric stands. The composition of this community is dynamic both spatially and temporally. While some monogeneric stands are relatively persistent on the reef (e.g. *Turbinaria*), other genera are ephemeral and can appear over several days and may only last several weeks (e.g. *Enteromorpha*). The green turtles on Heron Reef have adapted to this dynamic environment by feeding within both the algal turf and upon preferred monogeneric stands.

The green turtles on Heron Reef demonstrated significant levels of dietary selection and avoidance of various genera and rapid exploitation of desirable ephemeral

species when they become available (Section 6.3.2). This selection of desirable species was not based exclusively upon gross nutrient or energy content as many species with high nutrient and energy potential were avoided (Tables 6.6, 6.7 & 7.4).

There were no discernible differences in diet between the sexes (Section 6.3.3), however, the diet varied significantly both temporally and between age classes although there was no continuity or discernible pattern to this change (Section 6.3.3). The differences observed between the ages classes may disappear when desirable ephemeral species become available. There was no difference in diet strategy (feeding in monogeneric stands vs. algal turf) between the age classes. Nesting females appear to feed at greatly reduced rates compared to non-nesting females.

Although individual turtles were known to feed both within the algal turf and also upon monogeneric stands (Section 6.3.3), 70% of the lavage samples originated from turtles feeding on the turf (Section 6.3.1). However, when preferred monogeneric stands became available, some turtles of all age classes abandoned their base diet of algal turf and fed exclusively upon the preferred species (Table 6.3, Section 8.6).

The variability seen in the diet of the green turtle in this study and others (Tables 2.2 & 2.3) is consistent with extreme overall variability seen in other aspects of the green turtle's natural history such as growth rates, age and size at sexual maturity, migration distances, remigration intervals, nesting seasons, clutch size and the number of clutches per season. Much of this variation in the life history of the green turtle appears to have a nutritional basis (Section 2.2.3 & 8.4).

This chapter addresses the apparent influences acting upon the diet decision matrix of the green turtle foraging in a complex algal environment as well as the role of the

green turtle in a coral reef community. The applicability of optimal foraging models to the green turtle is also presented along with suggestions for additional research.

8.2 Diet Breadth and Diet Change

A continuum exists in the breadth of the diet of green turtles. Bjorndal (1980) studied a population in the Bahamas that fed almost exclusively on seagrasses (*Thalassia*) while Mortimer (1981) reports on Nicaraguan turtles that had a diet of 79% seagrasses (*Thalassia*) and 8% algae. In contrast, Garnett *et al.* (1985) studied a northern Australian population with a diet comprising only 9% seagrasses (*Thalassia*) while algae constituted 74%. The turtles in my study, with their exclusive diet of algae, represent the opposite end of the continuum from those studied by Bjorndal. This continuum is most likely a reflection of the diversity of habitats occupied by green turtles and the forage available in each of those habitats rather than a selection for seagrasses over algae or vice versa. However, this conclusion is difficult to substantiate at this time due to the near absence of diet studies in which quantitative assessments of forage availability have been made. Similar diversity in diet has been shown to occur in herbivorous reef fishes as a function of their geographic range and habitat (Horn, 1989).

Like most vertebrates, sea turtles consume mixed diets. Although the green sea turtle is appropriately considered to be herbivorous, it is opportunistically carnivorous and is known to consume seagrasses and a wide variety of algae. Optimal foraging models (Section 2.3.2.1) have sought to explain the process by which animals select their diets but the interactive matrix of factors affecting diet selection is still poorly understood. However, it is now clear that for most animal species, it is difficult to attribute a value to an individual diet item without considering the influences of the other diet items ingested with it (Freeland and Janzen, 1974; Westoby, 1978; Rapport,

1980; Van Soest, 1982; Robins, 1983; Kukor *et al.*, 1988; Bjorndal, 1991). The processes affecting diet selection are dynamic and therefore the value assigned to a diet item may not be constant and the value may not be independent of other items in the diet (Westoby, 1978; Bjorndal, 1991). Consequently, it is difficult to identify and evaluate the relative importance of the selection criteria in the diets of wild animals. This difficulty is compounded for an animal like the green turtle that lives in a complex environment with both ephemeral and more persistent species.

Green turtles feeding in seagrass communities occupy a habitat with a relatively low diversity of forage species (Preen, 1993) that is characterised by seasonal changes at least in some areas (Lanyon, 1991). Other seagrass communities have a relatively constant level of availability (Bjorndal, 1979a, 1985). Contrastingly, green turtles foraging on Heron Reef face a very diverse ephemeral assemblage of algae that can change in a matter of weeks with respect to availability (Section 5.3) and nutrient quality (Chapter 7). As a response to this changing environment, the composition of the diet also changes significantly. This shift in diet composition was best demonstrated in July 1989, when the ephemeral chlorophyte *Enteromorpha* became available. At this time *Enteromorpha* constituted 79.7% of the pooled diet of the green turtle, almost twice the volume contributed by any other genus at any time (Table 6.3). When *Enteromorpha* was available, *Laurencia* and *Turbinaria* , which were the two most important diet components in all other occasions, were abandoned in favour of *Enteromorpha* and the number of turtles feeding in the algal turf was reduced by 30% (Table 6.2). This and similar shifts in diet may occur as a result of one or more of the following: 1) the preferred genus may offer some energy or nutrient quality not possessed by other equally abundant genera; 2) certain genera may have been avoided due to morphological defences or the presence of defensive secondary metabolites; 3) although a preferred species of algae may not be of superior nutritive

or energy potential, it may be readily available in accessible monogeneric stands that are energetically optimal to harvest; 4) a preferred algal species may produce secondary metabolites that act as phagostimulants to stimulate feeding; 5) a change in the physiological requirements of the individual may necessitate a change in diet; 6) differential digestibilities or nonadditive associative effects of various forage species may effect diet selection. These and other possibilities are examined below.

8.3 Diet Selection

8.3.1 Diet Selection as a Function of Nutrient, Ash and Energy Content

The causative factors for diet change cited above are evaluated using the July, 1989 diet shift to *Enteromorpha* away from *Laurencia* and *Turbinaria*. It is unlikely that the shift to *Enteromorpha* was a result of its superior nutrient and energy content as the results of the nutrient and energy analyses (Table 7.4) do not support this assumption although it is possible that some component(s) not assayed was important in the selection of *Enteromorpha*. In addition, *Laurencia* possessed substantially higher levels of all nutrients and energy and lower levels of ash at this time than did *Enteromorpha*. Also, *Laurencia* was more abundant in July of 1989 that at any time during the study, yet *Laurencia* only contributed incidental amounts to the pooled diet at this time. Therefore, the shift to *Enteromorpha* was most likely not due to its superior nutrient or energy content or due to its availability.

Although some species may have been avoided due to their poor nutritive, energy and ash content, this was not the situation with *Chlorodesmis*. Although *Chlorodesmis* was avoided ($\overline{X}$ =0.4% of pooled diet, s.e. =0.16), it had significantly higher levels of energy and nutrients and lower levels of ash than did the preferred *Turbinaria* (Tables 7.2 & 7.3). *Chlorodesmis* also surpassed the preferred *Laurencia* in levels of energy and all nutrients except carbohydrates and also had lower ash levels. Overall,

Chlorodesmis had higher nutrient and energy levels than did most species of algae throughout the year but yet it was almost never eaten although abundant ($\overline{X}$ =4.7% of algal cover, s.e.=0.86). Contrastingly, *Turbinaria* was the first or second most important contributor to volume of the pooled diet during all sampling occasions except July 1989, yet with few exceptions, it had the lowest nutrient and energy levels of the species assayed (Tables 6.3 & 7.2). Therefore, it appears that factors other than nutrient and energy content of the algae influence diet selection. These factors may include such factors as secondary compounds, assimilation efficiency or the nonadditive or associative effects from diet mixing (Section 8.3.6).

Recognising that herbivores are frequently limited by nitrogen in their diets, Mattson (1980) suggested that they optimise their uptake of nitrogen from their environment. Meanwhile, traditional optimal foraging models predict that animals will modify their diets to optimise their intake of energy. However, in this study, neither of these predictions appeared to be validated as those species highest in energy (Table 7.4) were selected against (Table 6.7) with the exception of *Laurencia*. The same was true of nitrogen in that those species with the highest levels were not selected and *Turbinaria*, one of the two most important diet items in the study, had the lowest overall nitrogen content (Table 7.4). However, care must be taken in interpreting these results as only the total nutrient and energy content were measured and not nutrient and energy availability to the turtle which is of considerably more importance.

It is apparent that green turtles do not select forage species solely as a function of their energy or ash content , apparent palatability or upon the level of those nutrients assayed in this study. In fact, in some situations, as with *Chlorodesmis* , an inverse relationship would appear to be the case. It is possible that other as yet unidentified factor(s) may have an influence upon this selection regime. These factors may

include availability, phagostimulants, physiological requirements, associative effects from diet mixing or the presence of secondary compounds. These possible influences are discussed below.

8.3.2 Selection as a Function of Secondary Compounds

While feeding in either the algal turf or monogeneric stands, turtles demonstrated avoidance of certain algae species (Section 6.3.2). Other than the crustose algae, none of the genera avoided possessed functional form defences that would have precluded their being browsed by green turtles. As these unbrowsed noncrustose species were spatially available to green turtles, they may have been avoided due to their poor nutrient and energy potential or the presence of secondary metabolites acting as defences against grazing. The avoidance of *Chlorodesmis* with its high nutrient and energy levels and low ash content (Table 7.4) suggests that it may produce secondary metabolites effective as deterrents against green turtles grazing. The production of secondary metabolites in marine algae such as *Chlorodesmis* is well documented and is reviewed by Hay and Fenical (1988), Duffy and Hay (1990), Hay (1991), Paul (1991), and in Chapter 2. As *Chlorodesmis* may have been avoided because of its secondary metabolites, it is possible that *Enteropmorpha* may have been selected due to its lack of such compounds. Defensive metabolites have not yet been identified in *Enteromorpha* or any other member of the Order Ulvales or the Family Ulvaceae (de Nys, 1991). It is plausible that *Enteromorpha* was selected in lieu of other abundant genera with higher nutrient and energy content (e.g. *Laurencia*) that do contain such defences. However, although *Laurencia* is well known for its rich array of over 400 defensive secondary metabolites (Fenical, 1975, 1982; Erickson, 1983; de Nys, 1991), it was a primary diet component in all sampling occasions except when *Enteromorpha* was available (Table 6.3). When *Enteromorpha* became available, *Laurencia* dropped to incidental amounts in the pooled diet even though its

nutrient and energy levels were higher than during other sessions when it was a primary diet component (Chapter 7). This shift from *Laurencia* to *Enteromorpha* may have been influenced by the lack of defensive secondary metabolites in *Enteromorpha* and or an increase in those produced by *Laurencia*. The fact that *Enteromorpha* was selected over *Laurencia* , which was both more abundant and of greater nutrient and energy potential than *Enteromorpha* , adds support to this conclusion. However, associative effects from other diet items cannot be disregarded (Section 8.3.6).

Although the presence of defensive secondary metabolites in marine algae is well known, their effectiveness as grazing deterrents upon the continuum of marine herbivores remains unclear (Hay, 1991). Hay *et al.* (1988) found that the general structure of these compounds and their pharmacological assays were not useful predictors of antiherbivory properties in reef fishes or other marine herbivores. While some of the algal genera avoided by the green turtles in this study (e.g. *Chlorodesmis*) contain secondary metabolites known to act as grazing deterrents to other herbivores (Section 2.3.2.8), there are other known metabolite bearing genera (*Laurencia, Caulerpa*) that were readily consumed by green turtles. Similar inconsistencies in the action of secondary compounds are found in the studies of herbivorous fishes. Terpenoids extracted from *Laurencia obtusa* have been shown to deter parrotfish feeding in the Caribbean (Hay *et al.*, 1987) while the same algal species was a predominate component in the diet of parrotfishes from the Red Sea (Lundberg and Lipkin, 1979) suggesting different tolerances or digestive abilities for related species. In light of this paradox and in the absence of species specific interaction studies with green turtles, care should be exercised in concluding that secondary metabolites present in algae serve any deterrent function against marine turtles even though such an action may have been demonstrated in other marine herbivores. However, in this study, those algal species that were infrequently consumed had significantly higher

levels of lipids and nitrogen than did those species frequently consumed (Section 7.3.3). This would suggest that algae with higher nutrient potentials may be chemically defended against green turtles.

The presence of secondary metabolites and their temporal and spatial variability within a species may be a reason why most green turtles ($\overline{X}$ =70.4 %, s.e.=1.05) feed on the algal turf on Heron Reef (Section 6.3.1). By foraging upon a wide array of species, a turtle may be reducing the overall intake of secondary compounds when compared to foraging in monogeneric stands which may contain species with very high levels of such compounds. Foraging in the mixed algal turf may be the best way to reduce the probability of ingesting high quantities of deleterious secondary metabolites while at the same time exploiting a resource that is always available. A mixed diet from the algal turf may also reduce the physiological impacts of secondary compounds by producing antagonistic effects that result in a net reduction in the effect of the compounds present (Belovsky and Schmitz, 1994).

Although the presence of secondary metabolites in marine algae may not be the most important influence on diet selection, the results of this study suggest that these compounds may have an influence upon the diet selection process of green turtles. Further research is required to determine the effects of these compounds upon the diet selection process in green turtles. The effectiveness of potential antiherbivore defences must be determined in the context of the plant's absolute and relative abundance and the abundances and defences of other sympatric plants as these factors may also influence the selection of chemically protected plants (Belovsky and Schmitz; 1994).

8.3.3 Selection as a Function of Availability

Optimal foraging models suggest that animals may select diet items of suboptimal quality if the energetic or metabolic costs of obtaining them result in a net metabolic savings (Section Chapter 2.3.2.1). *Enteromorpha* forms dense growths in sandy areas on the reef platform. It was common to observe turtles concentrating their foraging in these areas for extended periods although dense stands of algal turf interspersed with monogeneric stands were only meters away. It may have been more energetically efficient to graze within the *Enteromorpha* than to selectively graze apparently nutritionally superior genera interspersed amongst the algal turf. However, this would seem unlikely as monogeneric stands of *Laurencia* , with its higher nutrient and energy content (Table 7.4), were located only meters away from the *Enteromorpha*. *Laurencia* was a primary component of the diet in all but one sampling occasion (July, 1989) (Table 6.3) and was more abundant in July of 1989 than *Enteromorpha* or any other genera at any time during this study (Tables 5.2 & 5.3). It is therefore unlikely that diet items have been selected solely on their abundance or availability. This assertion is further supported by examining the relative abundance of *Turbinaria* and *Halimeda* and their contribution to the pooled diet. *Turbinaria* was the greatest contributor to the pooled diet volume during four of the seven sampling occasions (Table 6.3) although it only represented an average of 1.3% (s.e.=0.37) of the total algal cover (Table 5.3). Meanwhile, *Halimeda* averaged 5.5% (s.e.=0.89) of the total cover (Table 5.3) but never exceeded incidental amounts in the diet (Table 6.3). Diet selection in green turtles is clearly not determined entirely by availability. Similar conclusions have been reached regarding selection in herbivorous marine fishes (Montgomery and Gerking, 1980; Horn, 1983; Lewis, 1986; Paul *et al.*, 1990).

8.3.4 Selection as a Function of Phagostimulants

The production of phagostimulatory secondary metabolites in the Chlorophyta and Phaeophyta has been shown to stimulate feeding in the sea hare (*Aplysia*) (Sakata *et al.*, 1986), the abalone (*Haliotis*) and the gastropods *Turbo* and *Omphalius* (Sakata *et al.* 1988). Similar responses to phagostimulants in marine vertebrates are poorly documented and unstudied in marine turtles. The observed complete diet shift to *Enteromorpha* may have been influenced by the production of phagostimulants. Although phagostimulants have not yet been identified from *Enteromorpha*, phagostimulants are known from other members of the Ulvaceae (Sakata *et al.*, 1988) and therefore further investigation into their effects upon diet selection by green turtles is warranted.

8.3.5 Selection as a Function of Physiological Requirements and Ontogeny

Changing physiological conditions of individual turtles may have had an influence upon the observed changes in the diet, but as physiological profiles were not conducted at capture, this question cannot be adequately addressed here. However, physiological requirements alone could not account for the simultaneous shift in diet observed across the age classes and sexes as demonstrated when *Enteromorpha* became available.

Ontogenetic changes in diet have been described in both temperate and tropical reef fish species that are herbivorous as adults (Montgomery, 1977; Barton, 1982; Horn *et al.*, 1982, 1985; Meekan, 1986). Mattson (1980) reviews the advantages of such changes in nitrogen limited herbivores. Seasonal dietary shifts demonstrated in the tropical surgeonfish *(Acanthurus nigrofuscus*) appear to be tied to their changing nutritional requirements during the reproductive cycle (Fishelson *et al.*, 1987). The

results of this study suggest that there may be ontogenetic changes in the diet of post-pelagic phase green sea turtles as demonstrated by the predominance of various species of algae in the diets of the different age classes (Section 6.33, 6.4.2, Figures 6.1 & 6.2). However, as individuals within each age class were known to feed outside of their predicted diet, there must be other influences acting upon diet selection besides age.

It has been suggested that herbivores should be opportunistically carnivorous in order to supplement their intake of nitrogen in an otherwise nitrogen limited herbivorous diet (Mattson, 1980; Preen, 1995). Nitrogen requirements are known to be higher for juveniles and subadults as they require additional nitrogen to build structural proteins for growth. The opportunistic consumption of the hydrozoan *Physalia* and mollusc egg casings by juveniles and subadults provides support to this model. Each time *Physalia* and mollusc egg casings became available, they appeared in the juvenile and subadult diets. Opportunistic consumption of animal matter (medusoid hydrozoans) by green turtles has also been observed in the Gulf of Carpentaria in Australia (John Bradley, pers. comm.). However, in the absence of data on the accessible nitrogen in these items, such conclusions should be made with caution.

8.3.6 Selection as a Function of Diet Mixing

In the absence of *Enteromorpha*, most Heron Reef green turtles fed upon a mixed diet from the algal turf (Section 6.3.1). The consumption of mixed species diets has been shown to produce both independent additive effects and dependent nonadditive or associative effects (Freeland and Janzen, 1974; Westoby, 1978; Rapport, 1980; Van Soest, 1982; Robbins, 1983; Kukor *et al.*, 1988; Bjorndal, 1991). Additive effects are the sum of all of the individual nutrient and energy attributes of each item in a diet; each attribute being independent of the others. Nonadditive or associative effects

occur when one item in the diet affects the digestion of other diet items either positively or negatively. Associative effects are well known in livestock (Church, 1977; McDonald, *et al.*, 1988) and have also been demonstrated in beetles (Kukor *et al.*, 1988), termites (Martin and Martin, 1978) and freshwater turtles (Bjorndal, 1991). Associative effects are of considerable importance to herbivores like the green turtle that rely upon microbial fermentation as certain diet items may either complement or impair microbial populations and therefore digestion (Bjorndal, 1991).

Mixed diets also appear to be important in temperate herbivorous reef fishes. Horn (1983) found that the fishes he studied did not select for the most energetically rich algal species even when abundant, but continued to maintain a mixed diet of lower value items. Horn also found that diet mixing increased when the number of algae species available decreased. Diet mixing has been demonstrated in limpets (Kitting, 1980), parrotfish (Lobel and Ogden, 1981), sea urchins (Lowe and Lawrence, 1976), beavers (Jenkins, 1979), howler monkeys (Milton, 1979; Glander, 1981), kudus (Owen-Smith and Novellie, 1982) and caviid rodents (Lacher *et al.*, 1982) as well as other species.

It is possible that the mixed diet of the green turtle is an artefact of its inability to harvest individual species from the heterogenous algal turf with its beak. Evidence against this argument is provided by the many lavage samples composed almost entirely of smaller, delicate species (e.g. *Gelidiella* , immature *Lobophora*) that grow interspersed within the turf. Underwater observations of green turtles feeding confirm their ability to harvest individual plants although a large percentage of the turf species are most likely unharvestable due to their small thalli. The ability to harvest small thalli is most likely inversely related to the size of the turtle.

The algal turf assemblage on Heron Reef is composed of over 60 species, many of which have rich biochemical profiles. The mixing of these species in the diet may either increase, decrease or mitigate their independent contribution to the diet. Consequently, the possibility for associative effects between diet components is quite likely and requires additional study in algal feeding green turtles.

8.4 Forage Quality and its Influence Upon Reproduction

The marked changes in the species composition (Section 5.3.3) and nutrient content (Section 7.3) of Heron Reef algae detected in this study indicate that green turtles on Heron Reef face a dynamic food source that may change over several weeks or months and is also variable within a species at any given time. It is also probable that more comprehensive seral changes in the algal community occur over time although this study was not long enough to detect them. Additionally, it is has been suggested that the forage of green turtles may be affected over a period of a year to several years by significant shifts in regional weather patterns (Limpus and Nicholls, 1988, 1994). Heron Reef and the South Pacific are influenced periodically by the atmospheric phenomenon known as the El Nino Southern Oscillation (ENSO) which has profound effects upon atmospheric pressure, temperature, rainfall, coastal upwelling and marine productivity (Rasmusson and Carpenter, 1982; Barber and Chavez, 1983; Colgan, 1990; Hansen, 1990; Nicholls, 1991). Limpus and Nicholls (1988, 1994) have demonstrated a correlation between the Southern Oscillation Index (SOI) and the number of green turtles nesting at Great Barrier Reef rookeries two years after the SOI, suggesting that the ENSO, as quantified by the SOI, can negatively impact the forage of the female green turtle and therefore its ability to acquire sufficient deposits of fat to complete vitellogenesis. The deposition of yolk around the developing follicles takes approximately 9 months and since vitellogenesis will not commence without sufficient

fat stores, the preparation for a breeding season begins more than a year in advance of oviposition (Limpus and Nicholls, 1988; Kwan, 1994).

In addition to affecting plant productivity, it may also be possible that the ENSO's influence upon water temperature may negatively impact the metabolism and or feeding behaviour of green turtles sufficiently enough to impede the deposition of suitable fat stores for reproduction. Therefore, significant temporal changes in the quality (Chapter 7) or quantity of the forage (Chapter 5) as detected in this study or changes in behaviour and or physiology, may have significant impacts upon the breeding biology of green turtles.

In view of the evidence demonstrating the influence of nutrition upon the entire reproductive cycle in green turtles (Section 2.2.3), it is apparent that changes in forage over localised or larger areas (e.g. ENSO influence) significantly influence the reproductive biology of the green turtle.

8.5 Nitrogen Limitation

Animals do not use nitrogen efficiently and therefore must consume relatively large quantities of nitrogen in order to meet their physiological needs (Mattson, 1980). Due to the low nitrogen content of their plant diets, herbivores are more limited in their intake of nitrogen than are carnivores. In order to meet their nitrogen requirements, herbivores must consume relatively large amounts of food and assimilate it efficiently (MatTson, 1980).

Overall health and growth rates are influenced by levels of nitrogen and therefore protein intake. Birds and mammals are believed to attain their maximum rates of growth on diets of 12-25% protein whereas fishes require diets containing 35-55%

protein (Horn, 1989). The limited research on growth in captive juvenile green turtles indicates that maximum growth may be obtained on artificial diets containing 35% protein (Wood and Wood, 1981). The average crude protein levels of those species of algae and cyanobacteria assayed during this study averaged 20.5% (ash free, dry weight; range of species means; 5.7-31.3%) or 18.0% if the cyanobacteria are excluded. Nitrogen levels averaged 3.3% and 2.9% if the cyanobacteria are excluded (range of species means; 0.9-5.0%) (Table 7.4). These nitrogen levels are well within the range for most terrestrial plant tissues such as grasses (0.9-4.0%), forbs (1.6-4.9%), gymnosperm leaves (0.7-2.5%), angiosperm leaves (1.5-5.0%) and aquatic plants (0.9-3.7%) (Mattson, 1980) and are comparable with or exceed the seagrass *Thalassia* (3.4%) (Bjorndal, 1980). Therefore, green turtles feeding upon algae may be no more nitrogen limited than terrestrial herbivores and subsequently may be expected to have evolved some of the same adaptations to nitrogen limitation seen in their herbivorous terrestrial counterparts.

Mattson (1980) has suggested that many herbivores have developed anatomical, physiological and behavioural adaptations to cope with the limited nitrogen in their diet including: 1) an ability to locate and utilise those plants or plant parts that are rich in nitrogen; 2) increased consumption rates to increase total nitrogen intake; 3) prolonged periods of feeding and digestion to increase intake and assimilation of nitrogen; 4) specialised alimentary tracts that rely on endosymbionts to facilitate assimilation of nitrogen; 5) occasional or opportunistic carnivory; 6) switching among plant parts or species that may have higher nitrogen levels; 7) regulation of plant chemistry to increase nitrogen content; 8) evolution of a larger body size. The discussion that follows assesses how well green turtles on Heron Reef satisfy Mattson's predictions for adaptations of nitrogen limited herbivores.

It appears that green turtles on Heron Reef satisfied Mattson's first assumption that those plant species higher in nitrogen would be located and consumed. *Laurencia* was the most important contributor or a primary component of the diet during all sampling occasions (Table 6.5, Section 6.3.2) and had a mean nitrogen content of 3.2% (ash-free, dry weight) which was the highest nitrogen level of any species assayed that was found in the diet (Table 7.4). Although there were species with higher contents of nitrogen available e.g. *Chlorodesmis* , *Halimeda* and *Plocamium*, these species were not consumed and are known to contain rich secondary metabolite profiles that may have deterred their consumption (Section 8.3.2).

Increased consumption rates are usually coupled with prolonged periods of feeding (Horn, 1989). All green turtles captured in this study with the exception of nesting females and a single emaciated male were found with full stomachs. C.J. Limpus (pers. comm.) reports that those non-nesting turtles that he has necropsied from Heron Reef have also been found with full digestive tracts. It would appear that the turtles adjust their consumption rate and length of feeding bouts in order to maintain a full alimentary tract in order to achieve maximum nutrient and therefore nitrogen uptake.

The alimentary tract of the green turtle has evolved to meet the requirements of its plant diet. The proximal colon is expanded into a type of "functional caecum" as described by Bjorndal (1985) and houses a rich microflora that produce cellulases and other degradative enzymes. Green turtles also have a higher ratio of intestine length to carapace length than carnivorous species (Bjorndal, 1985) as would be expected for an herbivorous vertebrate. The length of the intestine with its associated microflora result in a more efficient assimilation of nutrients and nitrogen.

Occasional or opportunistic carnivory has been identified in green turtles on Heron Reef and is most common in juvenile and subadult turtles (Section 6.4.5). As animals in their growth phase require more nitrogen than do adults (Mattson, 1980), it would be expected that juveniles and subadults would consume animal matter when available. It has been speculated that marine herbivorous fishes may meet some of their nitrogen needs by inadvertently consuming small animals that are found within the algal thalli that they consume (Horn, 1989). It is unlikely that this could be a significant or even a minor source of nitrogen for green turtles on Heron Reef. During this study, 507 lavage samples were analysed and over 337,000 identifications of diet components were made (Section 6.2.3). Even after this detailed analysis of the lavage samples, animal matter represented only 1.6% of the pooled diet across all sampling occasions and this was limited to a small number juvenile and subadult turtles (Section 6.4.5). It is therefore improbable that animal matter inadvertently consumed with algae supplies even a minor source of nitrogen.

There is no evidence to suggest that green turtles switched between various plant parts as this was not a focus of this study. However, there is evidence to show that turtles switched their foraging effort between species (Section 6.3.3). However, care should be exercised in the interpretation of the cause of this change as there may be influences other than nitrogen that could drive such changes.

Although there is evidence that green turtles influence plant chemistry by maintaining "grazing plots" in seagrass beds (*Thalassia*) (Bjorndal, 1980), there was no evidence of such direct behaviour in this study or in green turtles feeding in seagrass communities in northern Australia (L. V. Aragones, pers. comm./manuscript, 1996). However, the combined influence of the grazing of green turtles and the populations of herbivorous reef fishes found on Heron Reef may have the same effect by maintaining

the algal community in a subclimax stage (Section 8.6). Additional research would be required before conclusions could be made.

Mattson's (1980) final suggestion that herbivores evolve a large body size has been met by green turtles. Mattson (1980) suggests that a larger body size confers several advantages of which the following would be of benefit to the nitrogen limited herbivore. These advantages are: 1) larger bodies permit a greater efficiency of locomotion allowing a larger foraging area and higher rates and volumes of consumption; 2) as low nitrogen levels are frequently accompanied by increased plant toughness, a larger body would confer mechanical advantage in the harvesting and processing of these tissues; 3) a larger body size may be required for the development and housing of a complex digestive system that is capable of breaking down nitrogen poor food while increasing the volume of food consumed.

It appears that green turtles have at least partially met all of Mattson's (1980) suggested adaptations to a nitrogen limited diet. As the levels of nitrogen in marine algae would not be considered low when compared to most terrestrial plant tissues or to seagrasses, it is therefore possible that the nitrogen content of marine algae and the adaptations to a nitrogen limited diet as suggested by Mattson (1980), may be sufficient to meet the nitrogen requirements of the green turtle.

8.6 The Role of the Green Turtle in Community Structure

The algal turf assemblage is considered to be the major contributor to the very high productivity of coral reef communities (Rogers and Salesky, 1981; Hatcher, 1983). Gerkin (1994) estimates that a higher percentage of herbivorous fish live on coral reefs than any other single habitat. Numerous studies on the diet of herbivorous and omnivorous coral reef fishes indicate that species from the algal turf dominate the diet

of these fishes (Hiat and Strasburg, 1960; Randall, 1967; Tsuda and Randall, 1971; Hobson, 1974; Choat, 1991). As herbivorous and omnivorous fishes are the dominant fish trophic groups in shallow reef waters, they have a marked influence upon the species composition and biomass of both the algal turf and monogeneric stands of algae (Hobson, 1974; Goldman and Talbot, 1975; Jones and Chase, 1975; Nagelkerken, 1975; Frydl and Stearn, 1978; Robertson *et al.*, 1979; Choat, 1991). Although invertebrates also play an important role in grazing the algal turf in some tropical reef systems such as in the Caribbean (Breen and Mann, 1976; Ogden and Ziemann, 1977) their influence is minimal in most tropical reef systems (Newman, 1960) such as Heron Reef where herbivorous invertebrates are uncommon. Therefore, when green turtles are present, their influence upon the composition of tropical reef algal communities would be second only to that of the herbivorous fishes.

Although *per diem* intake and passage rates have not been determined for green turtles feeding on algae, Bjorndal (1982a) found that green turtles feeding upon the seagrass *Thalassia testudinum* consumed 0.24-0.33 % of their body weight each day (dry weight of food to wet weight of turtle) per day. *Thalassia* , with its high fibre content, should require a much longer gut transit time than low or nonfibrous algae. I predict that algae feeding turtles of Heron Reef consume greater quantities of forage than turtles feeding on *Thalassia*. However, even if Bjorndal's figures are used and multiplied by the estimated 800-1000 green turtles on Heron Reef at an average of 63.7 kg each (C. J. Limpus, pers. comm.) that would equate to 135-189 kg (dry weight) of algae being removed each day by 900 turtles on the reef or 900-1,260 kg of algae (wet weight) assuming a dry matter average of 15% of the wet weight. This rate of consumption suggests that green turtles play an important role in the trophic economy of Heron Reef.

Thayer *et al.* (1982) demonstrated that green turtles feeding in beds of *Thalassia* produced faeces that were higher in carbon and nitrogen than their seagrass food source with lower C:N ratios. Faecal material from green turtles would therefore be a source of C:N that could be incorporated into the C:N economy of the community. Although similar work has not been conducted in algal feeding turtles, changes in the number of green turtles on a reef could have a substantial influence upon its C:N economy. Although reefs and other green turtle feeding habitats experience regular decreases in turtle numbers due to nesting migrations, this interruption to the C:N economy of the habitat is only temporary and also is quite variable from year to year. A permanent reduction in the number of green turtles would presumably have profound and lasting consequences for the C:N economy of the community as a possibly important source of C:N would be reduced or eliminated. However, before conclusions can be made regarding the contribution of green turtles to the C:N economy of the reef, further study must be undertaken.

Studies at One Tree Reef, located 5 kilometres to the east of Heron Reef, indicate that grazing and browsing organisms remove 20-90% of the net daily production of the algal turf (Hatcher, 1981). The structure and composition of coral reef algal assemblages are a direct result of the herbivores grazing upon them (Ogden and Lobel, 1978; Lewis, 1986; Steneck, 1988; Duffy and Hay, 1990). As green turtles can be an important component of this grazing and browsing community, the removal or reduction of green turtles from algal based reef communities may have an impact upon the species composition and biomass of the algal assemblage. A reduction or elimination of reef grazers and browsers would most likely have a trophic cascading effect (Carpenter and Kitchell, 1985; Gerkin, 1994) in which all other trophic levels are impacted as a result of changes in a lower trophic level.

It has been demonstrated that the algal turf and the sediment trapped within it, interferes with the settlement and growth of encrusting coralline algae (Vine, 1974; Littler and Doty, 1975; Wanders, 1977; van den Hoek *et al.*, 1978) and sessile invertebrates, particularly corals (Vine, 1974; Birkeland, 1977; Sammarco, 1980). This interference increases with the density and stature of the algal turf (Brock, 1979). Therefore, inadequately grazed algal communities may inhibit or prevent settlement of coralline algae and corals, the two components most vital to coral reef construction and maintenance. Hughes (1994) describes just such an event in Jamaica where the reduction of herbivorous fishes and a herbivorous urchin (*Diadema antillarum*) resulted in the overgrowth of fleshy algae. In the absence of grazing, fleshy algae spread across the reefs and formed dense stands of high statured algae effectively eliminating coral recruitment. Hughes (1994) states that larval recruitment by all coral species, including the principle frame building coral of Jamaican reefs, *Montastrea annularis* , has failed for the past decade. The loss of recruitment of this coral species threatens the continuation of the entire reef community.

Constant cropping of the benthic plant community also yields nutritional benefits. Bjorndal (1980, 1985a) found that green turtles feeding on the high fibre seagrass *Thalassia testudinum* maintain grazing plots which were continuously recropped in order to stimulate and maintain the growth of blades with lower fibre and lignin and higher nitrogen. Young blades of *Thalassia* were more readily digestible than the older blades with high fibre and tannins. Green turtles from northern and eastern Australia also appear to select younger seagrass blades from a variety of species (Limpus, unpublished data cited in Lanyon *et al.*, 1989) or graze upon early seral species e.g., *Halophila spp.* (L. V. Aragones, pers. comm./manuscript, 1996) that are more nutritious. A similar strategy has been suggested as being used by the dugong (*Dugong dugon*) which may be avoiding condensed tannins by concentrating its

feeding upon early seral species of seagrasses (e.g. *Halophila*, *Halodule*) that have lower concentrations of chemical and mechanical defences (Lanyon, 1991; Preen, 1995). Preen (1995) has observed dugongs repeatedly grazing the same area and it is suggested that this was being done to maintain the more desirable earlier seral species. Wake (1975) and Anderson and Birtles (1978) found that dugongs selected against mature seagrasses in favour of the younger plants with their higher nutritive potential. Although fibre levels may be of minimal concern in algae, maintaining the algae in its exponential growth phase may be of benefit as it has been shown that nutrient levels are higher in younger plants (Mattson, 1980; Hay *et al.*, 1988). Additionally, it has been shown that cropped areas of seagrasses are more productive on a mass-specific basis than uncropped areas (Klumpp *et al.*, 1987). Cropping reduces self-shading and herbivore excretions may increase available nutrients to the plant and ultimately the herbivore (Carpenter, 1986, 1988; Polunin and Koike, 1987). Although I found no evidence to demonstrate that turtles maintain grazing plots in algal communities, in practice, green turtles and herbivorous reef fishes are maintaining an extensive cooperatively grazed area of young plants. As stated previously, fishes and other herbivores remove an average of 60% (range 20-90%) of the net daily production of the algal turf on the reef around One Tree Island (Hatcher, 1981). Such a high level of cropping would presumably maintain the turf community in an exponential growth phase and may subsequently increase its nutritive and energy potential and lower its ash content. Therefore, both green turtles and herbivorous reef fishes benefit from cooperatively maintaining the algal community in an early seral stage. A similar symbiosis exists between dugongs and green turtles in seagrass communities in northern Australia (L. V. Aragones, pers. comm./manuscript, 1996).

8.7 Multiple Influences Upon Diet Selection-The Decision Matrix

Many authors have found apparent correlations between diet and single variables such as nitrogen (Wallace *et al.*, 1972; Milton, 1979; Calvert, 1985), lignin (Calvert, 1985; Jachmann, 1989), carbohydrates (Reid *et al.*, 1966, 1967; Jachmann, 1989) and tannins (McKey *et al.*, 1981; Jachmann, 1989) and availability (Wake, 1975; Heinshohn, 1981). However, single variable influences upon diet selection most likely represent an oversimplification of the array of variables influencing this process. Additionally, many single variable models may not demonstrate a causal relationship between the variable and the diet but merely an apparent correlation. Attempting to produce a predictive model for diet selection based upon a single variable may be as futile as attempting to model all of the variables influencing diet selection especially when considering euryphagous animals feeding in complex environments such as the green turtle on Heron Reef. Effective modeling should lie somewhere in between these two extremes.

The results of this study indicate that diet selection by green turtles feeding in an algal communities does not fit widely accepted optimal foraging models that are based upon single variable criteria, e.g. energy, CHO, N. The green turtle appears to select its diet in response to a complex interdependent matrix of variables that influence the nutritive and energy potential of its diet while reducing the effects of algal secondary compounds. The content of nutrients, energy or secondary compounds, thallus form or availability are not predictive for diet selection in green turtles feeding in algal communities. The diet of green turtles feeding in complex algal environments appears to be a combination of positive and negative (avoidance) diet selection decisions relating to forage availability and the nutrient, energy and secondary compound profiles of the forage species . As the majority (70.4%, s.e.=1.05; Section 6.3.1) of green turtles on Heron Reef fed within the algal turf, a diet selected from the algal turf

may represent the most optimal diet and foraging strategy given the characteristics of the algal community.

8.8 An Optimal Foraging Strategy for the Green Turtle

Large generalist herbivores such as the green turtle have adapted to using foods which are abundant and available but usually of low nutritional value (Westoby, 1974; Matson, 1980; Bjorndal, 1982a; Belovsky, 1984). Large generalist herbivores keep their alimentary canals almost continuously full and therefore they are limited by how rapidly they can digest their food rather than by how fast they can obtain it. For coral reef herbivores, procurement of food is not difficult. Rather the difficulties lie in the variable quality of food items, their resistance to processing and digestion (Choat, 1991) and in the presence of secondary compounds. Westoby (1974) proposes that the nutrient quality of the diet item is more important than availability when digestion time is limiting rather than search time. Similarly, Choat (1991) states that the key to understanding the variability in the diet of algal feeding reef fishes is in their processing of food and not in the collection of the food. Search time does not appear to be limiting for green turtles on Heron Reef as the species consumed were abundant and readily available. Therefore, the problem with which a large generalist herbivore is faced on a coral reef is to obtain a wide spectrum of nutrients in the appropriate proportions from a relatively fixed volume and rate of intake (Westoby, 1974, 1978). The green turtle on Heron Reef may be able to meet these challenges by consuming a mixed diet from the algal turf.

As search time does not appear to be limiting for green turtles foraging on Heron Reef, the challenge then is to obtain a wide spectrum of nutrients within a presumably fixed volume and rate of intake while minimising any deleterious effects caused by secondary compounds. Westoby (1974, 1978) suggests that the attainment of optimal

nutrient mixing is achieved by relatively constant sampling of diet items in order to approach a nutritionally optimal diet. The significant temporal changes seen in the diet of the green turtles during this study (Section 6.3.3) support Westoby's model in that green turtles on Heron Reef are faced with an algal assemblage that changes rapidly in both availability and quality (Section 5.5.3). Sudden shifts in diet like those seen with the development of extensive stands of *Enteromorpha* in July of 1989 may represent just such a sampling of a newly available species. Such "diet shifts" are well known in fishes and are reviewed by Gerkin (1994). However, as the species composition of the algal turf is also dynamic, a diet of algal turf may produce the same benefits as switching between monogeneric stands as they become available. At the same time, a diet from the algal turf may provide benefits from the effects of additive and nonadditive diet mixing.

Studies have shown that marine algae use combinations of morphological, chemical and nutritive defences to deter herbivory and that the development and concentrations of these deterrents may change dramatically over weeks, days (Targett *et al.*, 1986; Paul and van Alstyne, 1988; Hay *et al.*, 1988) or even hours in the case of *Halimeda* (Hay *et al.*, 1988; Paul and Van Alstyne, 1988). The green turtle on Heron Reef is faced with constantly changing nutritional, energetic (Section 7.3) and secondary compounds characteristic of its forage species as well as variation within a species. Not only does the quality of the forage change but so does the quantity of forage (Section 5.3.3). Therefore, as soon as a foraging behaviour is optimised that incorporates the best mix of nutrients and energy and a reduction in secondary compounds, the relevant conditions that drove this selection process change. Therefore, I suggest that the best strategy for the green turtle is to browse within the mixed species algal turf and not attempt to optimise its nutrient and energy intake from monogeneric stands of ephemeral species. Horn (1983) suggested that the seasonal

changes in the mixed diets of the two temperate herbivorous reef fishes that he studied may also have been a strategy to approach an optimal diet by broadly sampling a food supply that changes seasonally in both abundance, species and chemical composition.

Although the nutrient and energy content of algae on Heron Reef varied significantly between species and within species, only nitrogen levels varied significantly over time and there was no pattern to this change between species. Consequently, with the exception of nitrogen, the overall nutrient and energy profile of reef algae did not change significantly over time. However, as herbivores are commonly nitrogen limited, the significant changes in nitrogen levels observed within species are important. By feeding in the algal turf, the green turtle may be assuring itself a constant level of nutrients (including nitrogen) and energy which may not be available when feeding upon monogeneric stands. Such nonselective behaviour is the norm in tropical algal feeding fishes (Choat, 1991).

Mixed diets can be obtained by either mixing plants selected at the individual level or feeding within patches of interspersed species, e.g, algal turf. The mixture of the algal species found in necropsied animals and in the lavage samples indicates that green turtles are following the latter strategy. Only 29.6% percent of the turtles sampled were known to feed in monogeneric stands and of those recaptured, only 11.0% (8 of 73) had not fed in the algal turf during at least one capture. Therefore, those turtles captured while feeding in monogeneric stands may not represent exceptions to the algal turf feeding strategy but may have merely been captured while they were "sampling" outside of their normal "base diet" of algal turf. However, this suggestion does not exclude the possibility that some turtles may be faithful to a monogeneric diet when the desired species is available.

Studies of optimal foraging and diet selection have commonly assumed that a dichotomy exists in the decision process (Belovsky and Schmitz, 1994). It is assumed that the selection of diet is based upon either: 1) the acquisition of nutrients or, 2) the avoidance of antiherbivore defences. Although it is important to consider each of these influences, it is not necessary and most likely not appropriate to consider them separately. An animal could not select forage species based solely upon their nutrient content if these plants were well protected with antiherbivore defences. Correspondingly, a herbivore could not ignore its nutritional requirements and only graze upon species that were unprotected but of low nutritional benefit. The decision to include a species in the diet must rest somewhere between these two extremes. However, nutritional considerations can never be overlooked and therefore the chemical and structural defences of forage species only operate to modify feeding decisions based solely on nutrition (Belovsky and Schmitz, 1994). Nutritional considerations are therefore of primary importance although they are influenced by the defences of plants.

In light of the primary influence of nutrition upon diet decisions, it has been suggested that mammalian herbivores attempt to achieve their nutritional requirements by the strategies of: 1) nutrient maximisation or, 2) time minimisation (Belovsky and Schmitz, 1994). Nutrient maximisation assumes that the herbivore selects the optimal diet based upon the nutrient content of the forage irrespective of the time required to locate and consume these items. Time minimisation assumes that some minimal amount of food is obtained in as short a time as possible. The selection pressure driving each of these models is that nutrient maximisation equates to better fitness and therefore higher reproductive success while time minimisation reduces exposure to predators and therefore increases the chance of surviving until reproductive age.

As tiger sharks (*Galeocerdo cuvier*) are a common predator of green turtles of all age classes and these sharks are common on Heron Reef, a foraging strategy that incorporates time minimisation and therefore exposure to predators, would be advantageous. Since the algal turf assemblage occurs across the reef flat and in all depths and also represents the majority of the reef areal cover, foraging in the algal turf may be more time efficient than attempting to locate and feed upon desirable monogeneric stands of algae.

Nutrient maximisation for green turtles on Heron Reef presents several constraints. Due to the constantly changing quality and quantity of the algal forage and their rich array of secondary compounds, nutrient maximisation may be hard to achieve because as soon as an optimal diet is selected, the relevant conditions that drove this selection process may change. Therefore, the time invested in identifying optimal species may yield only a temporary reward before the plant chemistry changes or the species is no longer available. As the algal turf always contains species of high nutritive and energy potential, utilising the algal turf as a base diet and opportunistically exploiting desirable ephemeral species may be the most efficient way to achieve nutrient maximisation.

I consider that diet optimisation in the green turtle on Heron Reef does not fit a dichotomous model of selection as a function of either time minimisation or nutrient maximisation but represents a balance of each of these strategies. The use of the algal turf as a base diet provides a nutrient rich diet which is obtainable in a minimal amount of time.

Although there were statistically different levels of nutrients and energy between many of the algae species during this study, the absolute differences between the species were commonly only several percentage points. Although optimal foraging theory

suggests that the consumer will select the best or optimal diet, the precision of this discrimination has yet to be demonstrated for turtles. If the green turtle is capable of such discrimination, it may be of limited value due to the extremely variable nutrient and energy levels of algae over short periods of time and even within a species at any given time. If the green turtle is incapable of discriminating between the nutrient and energy content of the majority of the species present, the best strategy may be to feed in the algal turf and reduce the chances of grazing upon inferior algae in the monogeneric stands. However, this strategy would not exclude the possibility of sampling ephemeral species as they became available as some of these species may be of detectable superiority in some desirable quality.

I consider that the algal turf diet of the green turtle on Heron Reef represents the most optimal diet or foraging strategy because: 1) By feeding in the heterogenous algal turf, search costs and risks are reduced by taking multiple species at one location; 2) Nutrient and energy potential of the forage species are always changing and therefore the identification of a "superior" diet item is difficult and once identified, may change; 3) Nutrient and energy levels vary within a species at any given time and therefore identification of a "superior" species may not be consistent within the species; 4) Many reef algae have rich and diverse secondary metabolite profiles and a mixed turf diet may reduce the amount of secondary compounds ingested and / or produce antagonistic effects that may mitigate the compound's influence; 5) Nonadditive or associative effects of nutrients may be best enhanced by diet mixing; 6) Optimal diets may not be able to be deduced from past experience or prior to consumption, therefore diet mixing will include at least some superior species; 7) Mixed diets may provide the best sources of a wide variety of necessary nutrients; 8) The algal turf is abundant and occurs in all reef habitats with hard substrates, therefore there will always be an area on the reef flat with water deep enough to continue to forage irrespective of tides

whereas certain tidal regimes might limit foraging time on monogeneric stands; 9) Most reef herbivores feed in the algal turf thereby cooperatively (although passively) maintaining an early seral community with young plants of potentially higher energy and nutrient quality and lower ash.

8.9 Areas for Further Investigation

As detailed studies of the feeding ecology of sea turtles are few in number, any additional research into the diet and feeding ecology of sea turtles would be beneficial. The following topics are of particular importance to a thorough understanding of the feeding ecology of the green turtle in algal communities and will be required in order to determine the relative importance of each component of the diet decision matrix and the cues by which green turtles are able to make their optimal diet decisions.

Information is required relating to the influence of secondary compounds upon diet decisions by the green turtle. A great deal of effort has already been invested in identifying the secondary compound profiles of many of the algae found in the green turtle diet (Section 2.3.2.8). Attention should now be focused on how these compounds influence diet decisions in green turtles specifically. This question needs to be approached in a synecology context. It is important to realise that the decision to consume or not consume a chemically protected species may not be made solely upon the level of chemical protection in a species. Rather, the decision may be based upon the absolute abundance and degree of protection of other species available in the environment and upon their associative effects in a mixed diet.

As green turtles on Heron Reef spend a high proportion of their foraging effort in the heterogenous algal turf, attention must also be focused upon the influence of diet

mixing with reference to both additive and nonadditive (associative) effects on the diet components and also upon the actions of secondary compounds. The algae found in the diet of the green turtle have significantly different levels of nutrients and energy accompanied by very rich secondary metabolite profiles. It is probable that the secondary compounds will not only influence nutrient uptake but that the compounds will have associative effects upon each other. Therefore, secondary compounds must be considered in any diet mixing study.

The question of nitrogen balance in green turtles feeding upon algae should also be addressed. As different herbivores have different abilities to extract nitrogen from their food, the green turtle may meet its nitrogen needs through its diet of algae. The very limited amount of animal matter in the diet of juvenile and subadult turtles and its almost complete absence in adults is of interest. If green turtles on Heron Reef are nitrogen limited, it would be expected that they might have a higher content of animal matter in their diet. It is therefore important that consumption rate, gut transit time and nutrient (including nitrogen) assimilation studies be conducted in order to address this question for green turtles feeding upon an algal diet.

The question of the El Nino Southern Oscillation and its impact upon the forage and physiology of the green turtle requires additional attention. A correlation between the ENSO and the number of turtles nesting two years later has been demonstrated (Section 8.4) and a trophic relationship is probable. It is now important that this relationship be investigated in order to determine its influence upon the reproductive biology of green turtles. This research should address the influences of the ENSO upon both plant productivity and the physiology of the green turtle as influenced by changes in water temperature.

It would be of benefit to obtain more detailed information on the diet of individual turtles throughout the year. A larger number of captures of fewer individuals would help address the question of when and why individual turtles change their diet. This could be accomplished by concentrating the capture effort in a limited portion of the reef.

Although much work has been done on the trophic relationships of herbivorous reef fishes on coral reef communities, no such work has been conducted to date with green turtles. It would be of interest to be able to quantify the percentage of the algal community that is harvested by turtles compared to other reef herbivores. This information, combined with passage rate studies for algal diets, would provide insight into the importance of green turtles in the trophic economy of the reef as well as their influence in maintaining the algal community at a subclimax successional stage. Additionally, as the most important influence upon the algal community is from herbivorous reef fishes, it would be of interest to see how the species composition and dynamics of the fish community affect the available forage of the green turtle.

8.10 Conclusions

1. Single variable optimal foraging models do not serve as useful predictors of diet in green turtles feeding in complex algal communities. Although diet selection does occur, green turtles on Heron Reef apparently do not select dietary items as an exclusive function of their availability, ash or energy content or the content of those nutrients assayed in this study.
2. The green turtle appears to select its diet in response to a complex interdependent matrix of variables that influences the nutritive and energy potential of their diet while reducing the effects of algal secondary compounds. Diet selection is most

likely a combination of positive and negative (avoidance) diet selection decisions. Levels of nutrients or energy, species availability and thallus form are not effective predictors of diet.

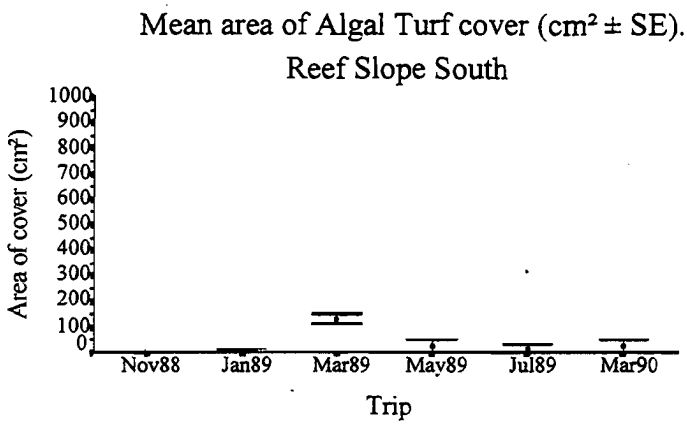
3. The green turtle may serve an important ecological role in maintaining the algal community in an early seral stage.
4. As predicted for nitrogen limited herbivores, juvenile and subadult turtles appear to supplement their nitrogen requirements by feeding upon animal matter when it is available. However, due to the low contribution of animal matter to the pooled diet of juveniles and subadults and its almost absence in adults, animal matter does not appear to be significant source of nitrogen. Green turtles may be obtaining the nitrogen they require from their algal diet by utilising a series of behavioural, anatomical and physiological adaptations. However, assimilation studies must be conducted before conclusion can be made.

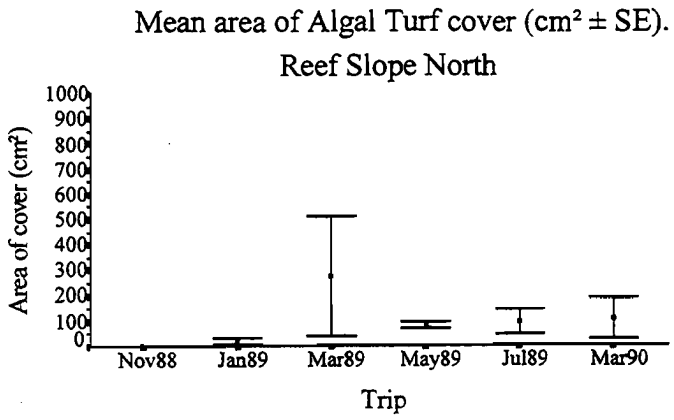
5. Green turtles on Heron Reef appear to have a base diet selected from the algal turf but they will opportunistically exploit monogeneric stands of algae when they become available.
6. When confronted with constantly changing algal chemistry, plant availability and a rich array of chemically protected species, the optimal strategy for the green turtle may be to forage within the heterogenous algal turf. Such a strategy would ensure that at least some superior species were included in the diet while at the same time possibly mitigating the influences of secondary compounds while optimising the benefits of diet mixing. As the composition of the algal turf is dynamic, this strategy would also ensure the inclusion of newly available species in the diet.

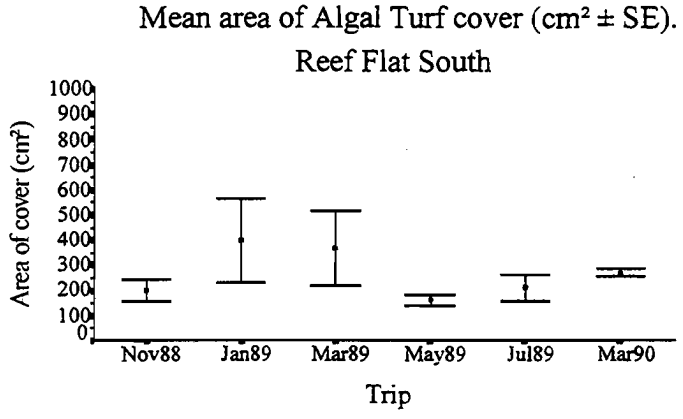
Appendices

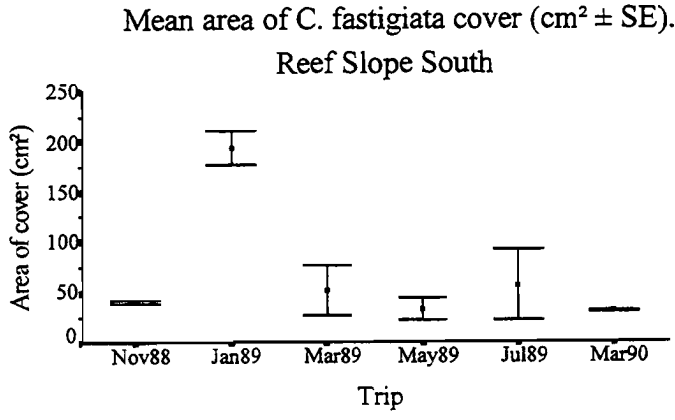
App. Table 5.1- Cyanobacterian and algal species of Heron Reef, Queensland as listed by Cribb (1966a, b). (*) denotes species listed in Cribb (1966 a,b) but not relisted in Cribb's final summary of the algae of the Capricorn- Bunker area in 1984 (Cribb, 1984b). The reason for the omissions are unknown. See Table 5.4 for additional species observed during this study.

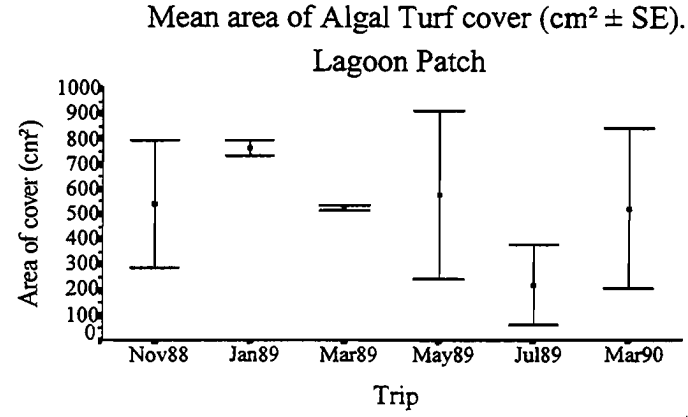
Cyanophyta	
Calothrix crustacea	Thuret ex. Bornet & Flahault
*Calothrix pilosa**	Harvey
Entophysalis conferta	(Kuetzing) Drouet & Daily
Entophysalis deusta	(Meneghini) Drouet & Daily
*Fremyella grisea**	(Thuret) J. de Toni
Hormothaminion s enteromorphoide	Grunow ex. Bornet & Flahault
Kyrtuthrix maculans	Gomont (Umezaki)
*Lyngbya majuscula**	Harvey ex. Gomont
*Lyngbya nordgardhii**	Wille
*Lyngbya rivularianum**	Gomont
*Lyngbya semiplena**	J. Agardh
*Lyngbya sp.**	
Mastigocoleus testarum	Lagerheim ex Bornet & Flahault
*Microcoleus tenerrimus**	Gomont
*Oscillatoria chalybea**	Mertens
*Oscillatoria margaritifera**	(Kuetzing) Gomont
Rivularia atra	Roth
*Spirulina tenerrima**	Kuetzing
Chlorophyta	
Acetabularia clavata	Yamada
Acetabularia moebii	Solms-Laubac
Boodlea composita	(Harvey) Brand
*Caulerpa cupressoides**	(Vahl) C. Agardh
Caulerpa racemosa	(Forsskal) J. Agardh
*Chlorodesmis comosa**	Bail
*Cladophora crystallina**	Kuetz prox.
Cladophora spp.	
Cladophoropsis vaucheriaeformia	(Areschoug) Papenfuss
Codium spongiosum	Harvey
Dictyosphaeria intermedia	Weber-van Bosse
Dictyosphaeria versluysii	Weber-van Bosse
*Enteromorpha clathrata**	Roth
Halimeda incrassata	(Ellis) Lamouroux
Halimeda cylindracea	Decaisne
Halimeda discoidea	Decaisne
Halimeda macroloba	Decaisne
Halimeda opuntia	(Linnaeus) Lamouroux
Microdictyon obscurum	J. Agardh
*Monostroma sp.**	
Ostreobium reineckei	Bornet in Reinbold
Penicillus sibogae	A. & E.S. Gepp
*Pilinia sp.**	
Pseudenodoclonium submarintum	Wille
*Pseudopringsheimia sp.**	
*Rhipidodesmis caespitosa**	(J. Agardh) A. & E.S. Gepp
Udotea javanensis	(Montagne) A. & E.S. Gepp
Valonia ventricosa	J. Agardh
Phaeophyta	
Chnoospora implexa	(Hering) J. Agardh
Dictyota bartayresii	Lamouroux
Ectocarpus indicus	Sonder
Ectocarpus irregularis	Kuetzing
Ectocarpus mitchellae	Harvey
Hydroclathrus clathratus	(Bory) Howe
Padina gymnospora	(Kuetzing) Vickers
*Pocockiella variegata**	(Lamourous) Papenfuss
Ralfsia sp.	
Sargassum crassifolium	J. Agardh
Sargassum polycystum	C. Agardh
Sargassum spp.	
Sphacelaria furcigera	Kuetzing
Sphacelaria novae-hollandiae	Sonder
Sphacelaria tribuloides	Meneghini
Turbinaria ornata	(Turner) J. Agardh
Rhodophyta	
Amansia glomerata	C. Agardh
Amphiroa crassa	Lamouroux
Amphiroa foliacca	Lamouroux
*Asterocytis ornata**	(D. Agardh) Hamel
Centroceras clavulatum	(C. Agardh) Montagne
Ceramium gracillimum	(Kuetzing) Griffith & Harvey
Ceramium spp.	
Champia parvula	(C. Agardh) Harvey
*Crouania sp.**	
Erythrotrichia carnea	(Dillwyn) J. Agardh
Gelidiella acerosa	(Forsskal) Feldmann & Hamel
*Gelidiella adnata**	Dawson
Gelidiella bornetii	(Weber-van Bosse) Feldmann & Hamel
Gelidiopsis intricata	(C. Agardh) Vickers
Goniotrichum alsidii	(Zanardini) Howe
Herposiphonia secunda	(C. Agardh) Ambronn
Herposiphonia tenella	(C. Agardh) Ambronn
*Hypnea nidulans**	Setchell
*Hypnea sp.**	
*Hypoglossum sp.**	
Jania adhaerens	Lamouroux
Laurencia flexilis	Setchell
Laurencia obtusa	(Hudson) Lamouroux
Laurencia pannosa	Zanardini
*Laurencia papillosa**	Forsskal
Laurencia spp.	
*Liagora cenomyce**	Dene.
Lithophyllum moluccense	Foslie
*Lithophyllum simulans**	Foslie
*Lophosiphonia scopulorum**	(Harvey) Womersly
*Peyssonelia hariotii**	Weber-van Bosse
*Peyssonelia sp.**	
Porolithon sp.	
Tolypiocladia glomerata	(C. Agardh) Schmitz in Schmitz & Hauptfleisch

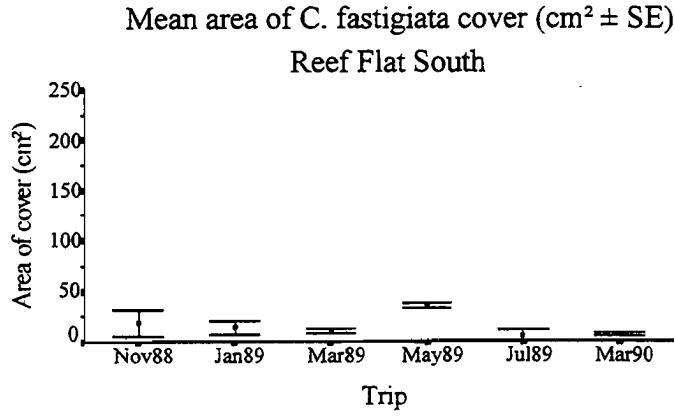


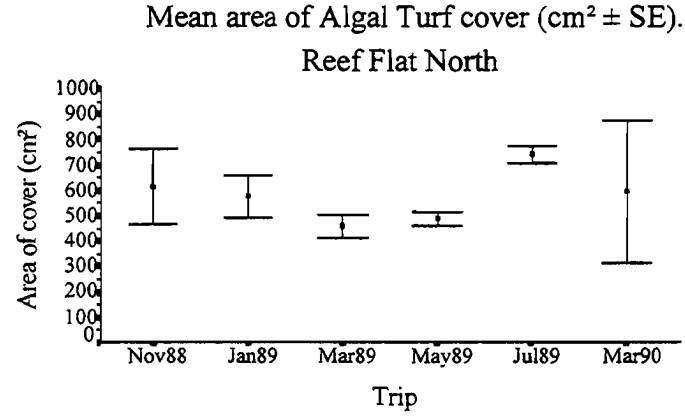


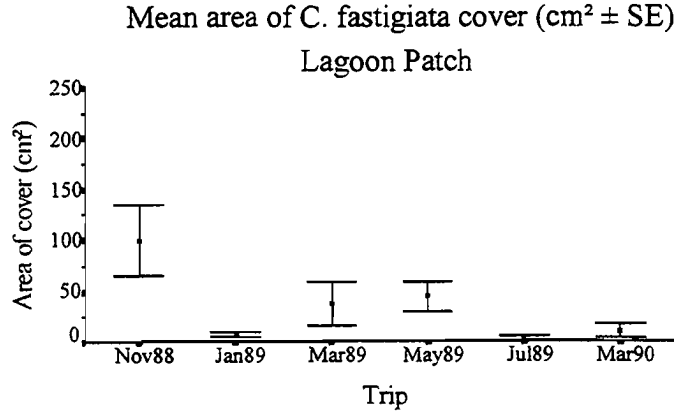






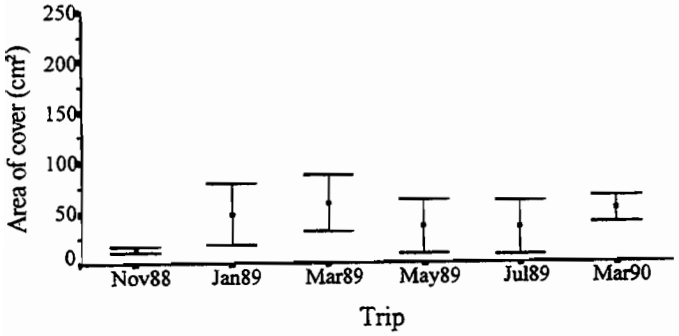




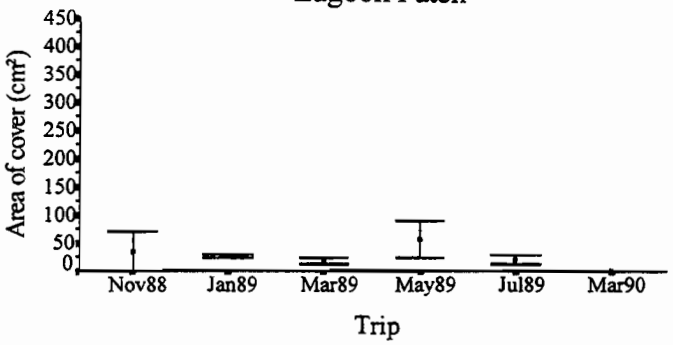


App. Figure 5.1-Mean absolute cover (cm^2 ± s.e.) for each algal component within each habitat. Note that the Y-axis scales vary between algal components.

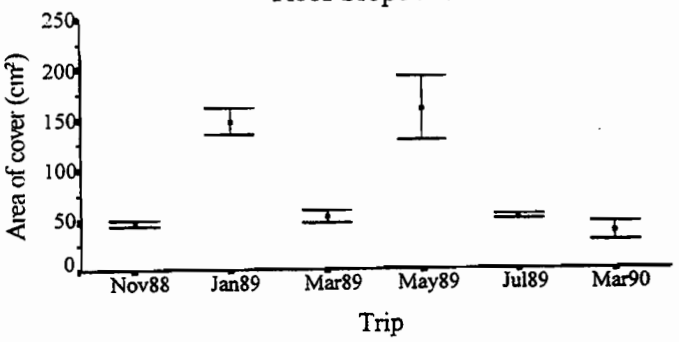
Mean area of C. fastigiata cover (cm² ± SE).
Reef Flat North



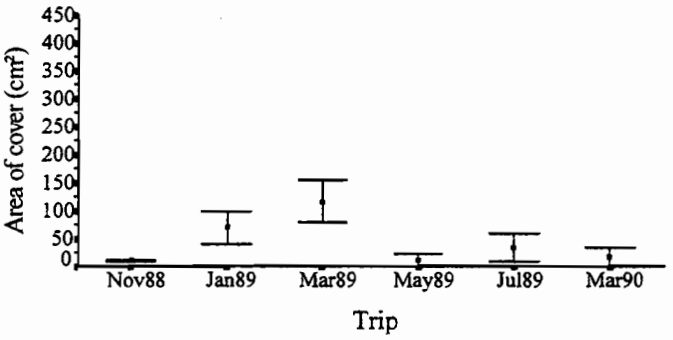
Mean area of Halimeda spp. cover (cm² ± SE).
Lagoon Patch



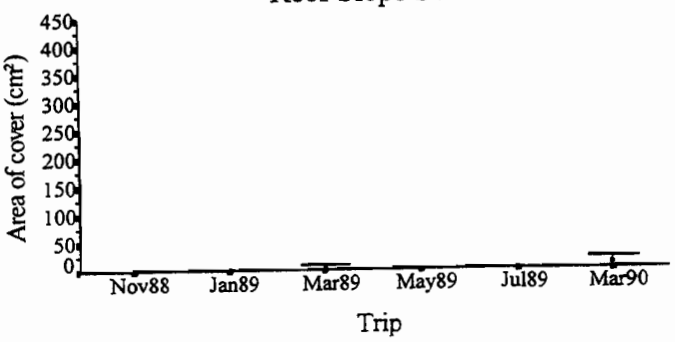
Mean area of C. fastigiata cover (cm² ± SE).
Reef Slope North



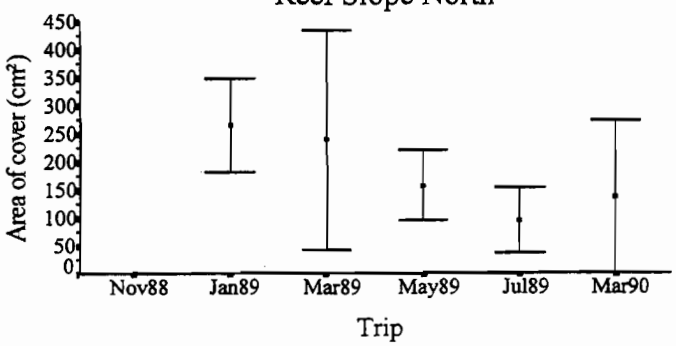
Mean area of Halimeda spp.cover (cm² ± SE).
Reef Flat North



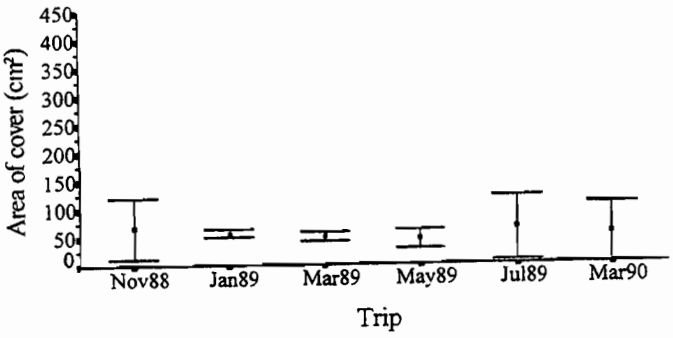
Mean area of Halimeda spp. cover (cm² ± SE).
Reef Slope South



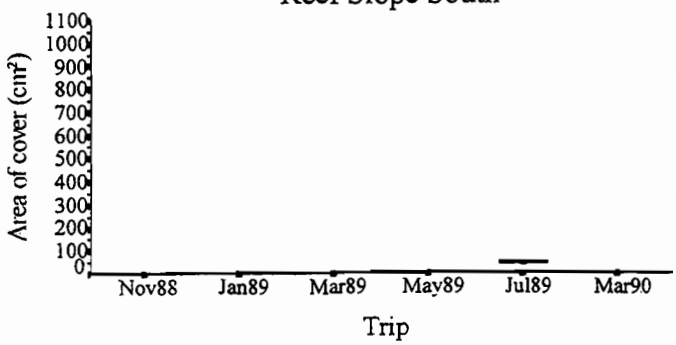
Mean area of Halimeda spp. cover (cm² ± SE)
Reef Slope North



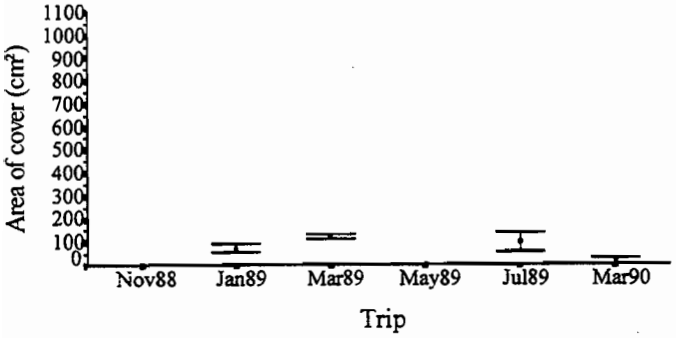
Mean area of Halimeda spp. cover (cm² ± SE).
Reef Flat South



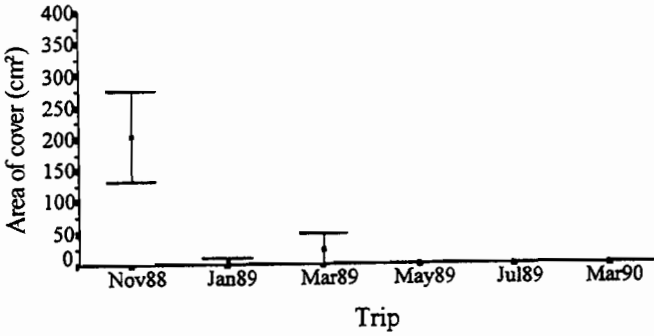
Mean area of Laurencia spp. cover (cm² ± SE
Reef Slope South



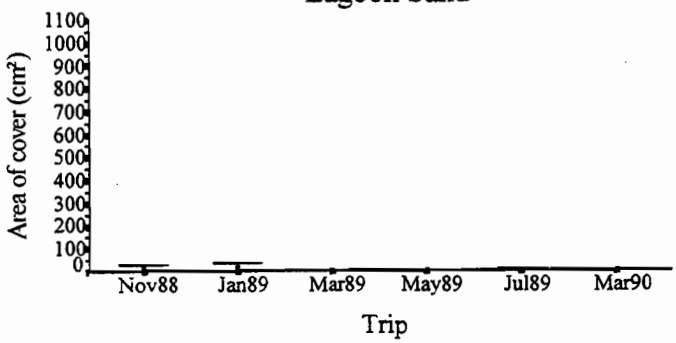
Mean area of Laurencia spp. cover (cm² ± SE)
Reef Flat South



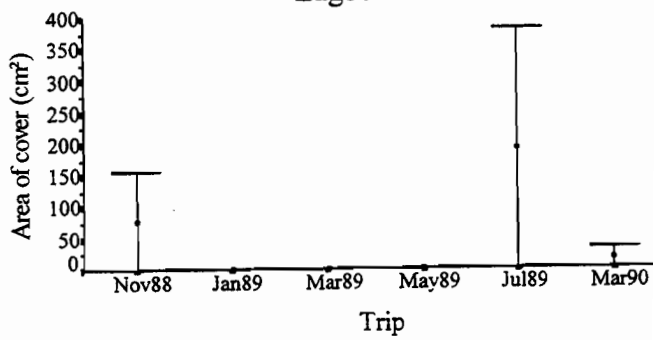
Mean area of L. variegata cover (cm² ± SE)
Reef Flat South



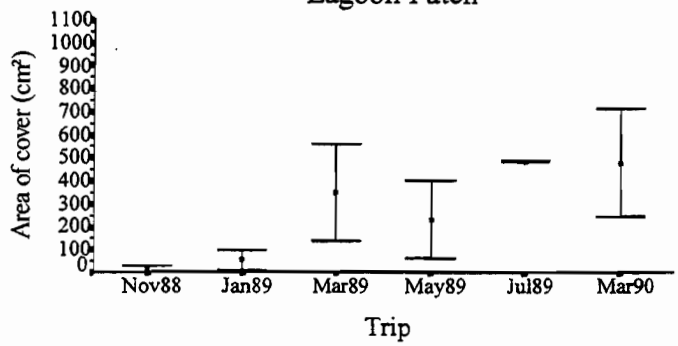
Mean area of Laurencia spp. cover (cm² ± SE)
Lagoon Sand



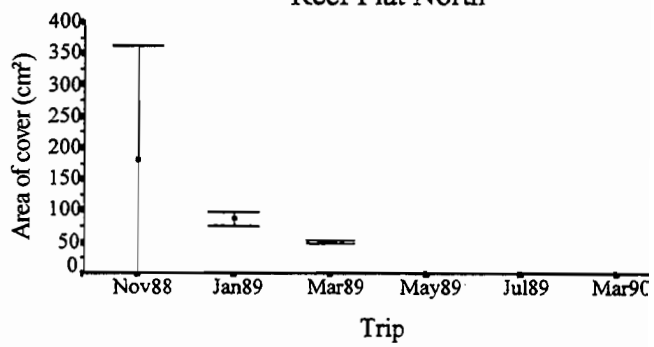
Mean area of L. variegata cover (cm² ± SE)
Lagoon Patch



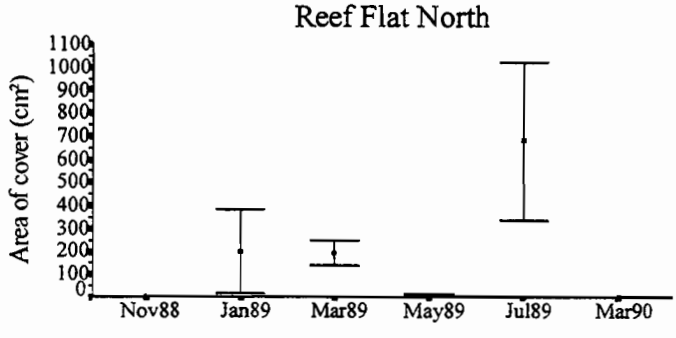
Mean area of Laurencia spp. cover (cm² ± SE)
Lagoon Patch



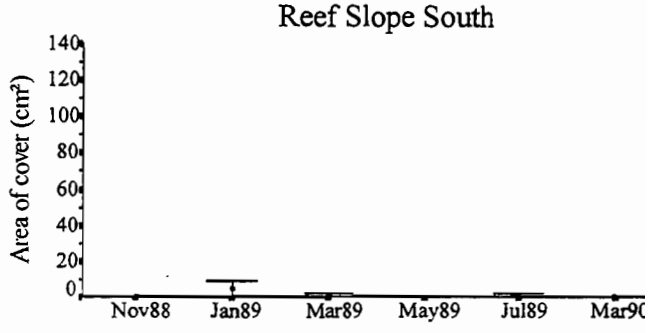
Mean area of L. variegata cover (cm² ± SE
Reef Flat North



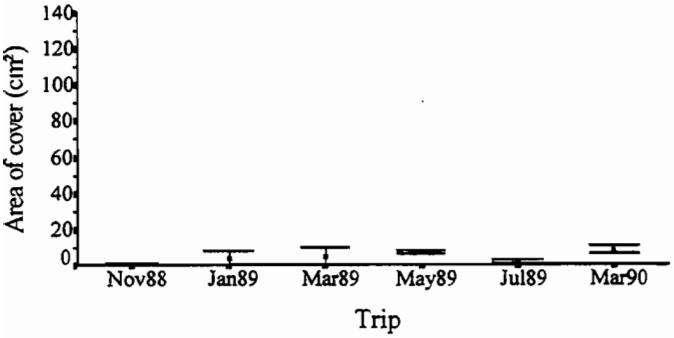
Mean area of Laurencia spp. cover (cm² ± SE)
Reef Flat North



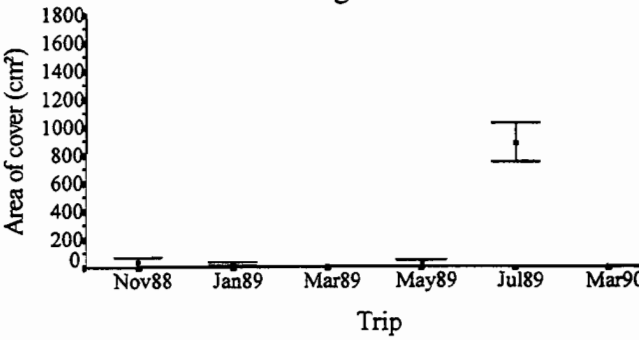
Mean area of Turbinaria spp. cover (cm² ± S
Reef Slope South



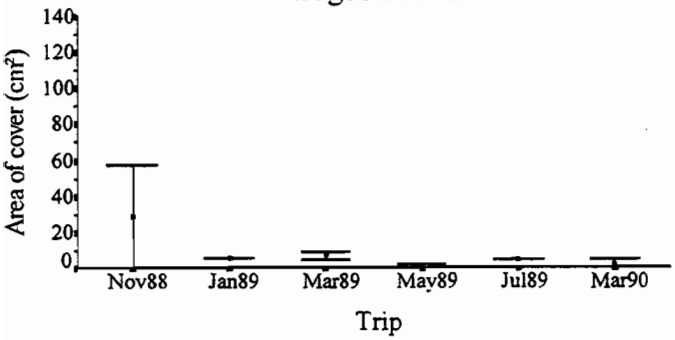
Mean area of Turbinaria spp. cover (cm² ± SE)
Reef Flat South



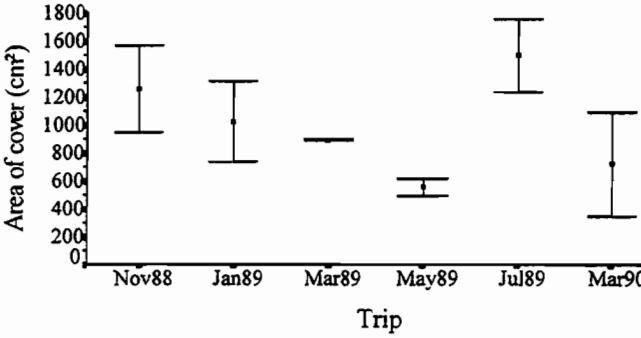
Mean area of Total Algae cover (cm² ± S
Lagoon Sand



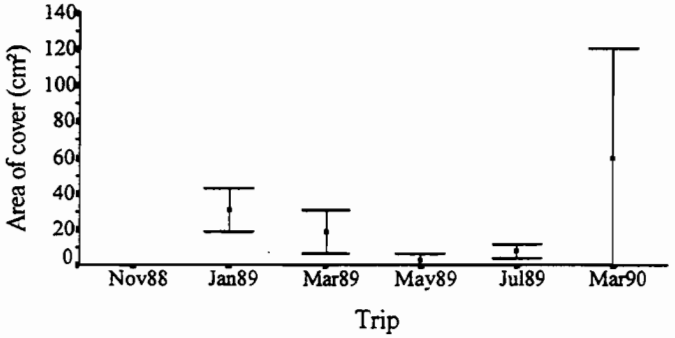
Mean area of Turbinaria spp. cover (cm² ± SE)
Lagoon Patch



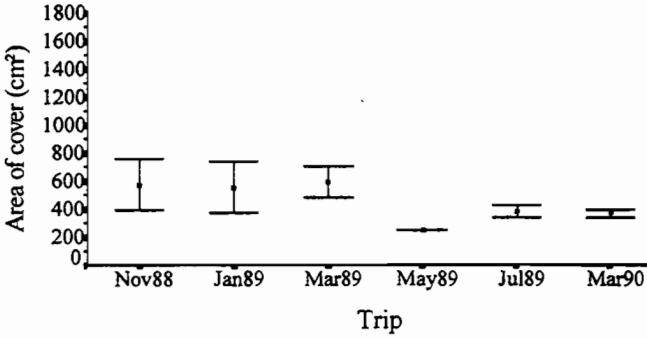
Mean area of Total Algae cover (cm² ± S
Reef Flat North



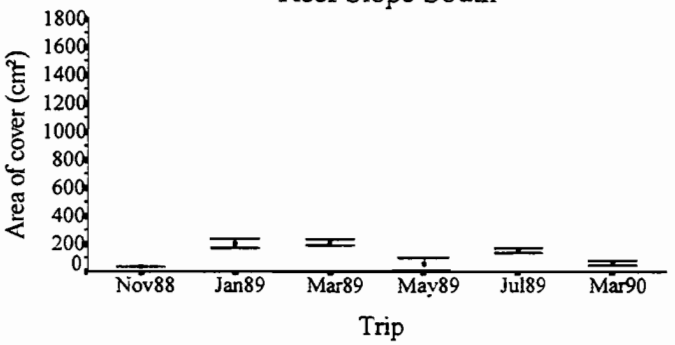
Mean area of Turbinaria spp. cover (cm² ± SE)
Reef Flat North



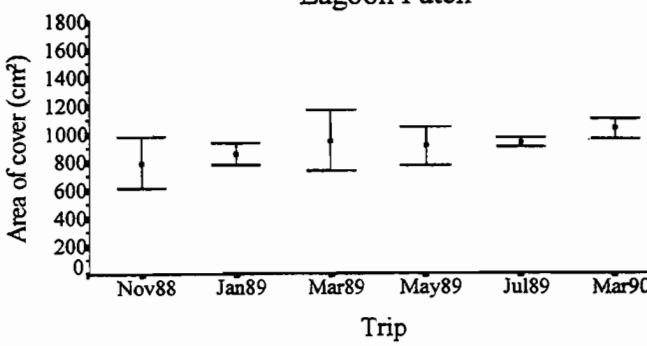
Mean area of Total Algae cover (cm² ± SE
Reef Flat South



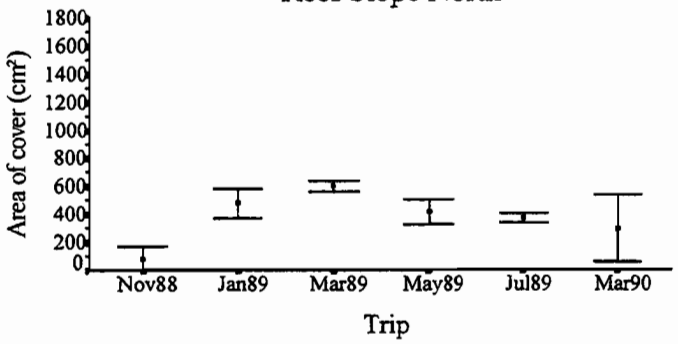
Mean area of Total Algae cover (cm² ± SE).
Reef Slope South

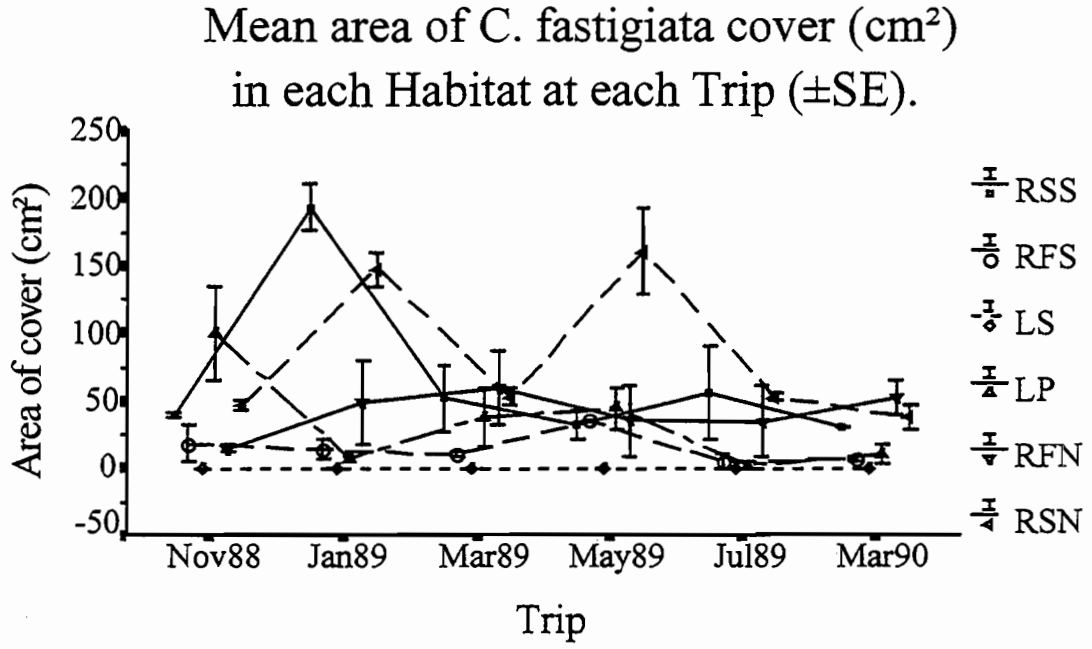


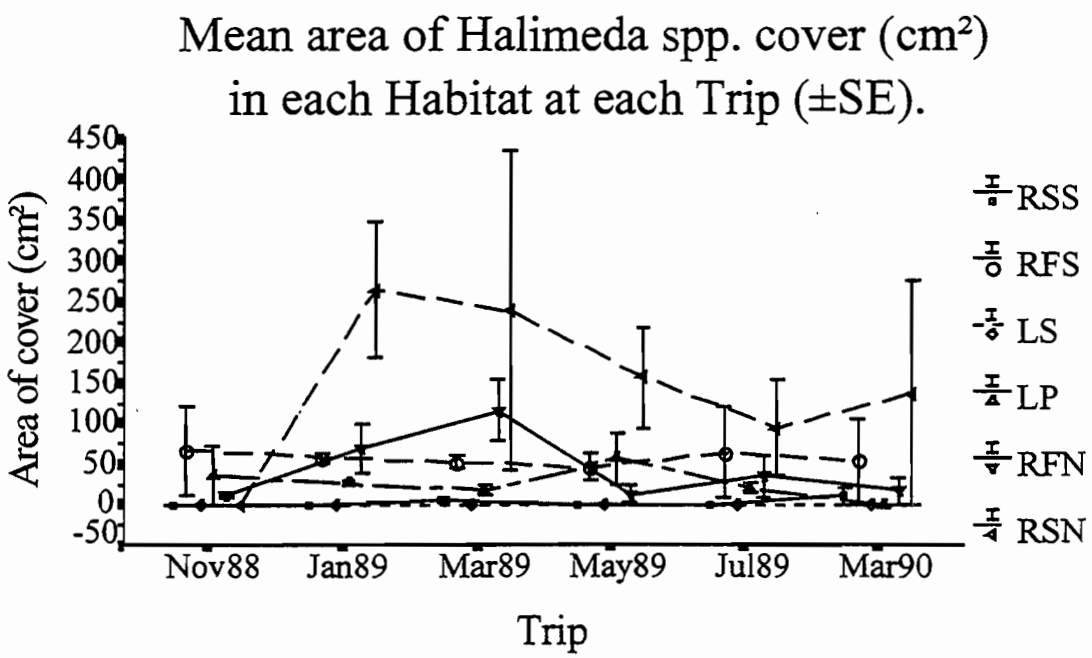
Mean area of Total Algae cover (cm² ± SE
Lagoon Patch



Mean area of Total Algae cover ($cm^2 \pm SE$).
Reef Slope North

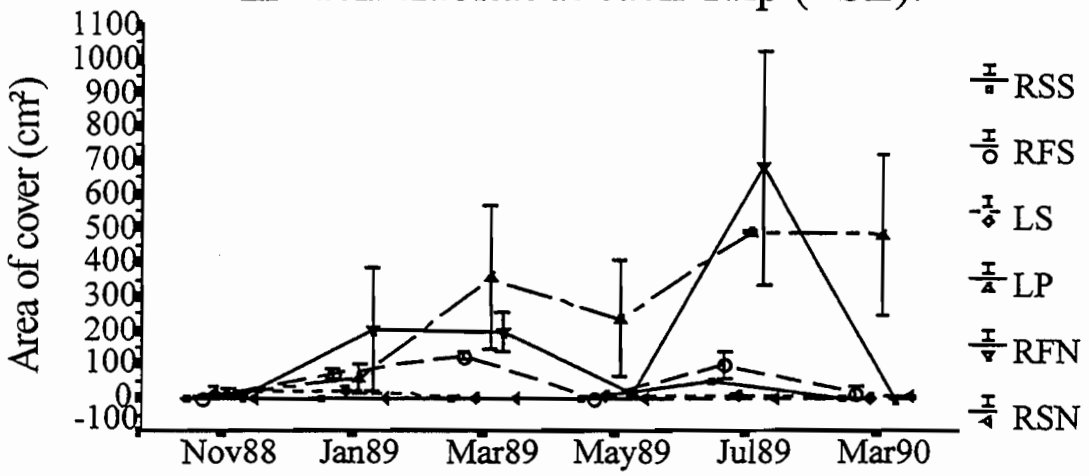




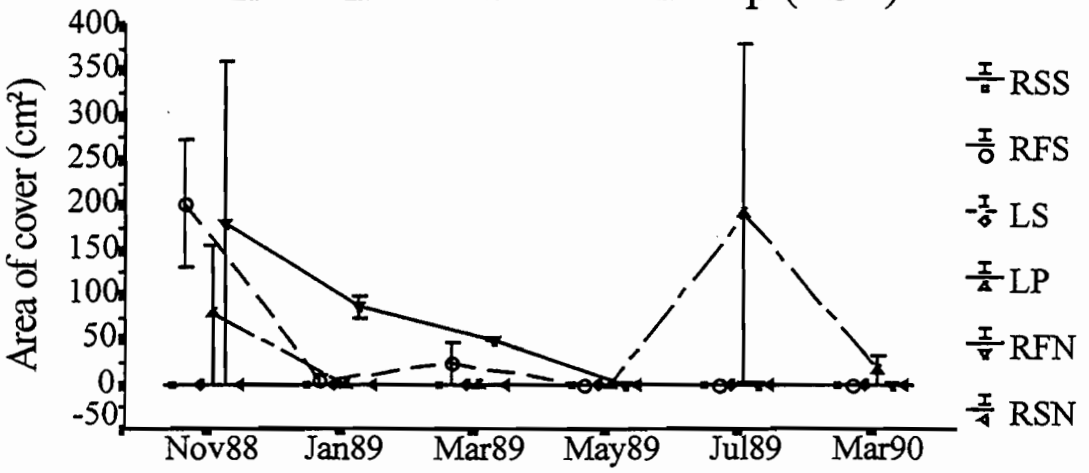


App. Figure 5.2- Mean area (cm ± s.e.) of algal components in each habitat during each sampling session. Each algal component is presented separately as per analysis Design #1. Note different Y-axis scales.

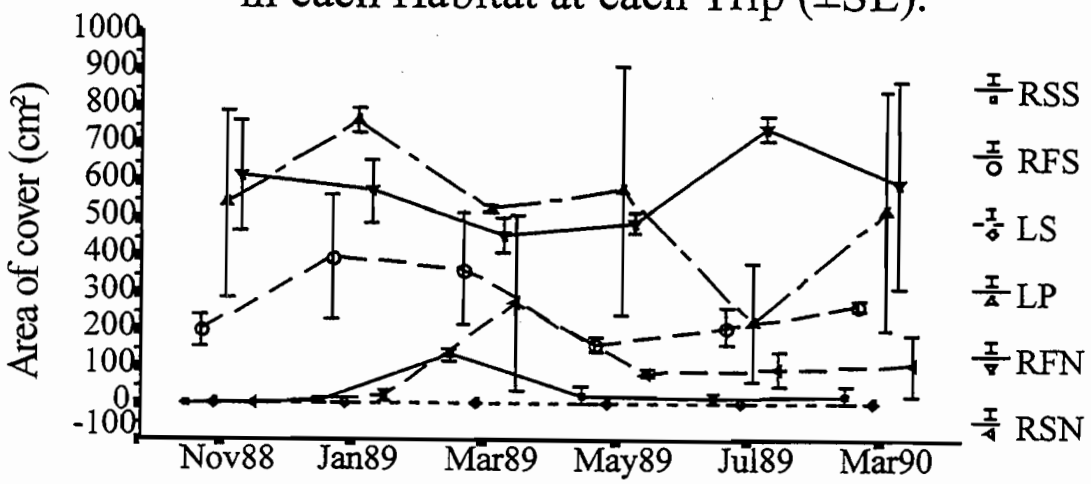
Mean area of Laurencia spp. cover (cm^2)
in each Habitat at each Trip (±SE).



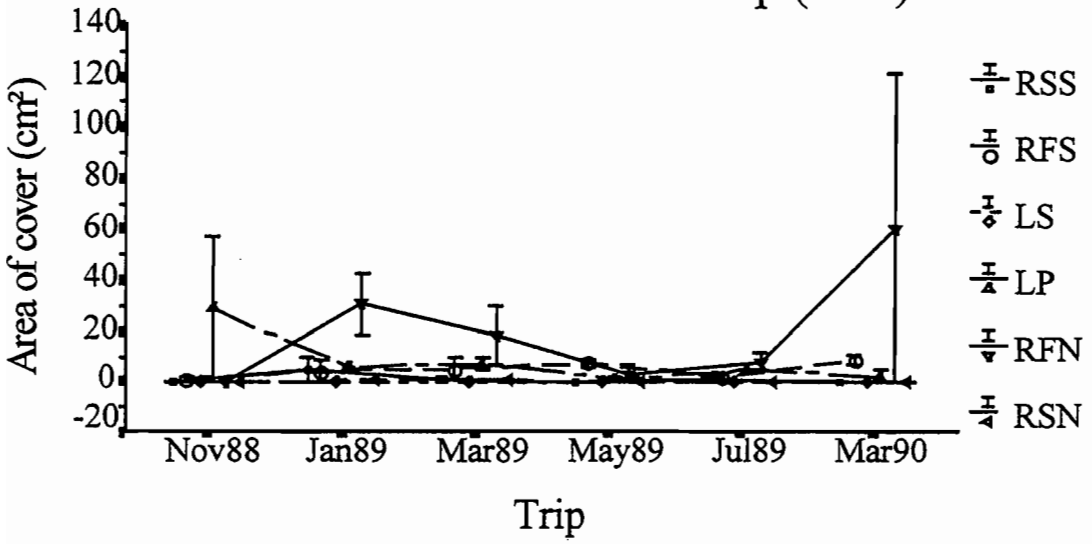
Mean area of L. variegata cover (cm^2)
in each Habitat at each Trip (±SE).



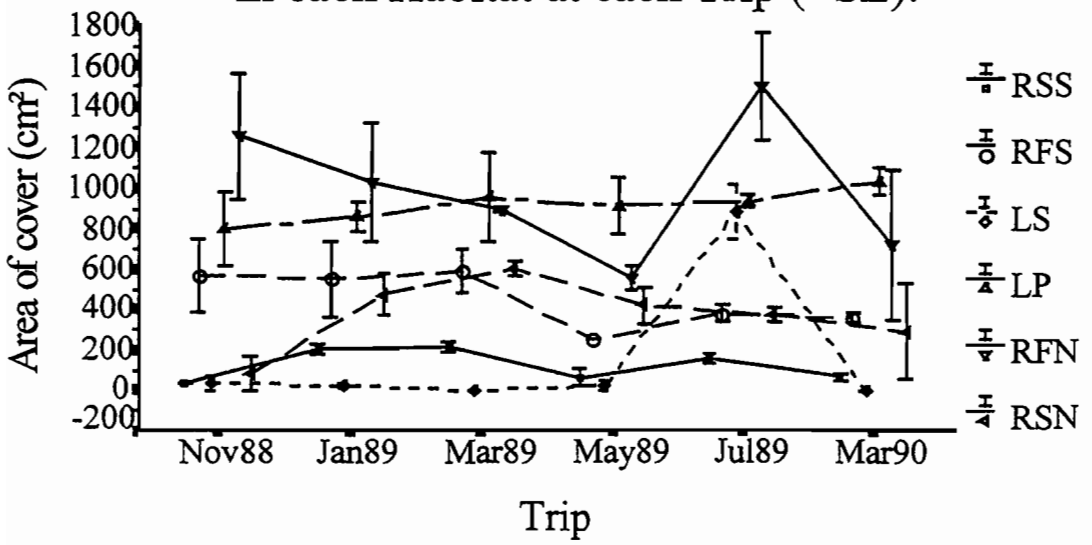
Mean area of Algal Turf cover (cm^2)
in each Habitat at each Trip (±SE).

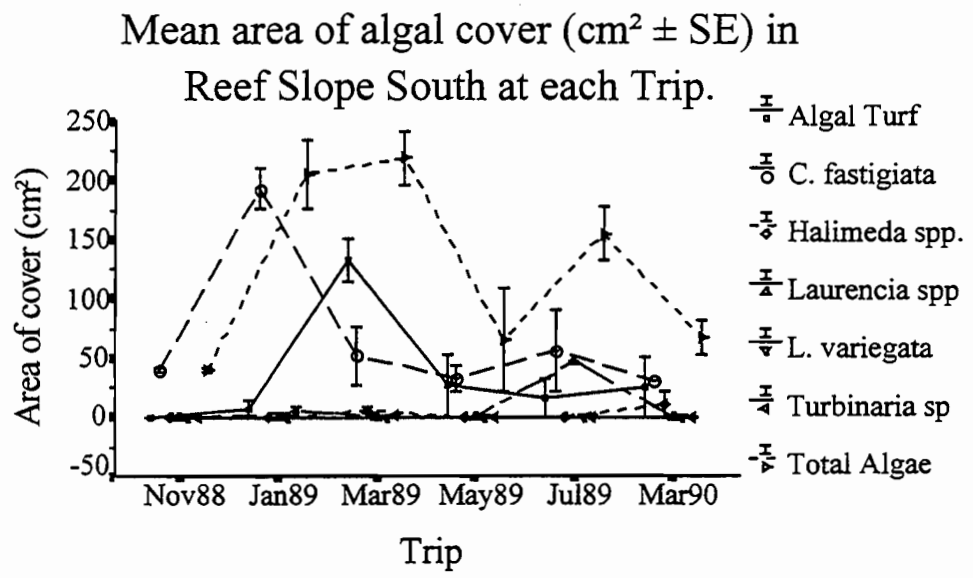


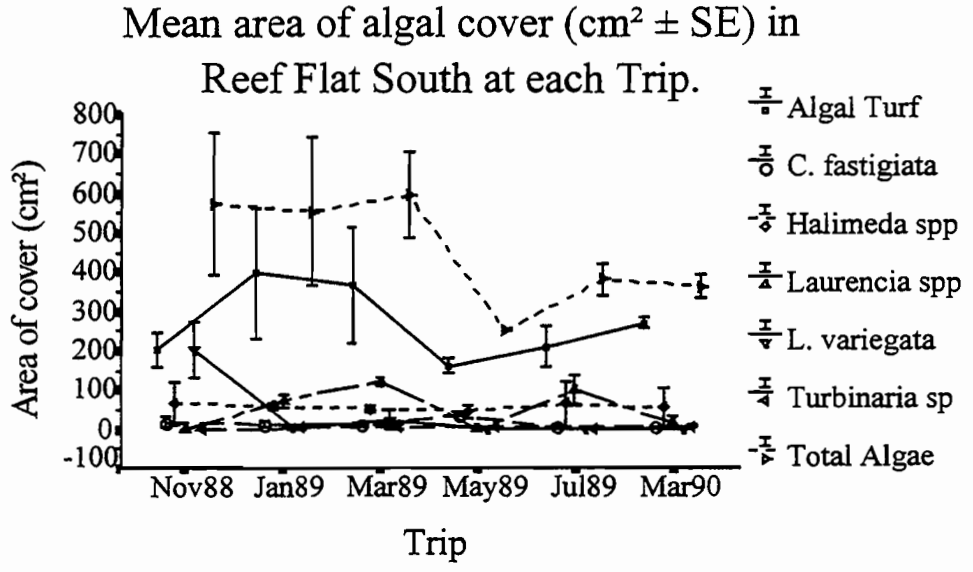
Mean area of Turbinaria spp. cover (cm^2) in each Habitat at each Trip (±SE).

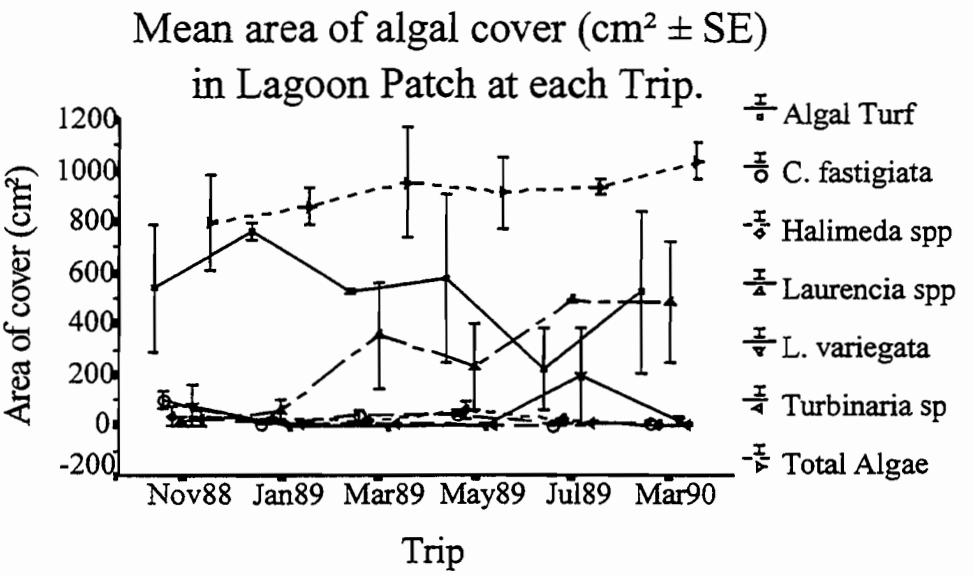


Mean area of Total Algae cover (cm^2) in each Habitat at each Trip (±SE).



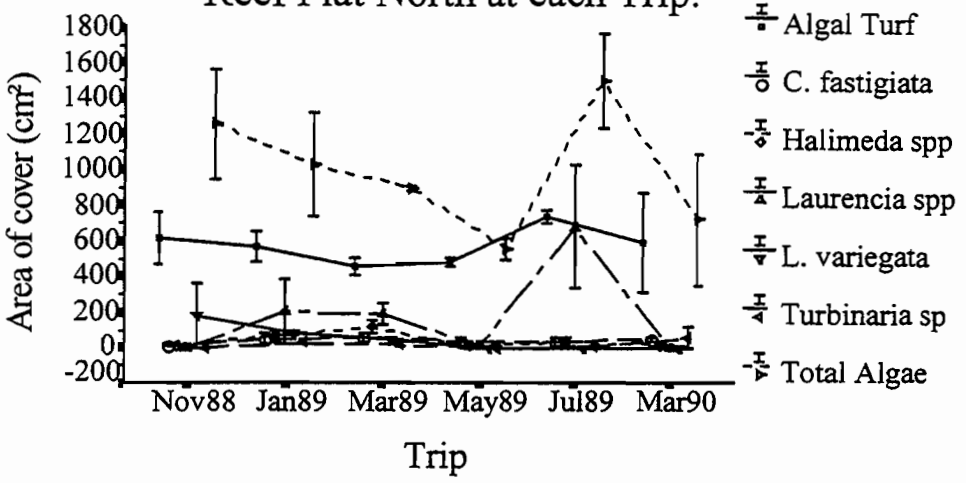




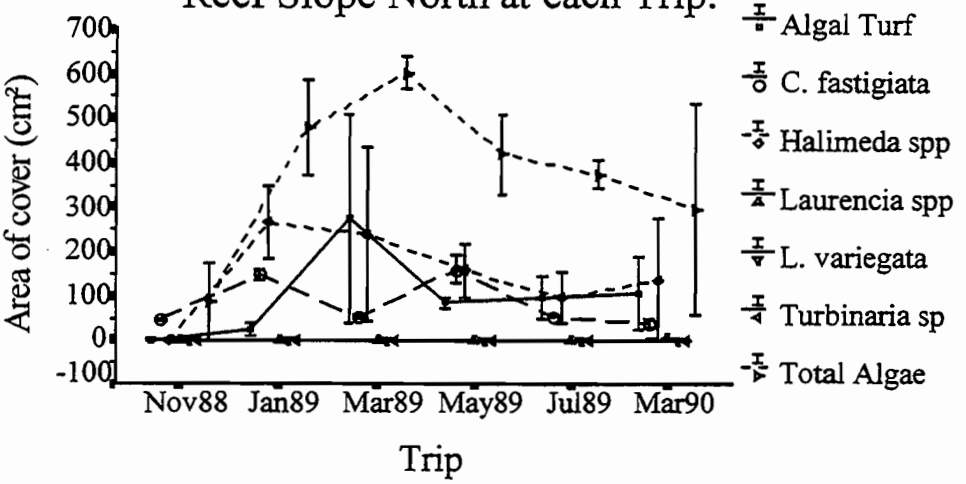


App. Figure 5.3- Mean area (cm ± s.e.) of algal components in each habitat during each sampling session. Each habitat is presented separately as per analysis Design #2. Note different Y-axis scales.

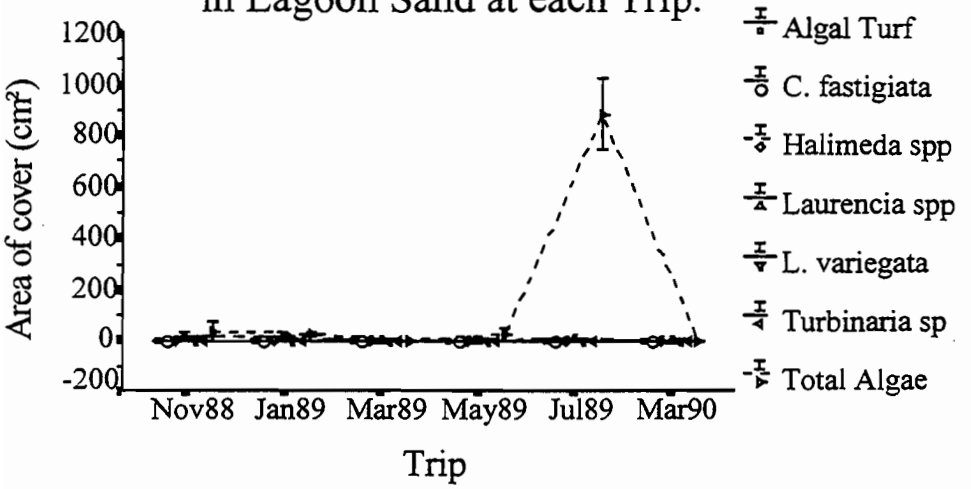
Mean area of algal cover ($cm^2 \pm SE$) in Reef Flat North at each Trip.



Mean area of algal cover ($cm^2 \pm SE$) in Reef Slope North at each Trip.



Mean area of algal cover ($cm^2 \pm SE$) in Lagoon Sand at each Trip.



Appendix 6.1

Gastric Lavage Procedure

Turtles were lavaged following the procedures of Forbes and Limpus (1993) as follows. Each turtle was placed on its carapace in a padded wheelbarrow with its head extending beyond the rim of the barrow. The flippers were restrained with ropes to prevent injury to persons performing the lavage and to the turtle. For optimal drainage, the posterior end of the turtle was elevated slightly higher than the head.

The head was held securely and the mouth opened by gently inserting a thin stainless steel pry bar between the maxilla and tomium (mandible). Pry bars were fabricated from flat stainless steel stock with all surfaces rounded and smoothed to reduce the risk of damage to the buccal cavity.

Pry bar and retrieval tube dimensions for use with various sized sea turtles.

CCL	Pry Bar Dimensions	Retrieval Tube Dimensions
< 50 cm	2.0 mm x12 mm x 15 cm	12 mm I.D. x 1.0 m
50-60 cm	2.5 mm x 20 mm x 20 cm	16 mm I.D. x 1.5 m
>60 cm	2.5 mm x 25 mm x 20 cm	20 mm I.D. x 1.5 m

The pry bar was inserted vertically between the first supralabial and first infralabial scales and then a gentle downward pressure was applied until the bar could be felt butting against the palate. The free end of the bar was then rotated gently downward (towards the cranium) to provide an irritating pressure which would cause the turtle to open its mouth. Care was taken not to force the mouth open as this would result in damage to the tomium and may hinder the animal's ability to feed once released. As the animal opened its mouth, the bar was slid rapidly through the buccal cavity and then held in place at both ends until a veterinary canine mouth gag could be placed in

the mouth. Caution was exercised in order to avoid striking the internal nares while passing the pry bar through the buccal cavity. While the pry bar was held in place by an assistant, a veterinary canine mouth gag was inserted at the anterior end of the mouth and then expanded. The gag was only expanded to the point at which it was secure as hyperextension of the mandibular symphysis could tear the soft dermal tissues ventral to the supralabials. If the turtle opened its mouth further, the gag's positive pressure spring automatically expanded the gag.

Following the insertion of the gag, two flexible clear plastic tubes were inserted into the oesophagus on each side of the gag. The first tube inserted was the retrieval tube which carried the displaced stomach contents into a mesh collection bag. The second tube was the water injection tube which carried the lavage water into the turtle. The retrieval tubing had a wall thickness of 2.0 mm. A thinner wall caused the tubing to collapse while a thicker wall did not provide enough flexibility. The greatest diameter of tube possible was used as large pieces of food such as sponges, soft coral and the alga *Codium* could clog the retrieval tube. The water injection tube was 5.0 mm I.D. with a wall thickness of 1.5 mm and a length of 3 m. Turtles <40 cm CCL required a water injection tube of 3.5 mm I.D.. The ends of all tubes were sanded or melted to provide smooth, rounded ends.

A collection bag fabricated from fibreglass window screen netting was fitted at one end of the retrieval tube. The top of the collection bag was equipped with purse draw strings which allowed the bag to be drawn tightly against the tube. To prevent the bag from slipping off the tube, several electrician's cable ties were secured permanently around the outside of the tube 2 cm from the end. Markings were made on both tubes at 10 cm intervals from the insertion end in order to monitor the length of tubing being inserted into the oesophagus.

Prior to insertion of the retrieval tube, one person firmly grasped the head of the turtle and extended its neck fully while keeping the head in line with the plastral mid-line and level with the plane of the plastron. This position was maintained throughout the flushing procedure in order to prevent harm to the animal.

The tip of the retrieval tube was dipped in a vegetable oil lubricant and then gently placed into the anterior end of the oesophagus. If the glottal papillae hindered the entrance of the tube, they were depressed with the pry bar. The person performing the lavage could usually feel resistance from the turtle's sphincter-like latissimus colli oesophageal muscle group once the tube passed the glottis. Careful manipulation of the tube into the oesophagus was made at this point to avoid damage to the delicate dermal tissues. As adult turtles may have a large and partially convoluted trachea which hampers the insertion of the tube, many animals required the external manipulation of their trachea in order to facilitate passage of the tube.

Once the retrieval tube entered the oesophagus, the lubricated injection tube was slid in laterally along the retrieval tube. Lateral positioning of this tube reduced the risk of the tube entering the trachea. Both tubes were then passed down the oesophagus simultaneously until resistance was felt from either the food bolus or the junction of the oesophagus and the stomach. This junction occurs dorsal to the heart. In feeding turtles, a food bolus was normally encountered before the junction. The distance to this junction was determined prior to tube insertion by laying the tube along the midline of the plastron and measuring from the junction of the humeral and pectoral scutes to the tip of the mouth. The stomach flushing procedure did not begin at a depth greater than this measured distance.

Freshwater was then delivered through the injection tube from a pressurised domestic

water supply system at a delivery pressure of 10-25 psi (9 l/min). Delivery pressures for turtles <40 cm CCL were in the low end of this range. Delivery pressures were monitored with an in-line pressure gauge placed just upstream from the flow valve.

Return flow normally began within seconds of water entering the turtle. If the return flow volume did not equal the delivery flow volume, the retrieval tube was withdrawn slightly to allow free entry of water into the tube or the delivery of water was stopped and both tubes were removed, cleared of obstructions and reinserted. Once proper return water flow was achieved, food particles could be seen travelling within the retrieval tube. If particles were not present or the quantity was low, the injection tube was held in place while the retrieval tube was moved firmly against the bolus and then withdrawn several centimetres to allow the dislodged particles to enter the tube.

The lavage process was continued until one of the following criteria was met: 1) one litre of sample had been collected 2) no more sample could be obtained 3) four minutes had passed. Sampling was discontinued after four minutes or if the animal appeared stressed in order to reduce the chance of its respiring and aspirating water. If the lavage process was interrupted without a complete sample, the process was repeated several minutes later. More than one litre of sample was not required as one of the objectives of the study was to determine what green turtles eat in relation to what was available to them. It was assumed that any food collected in excess of one litre might represent food consumed in an area other than the area of capture and therefore and area of unknown algal assemblage. Additionally, collection of more than one litre of sample appeared to stress the turtles and this stress was more pronounced in the juvenile and subadult turtles.

Once the desired quantity of sample had been collected, the water to the injection tube was turned off and water and food were allowed to continue to drain until all flow had

stopped. At this point, the posterior of the turtle was elevated slightly to assist in drainage. Complete drainage was important prior to removing the retrieval tube as the turtle may breathe as the tube is removed and the airway must be free of standing water to prevent aspiration. The injection tube was removed first and then the retrieval tube. As soon as the tubes were clear, the gag was removed rapidly and the turtle's head elevated slightly to drain any remaining water clear of the glottis and back into the oesophagus. The head was held in this position until the first breath was taken.

Lavage samples were preserved in 6.5 % (vol/vol) formalin/seawater and stored individually in screw top, air tight plastic containers.

App. Table 6.1-Diet composition of green turtles captured within the study site, March 1988, Heron Reef, Queensland. Data are arranged alphabetically within each division. Means and ranges refer only to those lavage samples in which the species was present. Data include animals of all age classes and both sexes. When individuals were recaptured during the sampling session, only the data from the first capture were used in the calculations below. Generic names followed by "spp" represent values for all species of that genus. Data are based upon the volume contribution of the diet item. Data include turtles feeding in monogeneric stands and or algal turf. (n=75)

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Chlorophyta													
Caulerpa brachypus	0.03	1	1.3	2.1	2.1	2.1	-	0	0.0	0	0.0	0	0.0
Caulerpa cupressoides	7.04	29	38.7	0.6	96.4	18.2	25.23	16	21.3	7	9.3	4	5.3
Caulerpa nummularia	0.25	14	18.7	0.2	4.4	1.4	1.44	0	0.0	0	0.0	0	0.0
Caulerpa racemosa	0.33	13	17.3	0.2	5.1	1.9	1.66	1	1.3	0	0.0	0	0.0
Caulerpa sp.	0.21	13	17.3	0.3	4.3	1.2	1.10	0	0.0	0	0.0	0	0.0
Caulerpa spp.	7.86	46	61.3	0.2	96.4	12.8	21.53	20	26.7	7	9.3	4	5.3
Cladophora sp.	0.02	3	4.0	0.2	0.8	0.4	0.33	0	0.0	0	0.0	0	0.0
Chlorodesmis fastigiata	0.00	2	2.7	0.2	0.2	0.2	0.002	0	0.0	0	0.0	0	0.0
Codium spp.	8.15	18	24.0	0.6	91.7	34.0	31.14	13	17.3	9	12.0	7	9.3
Dictyosphaeria sp.	0.29	14	18.7	0.2	10.1	1.5	2.69	1	1.3	0	0.0	0	0.0
Enteromorpha sp.	4.46	22	29.3	0.3	92.3	15.2	21.97	12	16.0	5	6.7	1	1.3
Halimeda tuna	0.02	1	1.3	1.2	1.2	1.2	-	0	0.0	0	0.0	0	0.0
Halimeda sp.	0.23	27	36.0	0.2	2.6	0.6	0.55	0	0.0	0	0.0	0	0.0
Halimeda sp. #1	0.05	5	6.7	0.3	1.2	0.8	0.34	0	0.0	0	0.0	0	0.0
Halimeda spp.	0.30	29	38.7	0.2	3.6	0.8	0.75	0	0.0	0	0.0	0	0.0
Rhizoclonium sp.	0.03	4	5.3	0.1	0.9	0.5	0.41	0	0.0	0	0.0	0	0.0
Valonia sp.	0.00	1	1.3	0.2	0.2	0.2	-	0	0.0	0	0.0	0	0.0
Total Chlorophyta	21.11	69	92.0	0.3	96.4	22.9	27.13	43	57.3	22	29.3	12	16.0
Phaeophyta													
Lobophora variegata	2.34	33	44.0	0.2	22.5	5.3	6.06	15	20.0	0	0.0	0	0.0
Sargassum spp.	0.98	30	40.0	0.2	16.6	2.5	3.64	4	5.3	0	0.0	0	0.0
Turbinaria ornata	12.46	57	76.0	0.2	97.3	16.4	22.59	29	38.7	14	18.7	6	8.0
Total Phaeophyta	15.79	62	82.7	0.2	99.1	19.1	22.03	41	54.7	16	21.3	6	8.0
Rhodophyta													
Acanthophora specifera	0.15	4	5.3	0.2	8.6	2.9	3.84	1	1.3	0	0.0	0	0.0
Amphiroa spp.	0.02	3	4.0	0.4	0.5	0.4	0.05	0	0.0	0	0.0	0	0.0

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Centroceras apiculatum	0.02	4	5.3	0.1	1.2	0.5	0.50	0	0.0	0	0.0	0	0.0
Centroceras clavulatum	0.02	2	2.7	0.5	0.8	0.6	0.24	0	0.0	0	0.0	0	0.0
Centroceras sp.	0.01	2	2.7	0.2	0.3	0.2	0.10	0	0.0	0	0.0	0	0.0
Centroceras spp.	0.04	5	6.7	0.1	1.2	0.7	0.42	0	0.0	0	0.0	0	0.0
Ceramium sp.	0.09	17	22.7	0.1	1.9	0.4	0.43	0	0.0	0	0.0	0	0.0
Champia parvula	0.32	33	44.0	0.1	4.9	0.7	1.15	0	0.0	0	0.0	0	0.0
Chondria sp.	7.75	31	41.3	0.2	66.8	18.8	18.29	22	29.3	10	13.3	2	2.7
Coelothrix irregularis	2.27	32	42.7	0.1	35.4	5.3	9.37	6	8.0	2	2.7	0	0.0
Gelidiella acerosa	5.20	23	30.7	0.2	72.0	17.0	21.39	13	17.3	5	6.7	3	4.0
Gelidiella pannosa	0.00	2	2.7	0.2	0.2	0.2	0.02	0	0.0	0	0.0	0	0.0
Gelidiella sp.	3.18	27	36.0	0.1	40.2	8.8	11.63	11	14.7	4	5.3	0	0.0
Gelidiella spp.	8.38	42	56.0	0.1	72.0	15.0	17.97	23	30.7	9	12.0	3	4.0
Hypnea pannosa	3.19	31	41.3	0.2	64.3	7.7	14.01	13	17.3	2	2.7	1	1.3
Hypnea spinella	0.51	7	9.3	0.3	17.1	5.5	7.95	2	2.7	0	0.0	0	0.0
Hypnea sp.	2.81	29	38.7	0.1	86.2	7.3	16.23	9	12.0	1	1.3	1	1.3
Hypnea spp.	6.51	49	65.3	0.1	86.2	10.0	16.41	25	33.3	4	5.3	2	2.7
Laurencia intricata	2.05	5	6.7	0.1	73.4	30.8	32.49	3	4.0	3	4.0	2	2.7
Laurencia majusculata	1.41	2	2.7	48.1	57.5	52.8	6.58	2	2.7	2	2.7	1	1.3
Laurencia succisa	0.06	3	4.0	0.6	3.3	1.6	1.50	0	0.0	0	0.0	0	0.0
Laurencia sp.	14.45	52	69.3	0.3	93.5	20.8	28.47	29	38.7	13	17.3	9	12.0
Laurencia spp.	17.97	57	76.0	0.3	93.5	23.6	28.97	34	45.3	18	24.0	12	16.0
Leveillea jungermannioides	0.01	3	4.0	0.1	0.5	0.3	0.18	0	0.0	0	0.0	0	0.0
Plocamium hamatum	0.01	1	1.3	0.4	0.4	0.4	-	0	0.0	0	0.0	0	0.0
Polysiphonia spp.	14.71	43	57.3	0.2	85.7	25.7	23.99	29	38.7	19	25.3	8	10.7
Pterocladia caerulescens	0.00	1	1.3	0.2	0.2	0.2	-	0	0.0	0	0.0	0	0.0
Rhodophyta Unknown	0.01	3	4.0	0.2	0.4	0.3	0.12	0	0.0	0	0.0	0	0.0
Spyridia filamentosa	0.02	3	4.0	0.3	0.8	0.5	0.26	0	0.0	0	0.0	0	0.0
Tolypiocladia glomerulata	3.68	43	57.3	0.2	59.4	6.4	11.99	14	18.7	2	2.7	1	1.3
Total Rhodophyta	61.96	73	97.3	2.1	98.8	63.7	27.47	71	94.7	64	85.3	52	69.3
Miscellaneous													
Animal flesh	0.01	3	4.0	0.2	0.2	0.2	0.05	0	0.0	0	0.0	0	0.0
Foraminiferan	0.05	5	6.7	0.2	2.9	0.8	1.16	0	0.0	0	0.0	0	0.0
Mollusk Eggs	0.04	9	12.0	0.1	0.8	0.3	0.22	0	0.0	0	0.0	0	0.0
Mollusk Egg Casing	0.04	2	2.7	0.5	2.7	1.6	1.56	0	0.0	0	0.0	0	0.0

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Mollusk Fragments	0.02	7	9.3	0.1	0.5	0.2	0.12	0	0.0	0	0.0	0	0.0
Physalia sp.	0.41	8	10.7	0.2	13.0	3.9	4.58	2	2.7	0	0.0	0	0.0
Polychaete Worm	0.05	4	5.3	0.2	3.0	1.0	1.34	0	0.0	0	0.0	0	0.0
Polychaete Worm Tube	0.32	19	25.3	0.1	4.8	1.3	1.54	0	0.0	0	0.0	0	0.0
Porifera	0.01	1	1.3	0.7	0.7	0.7	-	0	0.0	0	0.0	0	0.0
Sand-Rubble	0.19	28	37.3	0.1	2.7	0.5	0.57	0	0.0	0	0.0	0	0.0
Animal Matter Total	0.91	37	49.3	0.1	13.0	1.8	2.60	2	2.7	0	0.0	0	0.0
Total Misc.	1.15	49	65.3	0.1	13.0	1.8	2.32	3	4.0	0	0.0	0	0.0

App. Table 6.2-Diet composition of green turtles captured within the study site, March 1988, Heron Reef, Queensland. Data are arranged in order of descending contribution to the pooled diet within each division. Means and ranges refer only to those lavage samples in which the species was present. Data include animals of all age classes and both sexes. When individuals were recaptured during the sampling session, only the data from the first capture were used in the calculations below. Generic names followed by "spp" represent values for all species of that genus. Data are based upon the volume contribution of the diet item. Data include turtles feeding in monogeneric stands and or algal turf. (n=75)

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Chlorophyta													
Codium spp.	8.15	18	24.0	0.6	91.7	34.0	31.14	13	17.3	9	12.0	7	9.3
Caulerpa spp.	7.86	46	61.3	0.2	96.4	12.8	21.53	20	26.7	7	9.3	4	5.3
Caulerpa cupressoides	7.04	29	38.7	0.6	96.4	18.2	25.23	16	21.3	7	9.3	4	5.3
Enteromorpha sp.	4.46	22	29.3	0.3	92.3	15.2	21.97	12	16.0	5	6.7	1	1.3
Caulerpa racemosa	0.33	13	17.3	0.2	5.1	1.9	1.66	1	1.3	0	0.0	0	0.0
Halimeda spp.	0.30	29	38.7	0.2	3.6	0.8	0.75	0	0.0	0	0.0	0	0.0
Dictyosphaeria sp.	0.29	14	18.7	0.2	10.1	1.5	2.69	1	1.3	0	0.0	0	0.0
Caulerpa nummularia	0.25	14	18.7	0.2	4.4	1.4	1.44	0	0.0	0	0.0	0	0.0
Halimeda sp.	0.23	27	36.0	0.2	2.6	0.6	0.55	0	0.0	0	0.0	0	0.0
Caulerpa sp.	0.21	13	17.3	0.3	4.3	1.2	1.10	0	0.0	0	0.0	0	0.0
Halimeda sp. #1	0.05	5	6.7	0.3	1.2	0.8	0.34	0	0.0	0	0.0	0	0.0
Caulerpa brachypus	0.03	1	1.3	2.1	2.1	2.1	-	0	0.0	0	0.0	0	0.0
Rhizoclonium sp.	0.03	4	5.3	0.1	0.9	0.5	0.41	0	0.0	0	0.0	0	0.0
Cladophora sp.	0.02	3	4.0	0.2	0.8	0.4	0.33	0	0.0	0	0.0	0	0.0
Halimeda tuna	0.02	1	1.3	1.2	1.2	1.2	-	0	0.0	0	0.0	0	0.0
Chlorodesmis fastigiata	0.00	2	2.7	0.2	0.2	0.2	0.002	0	0.0	0	0.0	0	0.0
Valonia sp.	0.00	1	1.3	0.2	0.2	0.2	-	0	0.0	0	0.0	0	0.0
Total Chlorophyta	21.11	69	92.0	0.3	96.4	22.9	27.13	43	57.3	22	29.3	12	16.0
Phaeophyta													
Turbinaria ornata	12.46	57	76.0	0.2	97.3	16.4	22.59	29	38.7	14	18.7	6	8.0
Lobophora variegata	2.34	33	44.0	0.2	22.5	5.3	6.06	15	20.0	0	0.0	0	0.0
Sargassum spp.	0.98	30	40.0	0.2	16.6	2.5	3.64	4	5.3	0	0.0	0	0.0
Total Phaeophyta	15.79	62	82.7	0.2	99.1	19.1	22.03	41	54.7	16	21.3	6	8.0
Rhodophyta													
Laurencia spp.	17.97	57	76.0	0.3	93.5	23.6	28.97	34	45.3	18	24.0	12	16.0
Polysiphonia spp.	14.71	43	57.3	0.2	85.7	25.7	23.99	29	38.7	19	25.3	8	10.7

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Laurencia sp.	14.45	52	69.3	0.3	93.5	20.8	28.47	29	38.7	13	17.3	9	12.0
Gelidiella spp.	8.38	42	56.0	0.1	72.0	15.0	17.97	23	30.7	9	12.0	3	4.0
Chondria sp.	7.75	31	41.3	0.2	66.8	18.8	18.29	22	29.3	10	13.3	2	2.7
Hypnea spp.	6.51	49	65.3	0.1	86.2	10.0	16.41	25	33.3	4	5.3	2	2.7
Gelidiella acerosa	5.20	23	30.7	0.2	72.0	17.0	21.39	13	17.3	5	6.7	3	4.0
Tolypiocladia glomerulata	3.68	43	57.3	0.2	59.4	6.4	11.99	14	18.7	2	2.7	1	1.3
Hypnea pannosa	3.19	31	41.3	0.2	64.3	7.7	14.01	13	17.3	2	2.7	1	1.3
Gelidiella sp.	3.18	27	36.0	0.1	40.2	8.8	11.63	11	14.7	4	5.3	0	0.0
Hypnea sp.	2.81	29	38.7	0.1	86.2	7.3	16.23	9	12.0	1	1.3	1	1.3
Coelothrix irregularis	2.27	32	42.7	0.1	35.4	5.3	9.37	6	8.0	2	2.7	0	0.0
Laurencia intricata	2.05	5	6.7	0.1	73.4	30.8	32.49	3	4.0	3	4.0	2	2.7
Laurencia majusculata	1.41	2	2.7	48.1	57.5	52.8	6.58	2	2.7	2	2.7	1	1.3
Hypnea spinella	0.51	7	9.3	0.3	17.1	5.5	7.95	2	2.7	0	0.0	0	0.0
Champia parvula	0.32	33	44.0	0.1	4.9	0.7	1.15	0	0.0	0	0.0	0	0.0
Acanthophora specifera	0.15	4	5.3	0.2	8.6	2.9	3.84	1	1.3	0	0.0	0	0.0
Ceramium sp.	0.09	17	22.7	0.1	1.9	0.4	0.43	0	0.0	0	0.0	0	0.0
Laurencia succisa	0.06	3	4.0	0.6	3.3	1.6	1.50	0	0.0	0	0.0	0	0.0
Centroceras spp.	0.04	5	6.7	0.1	1.2	0.7	0.42	0	0.0	0	0.0	0	0.0
Centroceras apiculatum	0.02	4	5.3	0.1	1.2	0.5	0.50	0	0.0	0	0.0	0	0.0
Spyridia filamentosa	0.02	3	4.0	0.3	0.8	0.5	0.26	0	0.0	0	0.0	0	0.0
Centroceras clavulatum	0.02	2	2.7	0.5	0.8	0.6	0.24	0	0.0	0	0.0	0	0.0
Amphiroa spp.	0.02	3	4.0	0.4	0.5	0.4	0.05	0	0.0	0	0.0	0	0.0
Rhodophyta Unknown	0.01	3	4.0	0.2	0.4	0.3	0.12	0	0.0	0	0.0	0	0.0
Leveillea jungermannioides	0.01	3	4.0	0.1	0.5	0.3	0.18	0	0.0	0	0.0	0	0.0
Centroceras sp.	0.01	2	2.7	0.2	0.3	0.2	0.10	0	0.0	0	0.0	0	0.0
Plocamium hamatum	0.01	1	1.3	0.4	0.4	0.4	-	0	0.0	0	0.0	0	0.0
Gelidiella pannosa	0.00	2	2.7	0.2	0.2	0.2	0.02	0	0.0	0	0.0	0	0.0
Pterocladia caerulescens	0.00	1	1.3	0.2	0.2	0.2	-	0	0.0	0	0.0	0	0.0
Total Rhodophyta	61.96	73	97.3	2.1	98.8	63.7	27.47	71	94.7	64	85.3	52	69.3
Miscellaneous													
Animal Matter Total	0.91	37	49.3	0.1	13.0	1.8	2.60	2	2.7	0	0.0	0	0.0
Physalia sp.	0.41	8	10.7	0.2	13.0	3.9	4.58	2	2.7	0	0.0	0	0.0
Polychaete Worm Tube	0.32	19	25.3	0.1	4.8	1.3	1.54	0	0.0	0	0.0	0	0.0
Sand-Rubble	0.19	28	37.3	0.1	2.7	0.5	0.57	0	0.0	0	0.0	0	0.0

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Foraminiferan	0.05	5	6.7	0.2	2.9	0.8	1.16	0	0.0	0	0.0	0	0.0
Polychaete Worm	0.05	4	5.3	0.2	3.0	1.0	1.34	0	0.0	0	0.0	0	0.0
Mollusk Egg Casing	0.04	2	2.7	0.5	2.7	1.6	1.56	0	0.0	0	0.0	0	0.0
Mollusk Eggs	0.04	9	12.0	0.1	0.8	0.3	0.22	0	0.0	0	0.0	0	0.0
Mollusk Fragments	0.02	7	9.3	0.1	0.5	0.2	0.12	0	0.0	0	0.0	0	0.0
Porifera	0.01	1	1.3	0.7	0.7	0.7	-	0	0.0	0	0.0	0	0.0
Animal flesh	0.01	3	4.0	0.2	0.2	0.2	0.05	0	0.0	0	0.0	0	0.0
Total Misc.	1.15	49	65.3	0.1	13.0	1.8	2.32	3	4.0	0	0.0	0	0.0

App. Table 6.3-Diet composition of green turtles captured within the study site, March 1988, Heron Reef, Queensland. Data are arranged by descending contribution to the pooled diet. Means and ranges refer only to those lavage samples in which the species was present. Data include animals of all age classes and both sexes. When individuals were recaptured during the sampling session, only the data from the first capture were used in the calculations below. Generic names followed by "spp" represent values for all species of that genus. Data are based upon the volume contribution of the diet item. Data include turtles feeding in monogeneric stands and or algal turf. (n=75)

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Total Rhodophyta	61.96	73	97.3	2.1	98.8	63.7	27.47	71	94.7	64	85.3	52	69.3
Total Chlorophyta	21.11	69	92.0	0.3	96.4	22.9	27.13	43	57.3	22	29.3	12	16.0
Laurencia spp.	17.97	57	76.0	0.3	93.5	23.6	28.97	34	45.3	18	24.0	12	16.0
Total Phaeophyta	15.79	62	82.7	0.2	99.1	19.1	22.03	41	54.7	16	21.3	6	8.0
Polysiphonia spp.	14.71	43	57.3	0.2	85.7	25.7	23.99	29	38.7	19	25.3	8	10.7
Laurencia sp.	14.45	52	69.3	0.3	93.5	20.8	28.47	29	38.7	13	17.3	9	12.0
Turbinaria ornata	12.46	57	76.0	0.2	97.3	16.4	22.59	29	38.7	14	18.7	6	8.0
Gelidiella spp.	8.38	42	56.0	0.1	72.0	15.0	17.97	23	30.7	9	12.0	3	4.0
Codium spp.	8.15	18	24.0	0.6	91.7	34.0	31.14	13	17.3	9	12.0	7	9.3
Caulerpa spp.	7.86	46	61.3	0.2	96.4	12.8	21.53	20	26.7	7	9.3	4	5.3
Chondria sp.	7.75	31	41.3	0.2	66.8	18.8	18.29	22	29.3	10	13.3	2	2.7
Caulerpa cupressoides	7.04	29	38.7	0.6	96.4	18.2	25.23	16	21.3	7	9.3	4	5.3
Hypnea spp.	6.51	49	65.3	0.1	86.2	10.0	16.41	25	33.3	4	5.3	2	2.7
Gelidiella acerosa	5.20	23	30.7	0.2	72.0	17.0	21.39	13	17.3	5	6.7	3	4.0
Enteromorpha sp.	4.46	22	29.3	0.3	92.3	15.2	21.97	12	16.0	5	6.7	1	1.3
Tolypiocladia glomerulata	3.68	43	57.3	0.2	59.4	6.4	11.99	14	18.7	2	2.7	1	1.3
Hypnea pannosa	3.19	31	41.3	0.2	64.3	7.7	14.01	13	17.3	2	2.7	1	1.3
Gelidiella sp.	3.18	27	36.0	0.1	40.2	8.8	11.63	11	14.7	4	5.3	0	0.0
Hypnea sp.	2.81	29	38.7	0.1	86.2	7.3	16.23	9	12.0	1	1.3	1	1.3
Lobophora variegata	2.34	33	44.0	0.2	22.5	5.3	6.06	15	20.0	0	0.0	0	0.0
Coelothrix irregularis	2.27	32	42.7	0.1	35.4	5.3	9.37	6	8.0	2	2.7	0	0.0
Laurencia intricata	2.05	5	6.7	0.1	73.4	30.8	32.49	3	4.0	3	4.0	2	2.7
Laurencia majusculata	1.41	2	2.7	48.1	57.5	52.8	6.58	2	2.7	2	2.7	1	1.3
Total Misc.	1.15	49	65.3	0.1	13.0	1.8	2.32	3	4.0	0	0.0	0	0.0
Sargassum spp.	0.98	30	40.0	0.2	16.6	2.5	3.64	4	5.3	0	0.0	0	0.0
Animal Matter Total	0.91	37	49.3	0.1	13.0	1.8	2.60	2	2.7	0	0.0	0	0.0
Hypnea spinella	0.51	7	9.3	0.3	17.1	5.5	7.95	2	2.7	0	0.0	0	0.0
Physalia sp.	0.41	8	10.7	0.2	13.0	3.9	4.58	2	2.7	0	0.0	0	0.0
Caulerpa racemosa	0.33	13	17.3	0.2	5.1	1.9	1.66	1	1.3	0	0.0	0	0.0
Champia parvula	0.32	33	44.0	0.1	4.9	0.7	1.15	0	0.0	0	0.0	0	0.0

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Polychaete Worm Tube	0.32	19	25.3	0.1	4.8	1.3	1.54	0	0.0	0	0.0	0	0.0
Halimeda spp.	0.30	29	38.7	0.2	3.6	0.8	0.75	0	0.0	0	0.0	0	0.0
Dictyosphaeria sp.	0.29	14	18.7	0.2	10.1	1.5	2.69	1	1.3	0	0.0	0	0.0
Caulerpa nummularia	0.25	14	18.7	0.2	4.4	1.4	1.44	0	0.0	0	0.0	0	0.0
Halimeda sp.	0.23	27	36.0	0.2	2.6	0.6	0.55	0	0.0	0	0.0	0	0.0
Caulerpa sp.	0.21	13	17.3	0.3	4.3	1.2	1.10	0	0.0	0	0.0	0	0.0
Sand-Rubble	0.19	28	37.3	0.1	2.7	0.5	0.57	0	0.0	0	0.0	0	0.0
Acanthophora specifera	0.15	4	5.3	0.2	8.6	2.9	3.84	1	1.3	0	0.0	0	0.0
Ceramium sp.	0.09	17	22.7	0.1	1.9	0.4	0.43	0	0.0	0	0.0	0	0.0
Laurencia succisa	0.06	3	4.0	0.6	3.3	1.6	1.50	0	0.0	0	0.0	0	0.0
Foraminiferan	0.05	5	6.7	0.2	2.9	0.8	1.16	0	0.0	0	0.0	0	0.0
Polychaete Worm	0.05	4	5.3	0.2	3.0	1.0	1.34	0	0.0	0	0.0	0	0.0
Halimeda sp. #1	0.05	5	6.7	0.3	1.2	0.8	0.34	0	0.0	0	0.0	0	0.0
Centroceras spp.	0.04	5	6.7	0.1	1.2	0.7	0.42	0	0.0	0	0.0	0	0.0
Mollusk Egg Casing	0.04	2	2.7	0.5	2.7	1.6	1.56	0	0.0	0	0.0	0	0.0
Mollusk Eggs	0.04	9	12.0	0.1	0.8	0.3	0.22	0	0.0	0	0.0	0	0.0
Caulerpa brachypus	0.03	1	1.3	2.1	2.1	2.1	-	0	0.0	0	0.0	0	0.0
Rhizoclonium sp.	0.03	4	5.3	0.1	0.9	0.5	0.41	0	0.0	0	0.0	0	0.0
Mollusk Fragments	0.02	7	9.3	0.1	0.5	0.2	0.12	0	0.0	0	0.0	0	0.0
Centroceras apiculatum	0.02	4	5.3	0.1	1.2	0.5	0.50	0	0.0	0	0.0	0	0.0
Spyridia filamentosa	0.02	3	4.0	0.3	0.8	0.5	0.26	0	0.0	0	0.0	0	0.0
Centroceras clavulatum	0.02	2	2.7	0.5	0.8	0.6	0.24	0	0.0	0	0.0	0	0.0
Cladophora sp.	0.02	3	4.0	0.2	0.8	0.4	0.33	0	0.0	0	0.0	0	0.0
Amphiroa spp.	0.02	3	4.0	0.4	0.5	0.4	0.05	0	0.0	0	0.0	0	0.0
Halimeda tuna	0.02	1	1.3	1.2	1.2	1.2	-	0	0.0	0	0.0	0	0.0
Rhodophyta Unknown	0.01	3	4.0	0.2	0.4	0.3	0.12	0	0.0	0	0.0	0	0.0
Leveillea jungermannioides	0.01	3	4.0	0.1	0.5	0.3	0.18	0	0.0	0	0.0	0	0.0
Porifera	0.01	1	1.3	0.7	0.7	0.7	-	0	0.0	0	0.0	0	0.0
Animal flesh	0.01	3	4.0	0.2	0.2	0.2	0.05	0	0.0	0	0.0	0	0.0
Centroceras sp.	0.01	2	2.7	0.2	0.3	0.2	0.10	0	0.0	0	0.0	0	0.0
Plocamium hamatum	0.01	1	1.3	0.4	0.4	0.4	-	0	0.0	0	0.0	0	0.0
Gelidiella pannosa	0.00	2	2.7	0.2	0.2	0.2	0.02	0	0.0	0	0.0	0	0.0
Chlorodesmis fastigiata	0.00	2	2.7	0.2	0.2	0.2	0.002	0	0.0	0	0.0	0	0.0
Valonia sp.	0.00	1	1.3	0.2	0.2	0.2	-	0	0.0	0	0.0	0	0.0
Pterocladia caerulescens	0.00	1	1.3	0.2	0.2	0.2	-	0	0.0	0	0.0	0	0.0

App. Table 6.4-Diet composition of green turtles captured within the study site, November 1988, Heron Reef, Queensland. Data are arranged alphabetically within each division. Means and ranges refer only to those lavage samples in which the species was present. Data include animals of all age classes and both sexes. When individuals were recaptured during the sampling session, only the data from the first capture were used in the calculations below. Generic names followed by "spp" represent values for all species of that genus. Data are based upon the volume contribution of the diet item. Data include turtles feeding in monogeneric stands and or algal turf. (n=33)

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Chlorophyta													
Caulerpa brachypus	0.04	1	3.0	1.3	1.3	1.3	-	0	0.0	0	0.0	0	0.0
Caulerpa cupressoides	7.00	13	39.4	0.7	95.7	17.8	27.81	6	18.2	3	9.1	2	6.1
Caulerpa nummularia	0.14	4	12.1	0.3	2.3	1.2	0.88	0	0.0	0	0.0	0	0.0
Caulerpa racemosa	0.05	4	12.1	0.2	0.6	0.4	0.18	0	0.0	0	0.0	0	0.0
Caulerpa sp.	0.22	3	9.1	0.9	4.6	2.4	1.91	0	0.0	0	0.0	0	0.0
Caulerpa spp.	7.45	18	54.5	0.2	97.0	13.7	24.75	6	18.2	3	9.1	2	6.1
Cladophora sp.	0.00	1	3.0	0.1	0.1	0.1	-	0	0.0	0	0.0	0	0.0
Chlorodesmis fastigiata	0.76	1	3.0	25.1	25.1	25.1	-	1	3.0	1	3.0	0	0.0
Codium spp.	0.83	2	6.1	0.3	27.0	13.6	18.87	1	3.0	1	3.0	0	0.0
Dictyosphaeria sp.	0.79	13	39.4	0.2	7.5	2.0	2.34	2	6.1	0	0.0	0	0.0
Enteromorpha sp.	1.14	19	57.6	0.2	13.7	2.0	3.05	1	3.0	0	0.0	0	0.0
Halimeda sp.	0.58	11	33.3	0.2	9.8	1.7	2.90	1	3.0	0	0.0	0	0.0
Halimeda sp. #1	0.15	5	15.2	0.6	1.7	1.0	0.43	0	0.0	0	0.0	0	0.0
Halimeda spp.	0.73	12	36.4	0.2	9.8	2.0	2.64	1	3.0	0	0.0	0	0.0
Total Chlorophyta	11.71	30	90.9	0.4	97.0	12.9	19.87	15	45.5	5	15.2	2	6.1
Phaeophyta													
Chnoospora implexa	0.34	1	3.0	11.1	11.1	11.1	-	1	3.0	0	0.0	0	0.0
Dictyota bartayressi	0.14	7	21.2	0.2	2.4	0.7	0.80	0	0.0	0	0.0	0	0.0
Hydroclathrus clathratus	1.97	16	48.5	0.3	18.9	4.1	5.06	4	12.1	0	0.0	0	0.0
Lobophora variegata	3.86	21	63.6	0.1	27.1	6.1	8.63	6	18.2	2	6.1	0	0.0
Sargassum spp.	6.36	18	54.5	0.2	81.3	11.7	23.21	4	12.1	3	9.1	2	6.1
Turbinaria ornata	19.32	26	78.8	0.1	99.8	24.5	36.36	15	45.5	7	21.2	6	18.2
Total Phaeophyta	31.98	30	90.9	0.6	99.8	35.2	38.63	21	63.6	12	36.4	10	30.3
Rhodophyta													
Amphiroa sp.	0.34	2	6.1	0.2	11.0	5.6	7.64	1	3.0	0	0.0	0	0.0
Centroceras clavulatum	0.04	7	21.2	0.1	0.3	0.2	0.07	0	0.0	0	0.0	0	0.0
Centroceras sp.	0.09	3	9.1	0.2	2.3	1.0	1.16	0	0.0	0	0.0	0	0.0
Centroceras spp.	0.13	10	30.3	0.1	2.3	0.4	0.67	0	0.0	0	0.0	0	0.0
Ceramium sp.	0.04	6	18.2	0.1	0.3	0.2	0.07	0	0.0	0	0.0	0	0.0
Champia parvula	0.52	25	75.8	0.1	6.2	0.7	1.24	1	3.0	0	0.0	0	0.0
Chondria sp.	16.21	18	54.5	0.5	73.6	29.7	24.91	13	39.4	10	30.3	4	12.1

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Coelarthrum boergesenii	0.00	1	3.0	0.2	0.2	0.2	-	0	0.0	0	0.0	0	0.0
Coelothrix irregularis	1.18	14	42.4	0.2	17.8	2.8	5.02	2	6.1	0	0.0	0	0.0
Eucheuma denticulatum	0.09	1	3.0	3.1	3.1	3.1	-	0	0.0	0	0.0	0	0.0
Gelidiella acerosa	0.16	7	21.2	0.2	1.5	0.7	0.51	0	0.0	0	0.0	0	0.0
Gelidiella sp.	1.63	17	51.5	0.1	18.9	3.2	4.89	4	12.1	0	0.0	0	0.0
Gelidiella spp.	1.79	17	51.5	0.1	19.1	3.5	5.02	4	12.1	0	0.0	0	0.0
Hypnea pannosa	1.42	22	66.7	0.2	7.3	2.1	1.83	2	6.1	0	0.0	0	0.0
Hypnea sp.	0.83	19	57.6	0.2	9.8	1.4	2.17	1	3.0	0	0.0	0	0.0
Hypnea spp.	2.25	27	81.8	0.2	12.2	2.7	2.68	4	12.1	0	0.0	0	0.0
Hypoglossum spathulatum	0.06	1	3.0	2.0	2.0	2.0	-	0	0.0	0	0.0	0	0.0
Laurencia carolinensis	0.07	1	3.0	2.2	2.2	2.2	-	0	0.0	0	0.0	0	0.0
Laurencia intricata	0.01	1	3.0	0.2	0.2	0.2	-	0	0.0	0	0.0	0	0.0
Laurencia parvipapillata	0.03	2	6.1	0.5	0.5	0.5	0.03	0	0.0	0	0.0	0	0.0
Laurencia succisa	0.25	6	18.2	0.2	4.9	1.4	1.79	0	0.0	0	0.0	0	0.0
Laurencia sp.	14.07	24	72.7	0.3	85.9	19.3	27.79	11	33.3	6	18.2	4	12.1
Laurencia spp.	14.42	24	72.7	0.3	85.9	19.8	28.39	11	33.3	6	18.2	4	12.1
Polysiphonia sp.	12.50	21	63.6	0.1	56.3	19.6	18.25	13	39.4	8	24.2	2	6.1
Rhodophyta Unknown	0.00	1	3.0	0.1	0.1	0.1	-	0	0.0	0	0.0	0	0.0
Spyridia filamentosa	5.47	12	36.4	0.1	72.4	15.0	27.04	5	15.2	2	6.1	2	6.1
Tolypiocladia glomerulata	0.30	13	39.4	0.1	4.1	0.8	1.10	0	0.0	0	0.0	0	0.0
Total Rhodophyta	55.31	32	97.0	0.2	97.5	57.0	39.34	26	78.8	21	63.6	20	60.6
Miscellaneous													
Amphipod	0.02	3	9.1	0.2	0.3	0.2	0.09	0	0.0	0	0.0	0	0.0
Arthropod fragments	0.03	2	6.1	0.3	0.6	0.5	0.25	0	0.0	0	0.0	0	0.0
Foraminiferan	0.01	2	6.1	0.1	0.2	0.2	0.01	0	0.0	0	0.0	0	0.0
Microcoleus lyngbyaceus	0.00	1	3.0	0.1	0.1	0.1	-	0	0.0	0	0.0	0	0.0
Mollusk Eggs	0.01	2	6.1	0.1	0.2	0.2	0.01	0	0.0	0	0.0	0	0.0
Mollusk Fragments	0.14	9	27.3	0.1	2.6	0.5	0.79	0	0.0	0	0.0	0	0.0
Polychaete Worm	0.05	4	12.1	0.1	0.9	0.4	0.35	0	0.0	0	0.0	0	0.0
Polychaete Worm Tube	0.46	17	51.5	0.2	2.7	0.9	0.74	0	0.0	0	0.0	0	0.0
Porifera	0.00	1	3.0	0.2	0.2	0.2	-	0	0.0	0	0.0	0	0.0
Sand-Rubble	0.29	15	45.5	0.1	4.8	0.6	1.17	0	0.0	0	0.0	0	0.0
Animal Matter Total	0.70	26	78.8	0.2	3.6	0.9	0.95	0	0.0	0	0.0	0	0.0
Total Miscellaneous	1.01	27	81.8	28.0	82.4	0.2	1.65	1	3.0	0	0.0	0	0.0

App.Table 6.5-Diet composition of green turtles captured within the study site, November 1988, Heron Reef, Queensland. Data are arranged in order of descending contribution to the pooled diet within each division. Means and ranges refer only to those lavage samples in which the species was present. Data include animals of all age classes and both sexes. When individuals were recaptured during the sampling session, only the data from the first capture were used in the calculations below. Genus names followed by "spp" represent values for all species of that genus. Data are based upon the volume contribution of the diet item. Data include turtles feeding in monogeneric stands and or algal turf. (n=33)

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Chlorophyta													
Caulerpa spp.	7.45	18	54.5	0.2	97.0	13.7	24.75	6	18.2	3	9.1	2	6.1
Caulerpa cupressoides	7.00	13	39.4	0.7	95.7	17.8	27.81	6	18.2	3	9.1	2	6.1
Enteromorpha sp.	1.14	19	57.6	0.2	13.7	2.0	3.05	1	3.0	0	0.0	0	0.0
Codium spp.	0.83	2	6.1	0.3	27.0	13.6	18.87	1	3.0	1	3.0	0	0.0
Dictyosphaeria sp.	0.79	13	39.4	0.2	7.5	2.0	2.34	2	6.1	0	0.0	0	0.0
Chlorodesmis fastigiata	0.76	1	3.0	25.1	25.1	25.1	-	1	3.0	1	3.0	0	0.0
Halimeda spp.	0.73	12	36.4	0.2	9.8	2.0	2.64	1	3.0	0	0.0	0	0.0
Halimeda sp.	0.58	11	33.3	0.2	9.8	1.7	2.90	1	3.0	0	0.0	0	0.0
Caulerpa sp.	0.22	3	9.1	0.9	4.6	2.4	1.91	0	0.0	0	0.0	0	0.0
Halimeda sp. #1	0.15	5	15.2	0.6	1.7	1.0	0.43	0	0.0	0	0.0	0	0.0
Caulerpa nummularia	0.14	4	12.1	0.3	2.3	1.2	0.88	0	0.0	0	0.0	0	0.0
Caulerpa racemosa	0.05	4	12.1	0.2	0.6	0.4	0.18	0	0.0	0	0.0	0	0.0
Caulerpa brachypus	0.04	1	3.0	1.3	1.3	1.3	-	0	0.0	0	0.0	0	0.0
Cladophora sp.	0.00	1	3.0	0.1	0.1	0.1	-	0	0.0	0	0.0	0	0.0
Total Chlorophyta	11.71	30	90.9	0.4	97.0	12.9	19.87	15	45.5	5	15.2	2	6.1
Phaeophyta													
Turbinaria ornata	19.32	26	78.8	0.1	99.8	24.5	36.36	15	45.5	7	21.2	6	18.2
Sargassum spp.	6.36	18	54.5	0.2	81.3	11.7	23.21	4	12.1	3	9.1	2	6.1
Lobophora variegata	3.86	21	63.6	0.1	27.1	6.1	8.63	6	18.2	2	6.1	0	0.0
Hydroclathrus clathratus	1.97	16	48.5	0.3	18.9	4.1	5.06	4	12.1	0	0.0	0	0.0
Chnoospora implexa	0.34	1	3.0	11.1	11.1	11.1	-	1	3.0	0	0.0	0	0.0
Dictyota bartayressi	0.14	7	21.2	0.2	2.4	0.7	0.80	0	0.0	0	0.0	0	0.0
Total Phaeophyta	31.98	30	90.9	0.6	99.8	35.2	38.63	21	63.6	12	36.4	10	30.3
Rhodophyta													
Chondria sp.	16.21	18	54.5	0.5	73.6	29.7	24.91	13	39.4	10	30.3	4	12.1
Laurencia spp.	14.42	24	72.7	0.3	85.9	19.8	28.39	11	33.3	6	18.2	4	12.1
Laurencia sp.	14.07	24	72.7	0.3	85.9	19.3	27.79	11	33.3	6	18.2	4	12.1
Polysiphonia sp.	12.50	21	63.6	0.1	56.3	19.6	18.25	13	39.4	8	24.2	2	6.1
Spyridia filamentosa	5.47	12	36.4	0.1	72.4	15.0	27.04	5	15.2	2	6.1	2	6.1
Hypnea spp.	2.25	27	81.8	0.2	12.2	2.7	2.68	4	12.1	0	0.0	0	0.0
Gelidiella spp.	1.79	17	51.5	0.1	19.1	3.5	5.02	4	12.1	0	0.0	0	0.0

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Gelidiella sp.	1.63	17	51.5	0.1	18.9	3.2	4.89	4	12.1	0	0.0	0	0.0
Hypnea pannosa	1.42	22	66.7	0.2	7.3	2.1	1.83	2	6.1	0	0.0	0	0.0
Coelothrix irregularis	1.18	14	42.4	0.2	17.8	2.8	5.02	2	6.1	0	0.0	0	0.0
Hypnea sp.	0.83	19	57.6	0.2	9.8	1.4	2.17	1	3.0	0	0.0	0	0.0
Champia parvula	0.52	25	75.8	0.1	6.2	0.7	1.24	1	3.0	0	0.0	0	0.0
Amphiroa sp.	0.34	2	6.1	0.2	11.0	5.6	7.64	1	3.0	0	0.0	0	0.0
Tolypiocladia glomerulata	0.30	13	39.4	0.1	4.1	0.8	1.10	0	0.0	0	0.0	0	0.0
Laurencia succisa	0.25	6	18.2	0.2	4.9	1.4	1.79	0	0.0	0	0.0	0	0.0
Gelidiella acerosa	0.16	7	21.2	0.2	1.5	0.7	0.51	0	0.0	0	0.0	0	0.0
Centroceras spp.	0.13	10	30.3	0.1	2.3	0.4	0.67	0	0.0	0	0.0	0	0.0
Eucheuma denticulatum	0.09	1	3.0	3.1	3.1	3.1	-	0	0.0	0	0.0	0	0.0
Centroceras sp.	0.09	3	9.1	0.2	2.3	1.0	1.16	0	0.0	0	0.0	0	0.0
Laurencia carolinensis	0.07	1	3.0	2.2	2.2	2.2	-	0	0.0	0	0.0	0	0.0
Hypoglossum spathulatum	0.06	1	3.0	2.0	2.0	2.0	-	0	0.0	0	0.0	0	0.0
Centroceras clavulatum	0.04	7	21.2	0.1	0.3	0.2	0.07	0	0.0	0	0.0	0	0.0
Ceramium sp.	0.04	6	18.2	0.1	0.3	0.2	0.07	0	0.0	0	0.0	0	0.0
Laurencia parvipapillata	0.03	2	6.1	0.5	0.5	0.5	0.03	0	0.0	0	0.0	0	0.0
Laurencia intricata	0.01	1	3.0	0.2	0.2	0.2	-	0	0.0	0	0.0	0	0.0
Coelarthrum boergesenii	0.00	1	3.0	0.2	0.2	0.2	-	0	0.0	0	0.0	0	0.0
Rhodophyta Unknown	0.00	1	3.0	0.1	0.1	0.1	-	0	0.0	0	0.0	0	0.0
Total Rhodophyta	55.31	32	97.0	0.2	97.5	57.0	39.34	26	78.8	21	63.6	20	60.6
Miscellaneous													
Animal Matter Total	0.70	26	78.8	0.2	3.6	0.9	0.95	0	0.0	0	0.0	0	0.0
Polychaete Worm Tube	0.46	17	51.5	0.2	2.7	0.9	0.74	0	0.0	0	0.0	0	0.0
Sand-Rubble	0.29	15	45.5	0.1	4.8	0.6	1.17	0	0.0	0	0.0	0	0.0
Mollusk Fragments	0.14	9	27.3	0.1	2.6	0.5	0.79	0	0.0	0	0.0	0	0.0
Polychaete Worm	0.05	4	12.1	0.1	0.9	0.4	0.35	0	0.0	0	0.0	0	0.0
Arthropod fragments	0.03	2	6.1	0.3	0.6	0.5	0.25	0	0.0	0	0.0	0	0.0
Amphipod	0.02	3	9.1	0.2	0.3	0.2	0.09	0	0.0	0	0.0	0	0.0
Foraminiferan	0.01	2	6.1	0.1	0.2	0.2	0.01	0	0.0	0	0.0	0	0.0
Mollusk Eggs	0.01	2	6.1	0.1	0.2	0.2	0.01	0	0.0	0	0.0	0	0.0
Porifera	0.00	1	3.0	0.2	0.2	0.2	-	0	0.0	0	0.0	0	0.0
Microcoleus lyngbyaceus	0.00	1	3.0	0.1	0.1	0.1	-	0	0.0	0	0.0	0	0.0
Total Miscellaneous	1.01	27	81.8	28.0	82.4	0.2	1.65	1	3.0	0	0.0	0	0.0

App. Table 6.6-Diet composition of green turtles captured within the study site, November 1988, Heron Reef, Queensland. Data are arranged by descending contribution to the pooled diet. Means and ranges refer only to those lavage samples in which the species was present. Data include animals of all age classes and both sexes. When individuals were recaptured during the sampling session, only the data from the first capture were used in the calculations below. Generic names followed by "spp" represent values for all species of that genus. Data are based upon the volume contribution of the diet item. Data include turtles feeding in monogeneric stands and or algal turf. (n=33)

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Total Rhodophyta	55.31	32	97.0	0.2	97.5	57.0	39.34	26	78.8	21	63.6	20	60.6
Total Phaeophyta	31.98	30	90.9	0.6	99.8	35.2	38.63	21	63.6	12	36.4	10	30.3
Turbinaria ornata	19.32	26	78.8	0.1	99.8	24.5	36.36	15	45.5	7	21.2	6	18.2
Chondria sp.	16.21	18	54.5	0.5	73.6	29.7	24.91	13	39.4	10	30.3	4	12.1
Laurencia spp.	14.42	24	72.7	0.3	85.9	19.8	28.39	11	33.3	6	18.2	4	12.1
Laurencia sp.	14.07	24	72.7	0.3	85.9	19.3	27.79	11	33.3	6	18.2	4	12.1
Polysiphonia sp.	12.50	21	63.6	0.1	56.3	19.6	18.25	13	39.4	8	24.2	2	6.1
Total Chlorophyta	11.71	30	90.9	0.4	97.0	12.9	19.87	15	45.5	5	15.2	2	6.1
Caulerpa spp.	7.45	18	54.5	0.2	97.0	13.7	24.75	6	18.2	3	9.1	2	6.1
Caulerpa cupressoides	7.00	13	39.4	0.7	95.7	17.8	27.81	6	18.2	3	9.1	2	6.1
Sargassum spp.	6.36	18	54.5	0.2	81.3	11.7	23.21	4	12.1	3	9.1	2	6.1
Spyridia filamentosa	5.47	12	36.4	0.1	72.4	15.0	27.04	5	15.2	2	6.1	2	6.1
Lobophora variegata	3.86	21	63.6	0.1	27.1	6.1	8.63	6	18.2	2	6.1	0	0.0
Hypnea spp.	2.25	27	81.8	0.2	12.2	2.7	2.68	4	12.1	0	0.0	0	0.0
Hydroclathrus clathratus	1.97	16	48.5	0.3	18.9	4.1	5.06	4	12.1	0	0.0	0	0.0
Gelidiella spp.	1.79	17	51.5	0.1	19.1	3.5	5.02	4	12.1	0	0.0	0	0.0
Gelidiella sp.	1.63	17	51.5	0.1	18.9	3.2	4.89	4	12.1	0	0.0	0	0.0
Hypnea pannosa	1.42	22	66.7	0.2	7.3	2.1	1.83	2	6.1	0	0.0	0	0.0
Coelothrix irregularis	1.18	14	42.4	0.2	17.8	2.8	5.02	2	6.1	0	0.0	0	0.0
Enteromorpha sp.	1.14	19	57.6	0.2	13.7	2.0	3.05	1	3.0	0	0.0	0	0.0
Total Miscellaneous	1.01	27	81.8	28.0	82.4	0.2	1.65	1	3.0	0	0.0	0	0.0
Hypnea sp.	0.83	19	57.6	0.2	9.8	1.4	2.17	1	3.0	0	0.0	0	0.0
Codium spp.	0.83	2	6.1	0.3	27.0	13.6	18.87	1	3.0	1	3.0	0	0.0
Dictyosphaeria sp.	0.79	13	39.4	0.2	7.5	2.0	2.34	2	6.1	0	0.0	0	0.0
Chlorodesmis fastigiata	0.76	1	3.0	25.1	25.1	25.1	-	1	3.0	1	3.0	0	0.0
Halimeda spp.	0.73	12	36.4	0.2	9.8	2.0	2.64	1	3.0	0	0.0	0	0.0
Animal Matter Total	0.70	26	78.8	0.2	3.6	0.9	0.95	0	0.0	0	0.0	0	0.0
Halimeda sp.	0.58	11	33.3	0.2	9.8	1.7	2.90	1	3.0	0	0.0	0	0.0
Champia parvula	0.52	25	75.8	0.1	6.2	0.7	1.24	1	3.0	0	0.0	0	0.0
Polychaete Worm Tube	0.46	17	51.5	0.2	2.7	0.9	0.74	0	0.0	0	0.0	0	0.0
Chnoospora implexa	0.34	1	3.0	11.1	11.1	11.1	-	1	3.0	0	0.0	0	0.0
Amphiroa sp.	0.34	2	6.1	0.2	11.0	5.6	7.64	1	3.0	0	0.0	0	0.0
Tolypiocladia glomerulata	0.30	13	39.4	0.1	4.1	0.8	1.10	0	0.0	0	0.0	0	0.0
Sand-Rubble	0.29	15	45.5	0.1	4.8	0.6	1.17	0	0.0	0	0.0	0	0.0

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Laurencia succisa	0.25	6	18.2	0.2	4.9	1.4	1.79	0	0.0	0	0.0	0	0.0
Caulerpa sp.	0.22	3	9.1	0.9	4.6	2.4	1.91	0	0.0	0	0.0	0	0.0
Gelidiella acerosa	0.16	7	21.2	0.2	1.5	0.7	0.51	0	0.0	0	0.0	0	0.0
Halimeda sp. #1	0.15	5	15.2	0.6	1.7	1.0	0.43	0	0.0	0	0.0	0	0.0
Dictyota bartayressi	0.14	7	21.2	0.2	2.4	0.7	0.80	0	0.0	0	0.0	0	0.0
Caulerpa nummularia	0.14	4	12.1	0.3	2.3	1.2	0.88	0	0.0	0	0.0	0	0.0
Mollusk Fragments	0.14	9	27.3	0.1	2.6	0.5	0.79	0	0.0	0	0.0	0	0.0
Centroceras spp.	0.13	10	30.3	0.1	2.3	0.4	0.67	0	0.0	0	0.0	0	0.0
Eucheuma denticulatum	0.09	1	3.0	3.1	3.1	3.1	-	0	0.0	0	0.0	0	0.0
Centroceras sp.	0.09	3	9.1	0.2	2.3	1.0	1.16	0	0.0	0	0.0	0	0.0
Laurencla carolinensis	0.07	1	3.0	2.2	2.2	2.2	-	0	0.0	0	0.0	0	0.0
Hypoglossum spathulatum	0.06	1	3.0	2.0	2.0	2.0	-	0	0.0	0	0.0	0	0.0
Caulerpa racemosa	0.05	4	12.1	0.2	0.6	0.4	0.18	0	0.0	0	0.0	0	0.0
Polychaete Worm	0.05	4	12.1	0.1	0.9	0.4	0.35	0	0.0	0	0.0	0	0.0
Centroceras clavulatum	0.04	7	21.2	0.1	0.3	0.2	0.07	0	0.0	0	0.0	0	0.0
Caulerpa brachypus	0.04	1	3.0	1.3	1.3	1.3	-	0	0.0	0	0.0	0	0.0
Ceramium sp.	0.04	6	18.2	0.1	0.3	0.2	0.07	0	0.0	0	0.0	0	0.0
Laurencia parvipapillata	0.03	2	6.1	0.5	0.5	0.5	0.03	0	0.0	0	0.0	0	0.0
Arthropod fragments	0.03	2	6.1	0.3	0.6	0.5	0.25	0	0.0	0	0.0	0	0.0
Amphipod	0.02	3	9.1	0.2	0.3	0.2	0.09	0	0.0	0	0.0	0	0.0
Foraminiferan	0.01	2	6.1	0.1	0.2	0.2	0.01	0	0.0	0	0.0	0	0.0
Mollusk Eggs	0.01	2	6.1	0.1	0.2	0.2	0.01	0	0.0	0	0.0	0	0.0
Laurencia intricata	0.01	1	3.0	0.2	0.2	0.2	-	0	0.0	0	0.0	0	0.0
Porifera	0.00	1	3.0	0.2	0.2	0.2	-	0	0.0	0	0.0	0	0.0
Coelarthrum boergesenii	0.00	1	3.0	0.2	0.2	0.2	-	0	0.0	0	0.0	0	0.0
Microcoleus lyngbyaceus	0.00	1	3.0	0.1	0.1	0.1	-	0	0.0	0	0.0	0	0.0
Cladophora sp.	0.00	1	3.0	0.1	0.1	0.1	-	0	0.0	0	0.0	0	0.0
Rhodophyta Unknown	0.00	1	3.0	0.1	0.1	0.1	-	0	0.0	0	0.0	0	0.0

App. Table 6.7-Diet composition of green turtles captured within the study site, January 1989, Heron Reef, Queensland. Data are arranged alphabetically within each division. Means and ranges refer only to those lavage samples in which the species was present. Data include animals of all age classes and both sexes. When individuals were recaptured during the sampling session, only the data from the first capture were used in the calculations below. Genus names followed by "spp" represent values for all species of that genus. Data are based upon the volume contribution of the diet item. Data include turtles feeding in monogeneric stands or algal turf. (n=51)

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Chlorophyta													
Caulerpa cupressoides	1.52	8	15.7	0.2	27.7	9.7	9.72	4	7.8	1	2.0	0	0.0
Caulerpa lentillifera	0.02	2	3.9	0.4	0.6	0.5	0.14	0	0.0	0	0.0	0	0.0
Caulerpa nummularia	0.10	8	15.7	0.2	2.0	0.6	0.70	0	0.0	0	0.0	0	0.0
Caulerpa racemosa	1.77	4	7.8	0.7	50.4	22.5	20.75	3	5.9	1	2.0	1	2.0
Caulerpa sp.	0.17	6	11.8	0.5	3.0	1.5	0.86	0	0.0	0	0.0	0	0.0
Caulerpa spp.	3.59	17	33.3	0.2	50.4	10.8	13.73	8	15.7	2	3.9	1	2.0
Cladophora sp.	0.04	3	5.9	0.2	1.6	0.8	0.74	0	0.0	0	0.0	0	0.0
Chlorodesmis fastigiata	0.01	2	3.9	0.1	0.2	0.2	0.01	0	0.0	0	0.0	0	0.0
Chlorophyta Unknown	0.05	2	3.9	0.2	2.3	1.2	1.48	0	0.0	0	0.0	0	0.0
Codium spp.	6.94	18	35.3	0.2	90.1	19.7	25.55	10	19.6	4	7.8	2	3.9
Dictyosphaeria sp.	0.25	9	17.6	0.2	3.9	1.4	1.24	0	0.0	0	0.0	0	0.0
Enteromorpha sp.	2.09	3	5.9	0.2	68.6	35.5	34.29	2	3.9	2	3.9	1	2.0
Halimeda sp.	1.85	20	39.2	0.1	48.7	4.7	10.82	6	11.8	1	2.0	0	0.0
Halimeda sp. #1	0.27	19	37.3	0.1	2.2	0.7	0.58	0	0.0	0	0.0	0	0.0
Halimeda spp.	2.12	27	52.9	0.2	48.7	4.0	9.40	6	11.8	1	2.0	0	0.0
Valonia sp.	0.05	2	3.9	0.4	2.0	1.2	1.13	0	0.0	0	0.0	0	0.0
Total Chlorophyta	15.13	39	76.5	0.2	90.1	19.8	24.13	22	43.1	10	19.6	7	13.7
Phaeophyta													
Dictyota bartayressi	0.04	2	3.9	0.2	1.7	0.9	1.13	0	0.0	0	0.0	0	0.0
Lobophora variegata	10.26	44	86.3	0.3	57.4	11.9	13.60	28	54.9	8	15.7	1	2.0
Padina sp.	0.20	2	3.9	3.3	6.9	5.1	2.55	1	2.0	0	0.0	0	0.0
Phaeophyta Unknown	0.01	1	2.0	0.4	0.4	0.4	-	0	0.0	0	0.0	0	0.0
Sargassum spp.	9.25	24	47.1	0.3	81.7	19.7	26.05	12	23.5	6	11.8	4	7.8
Turbinaria ornata	31.23	49	96.1	0.3	96.8	32.5	35.26	38	74.5	18	35.3	15	29.4
Total Phaeophyta	50.99	51	100.0	1.8	99.5	51.0	32.75	48	94.1	35	68.6	24	47.1
Rhodophyta													
Acanthophora specifera	0.74	5	9.8	0.3	33.9	7.6	14.74	1	2.0	1	2.0	0	0.0
Amphiroa spp.	0.78	9	17.6	0.3	18.0	4.4	5.81	2	3.9	0	0.0	0	0.0
Centroceras sp.	0.02	2	3.9	0.3	0.8	0.6	0.34	0	0.0	0	0.0	0	0.0
Ceramium sp.	0.01	1	2.0	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Champia parvula	0.21	24	47.1	0.2	1.3	0.5	0.33	0	0.0	0	0.0	0	0.0

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Chondria sp.	0.24	2	3.9	2.9	9.1	6.0	4.42	1	2.0	0	0.0	0	0.0
Coelothrix irregularis	1.18	11	21.6	0.3	18.8	5.5	5.39	4	7.8	0	0.0	0	0.0
Galaxaura subfruticulosa	0.17	2	3.9	0.3	8.1	4.2	5.48	1	2.0	0	0.0	0	0.0
Gelidiella acerosa	8.38	20	39.2	0.2	89.9	21.4	26.83	12	23.5	6	11.8	3	5.9
Gelidiella pannosa	0.59	1	2.0	30.3	30.3	30.3	-	1	2.0	1	2.0	0	0.0
Gelidiella sp.	3.52	26	51.0	0.1	37.0	6.9	8.85	12	23.5	1	2.0	0	0.0
Gelidiella spp.	12.49	37	72.5	0.1	89.9	17.2	22.08	20	39.2	10	19.6	3	5.9
Hypnea pannosa	0.77	11	21.6	0.3	18.0	3.6	5.96	2	3.9	0	0.0	0	0.0
Hypnea sp.	0.65	11	21.6	0.2	22.3	3.0	6.50	1	2.0	0	0.0	0	0.0
Hypnea spp.	1.42	19	37.3	0.2	22.3	3.8	6.61	4	7.8	0	0.0	0	0.0
Laurencia intricata	4.11	7	13.7	0.2	90.6	30.0	38.34	4	7.8	3	5.9	2	3.9
Laurencia parvipapillata	0.04	5	9.8	0.1	0.8	0.4	0.22	0	0.0	0	0.0	0	0.0
Laurencia succisa	0.09	6	11.8	0.2	1.8	0.8	0.73	0	0.0	0	0.0	0	0.0
Laurenciasp.	5.27	40	78.4	0.2	47.7	6.7	9.98	14	27.5	2	3.9	0	0.0
Laurencia spp.	9.51	44	86.3	0.2	90.6	11.0	19.12	18	35.3	5	9.8	2	3.9
Lomentaria corallicola	0.53	6	11.8	0.3	16.0	4.5	5.91	1	2.0	0	0.0	0	0.0
Polysiphonia spp.	0.12	1	2.0	6.2	6.2	6.2	-	1	2.0	0	0.0	0	0.0
Rhodophyta Unknown	0.09	11	21.6	0.1	0.8	0.4	0.24	0	0.0	0	0.0	0	0.0
Spyridia filamentosa	0.19	1	2.0	9.4	9.4	9.4	-	1	2.0	0	0.0	0	0.0
Tolypiocladia glomerulata	0.66	8	15.7	0.1	19.9	4.2	6.65	2	3.9	0	0.0	0	0.0
Total Rhodophyta	28.36	50	98.0	0.5	95.1	28.9	27.68	38	74.5	23	45.1	12	23.5
Miscellaneous													
Algae Unidentifiable	0.02	1	2.0	1.2	1.2	1.2	-	0	0.0	0	0.0	0	0.0
Amphipod	0.01	2	3.9	0.3	0.4	0.3	0.04	0	0.0	0	0.0	0	0.0
Animal Flesh	0.12	5	9.8	0.1	2.3	1.2	1.00	0	0.0	0	0.0	0	0.0
Mollusk Eggs	0.12	5	9.8	0.3	3.8	1.2	1.50	0	0.0	0	0.0	0	0.0
Mollusk Egg Casing	1.01	5	9.8	0.7	31.2	10.3	12.08	3	5.9	1	2.0	0	0.0
Mollusk Fragments	0.19	5	9.8	0.2	4.2	1.9	1.62	0	0.0	0	0.0	0	0.0
Octocoral	0.10	1	2.0	5.1	5.1	5.1	-	1	2.0	0	0.0	0	0.0
Osteichthyes Scale	0.00	1	2.0	0.2	0.2	0.2	-	0	0.0	0	0.0	0	0.0
Physalia sp.	0.90	9	17.6	0.2	30.0	5.1	9.45	1	2.0	1	2.0	0	0.0
Polychaete WormTube	0.02	2	3.9	0.3	0.5	0.4	0.13	0	0.0	0	0.0	0	0.0
Porifera	0.01	1	2.0	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Sand	1.43	16	31.4	0.2	35.1	4.6	8.80	3	5.9	1	2.0	0	0.0
Sand-Rubble	0.01	2	3.9	0.2	0.2	0.2	0.01	0	0.0	0	0.0	0	0.0
Scyphozoa	1.58	2	3.9	1.8	78.8	40.3	54.43	1	2.0	1	2.0	1	2.0
Animal Matter Total	4.06	27	52.9	0.2	79.3	7.7	16.29	6	11.8	3	5.9	1	2.0
Total Miscellaneous	5.52	33	64.7	0.3	79.3	8.5	15.60	12	23.5	4	7.8	1	2.0

App. Table 6.8-Diet composition of green turtles captured within the study site, January 1988, Heron Reef, Queensland. Data are arranged in order of descending contribution to the pooled diet within each division. Means and ranges refer only to those lavage samples in which the species was present. Data include animals of all age classes and both sexes. When individuals were recaptured during the sampling session, only the data from the first capture were used in the calculations below. Generic names followed by "spp" represent values for all species of that genus. Data are based upon the volume contribution of the diet item. Data include turtles feeding in monogeneric stands and or algal turf. (n=51)

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Chlorophyta													
Codium spp.	6.94	18	35.3	0.2	90.1	19.7	25.55	10	19.6	4	7.8	2	3.9
Caulerpa spp.	3.59	17	33.3	0.2	50.4	10.8	13.73	8	15.7	2	3.9	1	2.0
Halimeda spp.	2.12	27	52.9	0.2	48.7	4.0	9.40	6	11.8	1	2.0	0	0.0
Enteromorpha sp.	2.09	3	5.9	0.2	68.6	35.5	34.29	2	3.9	2	3.9	1	2.0
Halimeda sp.	1.85	20	39.2	0.1	48.7	4.7	10.82	6	11.8	1	2.0	0	0.0
Caulerpa racemosa	1.77	4	7.8	0.7	50.4	22.5	20.75	3	5.9	1	2.0	1	2.0
Caulerpa cupressoides	1.52	8	15.7	0.2	27.7	9.7	9.72	4	7.8	1	2.0	0	0.0
Halimeda sp. #1	0.27	19	37.3	0.1	2.2	0.7	0.58	0	0.0	0	0.0	0	0.0
Dictyosphaeria sp.	0.25	9	17.6	0.2	3.9	1.4	1.24	0	0.0	0	0.0	0	0.0
Caulerpa sp.	0.17	6	11.8	0.5	3.0	1.5	0.86	0	0.0	0	0.0	0	0.0
Caulerpa nummularia	0.10	8	15.7	0.2	2.0	0.6	0.70	0	0.0	0	0.0	0	0.0
Chlorophyta Unknown	0.05	2	3.9	0.2	2.3	1.2	1.48	0	0.0	0	0.0	0	0.0
Valonia sp.	0.05	2	3.9	0.4	2.0	1.2	1.13	0	0.0	0	0.0	0	0.0
Cladophora sp.	0.04	3	5.9	0.2	1.6	0.8	0.74	0	0.0	0	0.0	0	0.0
Caulerpa lentillifera	0.02	2	3.9	0.4	0.6	0.5	0.14	0	0.0	0	0.0	0	0.0
Chlorodesmis fastigiata	0.01	2	3.9	0.1	0.2	0.2	0.01	0	0.0	0	0.0	0	0.0
Total Chlorophyta	15.13	39	76.5	0.2	90.1	19.8	24.13	22	43.1	10	19.6	7	13.7
Phaeophyta													
Turbinaria ornata	31.23	49	96.1	0.3	96.8	32.5	35.26	38	74.5	18	35.3	15	29.4
Lobophora variegata	10.26	44	86.3	0.3	57.4	11.9	13.60	28	54.9	8	15.7	1	2.0
Sargassum spp.	9.25	24	47.1	0.3	81.7	19.7	26.05	12	23.5	6	11.8	4	7.8
Padina sp.	0.20	2	3.9	3.3	6.9	5.1	2.55	1	2.0	0	0.0	0	0.0
Dictyota bartayressi	0.04	2	3.9	0.2	1.7	0.9	1.13	0	0.0	0	0.0	0	0.0
Phaeophyta Unknown	0.01	1	2.0	0.4	0.4	0.4	-	0	0.0	0	0.0	0	0.0
Total Phaeophyta	50.99	51	100.0	1.8	99.5	51.0	32.75	48	94.1	35	68.6	24	47.1
Rhodophyta													
Gelidiella spp.	12.49	37	72.5	0.1	89.9	17.2	22.08	20	39.2	10	19.6	3	5.9
Laurencia spp.	9.51	44	86.3	0.2	90.6	11.0	19.12	18	35.3	5	9.8	2	3.9
Gelidiella acerosa	8.38	20	39.2	0.2	89.9	21.4	26.83	12	23.5	6	11.8	3	5.9
Laurenciasp.	5.27	40	78.4	0.2	47.7	6.7	9.98	14	27.5	2	3.9	0	0.0
Laurencia intricata	4.11	7	13.7	0.2	90.6	30.0	38.34	4	7.8	3	5.9	2	3.9

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Gelidiella sp.	3.52	26	51.0	0.1	37.0	6.9	8.85	12	23.5	1	2.0	0	0.0
Hypnea spp.	1.42	19	37.3	0.2	22.3	3.8	6.61	4	7.8	0	0.0	0	0.0
Coelothrix Irregularis	1.18	11	21.6	0.3	18.8	5.5	5.39	4	7.8	0	0.0	0	0.0
Amphiroa spp.	0.78	9	17.6	0.3	18.0	4.4	5.81	2	3.9	0	0.0	0	0.0
Hypnea pannosa	0.77	11	21.6	0.3	18.0	3.6	5.96	2	3.9	0	0.0	0	0.0
Acanthophora specifera	0.74	5	9.8	0.3	33.9	7.6	14.74	1	2.0	1	2.0	0	0.0
Tolypiocladia glomerulata	0.66	8	15.7	0.1	19.9	4.2	6.65	2	3.9	0	0.0	0	0.0
Hypnea sp.	0.65	11	21.6	0.2	22.3	3.0	6.50	1	2.0	0	0.0	0	0.0
Gelidiella pannosa	0.59	1	2.0	30.3	30.3	30.3	-	1	2.0	1	2.0	0	0.0
Lomentaria corallicola	0.53	6	11.8	0.3	16.0	4.5	5.91	1	2.0	0	0.0	0	0.0
Chondria sp.	0.24	2	3.9	2.9	9.1	6.0	4.42	1	2.0	0	0.0	0	0.0
Champia parvula	0.21	24	47.1	0.2	1.3	0.5	0.33	0	0.0	0	0.0	0	0.0
Spyridia filamentosa	0.19	1	2.0	9.4	9.4	9.4	-	1	2.0	0	0.0	0	0.0
Galaxaura subfruticulosa	0.17	2	3.9	0.3	8.1	4.2	5.48	1	2.0	0	0.0	0	0.0
Polysiphonia spp.	0.12	1	2.0	6.2	6.2	6.2	-	1	2.0	0	0.0	0	0.0
Rhodophyta Unknown	0.09	11	21.6	0.1	0.8	0.4	0.24	0	0.0	0	0.0	0	0.0
Laurencia succisa	0.09	6	11.8	0.2	1.8	0.8	0.73	0	0.0	0	0.0	0	0.0
Laurencia parvipapillata	0.04	5	9.8	0.1	0.8	0.4	0.22	0	0.0	0	0.0	0	0.0
Centroceras sp.	0.02	2	3.9	0.3	0.8	0.6	0.34	0	0.0	0	0.0	0	0.0
Ceramium sp.	0.01	1	2.0	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Total Rhodophyta	28.36	50	98.0	0.5	95.1	28.9	27.68	38	74.5	23	45.1	12	23.5
Miscellaneous													
Animal Matter Total	4.06	27	52.9	0.2	79.3	7.7	16.29	6	11.8	3	5.9	1	2.0
Scyphozoa	1.58	2	3.9	1.8	78.8	40.3	54.43	1	2.0	1	2.0	1	2.0
Sand	1.43	16	31.4	0.2	35.1	4.6	8.80	3	5.9	1	2.0	0	0.0
Mollusk Egg Casing	1.01	5	9.8	0.7	31.2	10.3	12.08	3	5.9	1	2.0	0	0.0
Physalia sp.	0.90	9	17.6	0.2	30.0	5.1	9.45	1	2.0	1	2.0	0	0.0
Mollusk Fragments	0.19	5	9.8	0.2	4.2	1.9	1.62	0	0.0	0	0.0	0	0.0
Animal Flesh	0.12	5	9.8	0.1	2.3	1.2	1.00	0	0.0	0	0.0	0	0.0
Mollusk Eggs	0.12	5	9.8	0.3	3.8	1.2	1.50	0	0.0	0	0.0	0	0.0
Octocoral	0.10	1	2.0	5.1	5.1	5.1	-	1	2.0	0	0.0	0	0.0
Algae Unidentifiable	0.02	1	2.0	1.2	1.2	1.2	-	0	0.0	0	0.0	0	0.0
Polychaete WormTube	0.02	2	3.9	0.3	0.5	0.4	0.13	0	0.0	0	0.0	0	0.0
Amphipod	0.01	2	3.9	0.3	0.4	0.3	0.04	0	0.0	0	0.0	0	0.0
Sand-Rubble	0.01	2	3.9	0.2	0.2	0.2	0.01	0	0.0	0	0.0	0	0.0
Porifera	0.01	1	2.0	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Osteichthyes Scale	0.00	1	2.0	0.2	0.2	0.2	-	0	0.0	0	0.0	0	0.0
Total Miscellaneous	5.52	33	64.7	0.3	79.3	8.5	15.60	12	23.5	4	7.8	1	2.0

App. Table 6.9-Diet composition of green turtles captured within the study site, January 1988, Heron Reef, Queensland. Data are arranged by descending contribution to the pooled diet. Means and ranges refer only to those lavage samples in which the species was present. Data include animals of all age classes and both sexes. When individuals were recaptured during the sampling session, only the data from the first capture were used in the calculations below. Generic names followed by "spp" represent values for all species of that genus. Data are based upon the volume contribution of the diet item. Data include turtles feeding in monogeneric and or algal turf. (n=51)

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Total Phaeophyta	50.99	51	100.0	1.8	99.5	51.0	32.75	48	94.1	35	68.6	24	47.1
Turbinaria ornata	31.23	49	96.1	0.3	96.8	32.5	35.26	38	74.5	18	35.3	15	29.4
Total Rhodophyta	28.36	50	98.0	0.5	95.1	28.9	27.68	38	74.5	23	45.1	12	23.5
Total Chlorophyta	15.13	39	76.5	0.2	90.1	19.8	24.13	22	43.1	10	19.6	7	13.7
Gelidiella spp.	12.49	37	72.5	0.1	89.9	17.2	22.08	20	39.2	10	19.6	3	5.9
Lobophora variegata	10.26	44	86.3	0.3	57.4	11.9	13.60	28	54.9	8	15.7	1	2.0
Laurencia spp.	9.51	44	86.3	0.2	90.6	11.0	19.12	18	35.3	5	9.8	2	3.9
Sargassum spp.	9.25	24	47.1	0.3	81.7	19.7	26.05	12	23.5	6	11.8	4	7.8
Gelidiella acerosa	8.38	20	39.2	0.2	89.9	21.4	26.83	12	23.5	6	11.8	3	5.9
Codium spp.	6.94	18	35.3	0.2	90.1	19.7	25.55	10	19.6	4	7.8	2	3.9
Total Miscellaneous	5.52	33	64.7	0.3	79.3	8.5	15.60	12	23.5	4	7.8	1	2.0
Laurenciasp.	5.27	40	78.4	0.2	47.7	6.7	9.98	14	27.5	2	3.9	0	0.0
Laurencia intricata	4.11	7	13.7	0.2	90.6	30.0	38.34	4	7.8	3	5.9	2	3.9
Animal Matter Total	4.06	27	52.9	0.2	79.3	7.7	16.29	6	11.8	3	5.9	1	2.0
Caulerpa spp.	3.59	17	33.3	0.2	50.4	10.8	13.73	8	15.7	2	3.9	1	2.0
Gelidiella sp.	3.52	26	51.0	0.1	37.0	6.9	8.85	12	23.5	1	2.0	0	0.0
Halimeda spp.	2.12	27	52.9	0.2	48.7	4.0	9.40	6	11.8	1	2.0	0	0.0
Enteromorpha sp.	2.09	3	5.9	0.2	68.6	35.5	34.29	2	3.9	2	3.9	1	2.0
Halimeda sp.	1.85	20	39.2	0.1	48.7	4.7	10.82	6	11.8	1	2.0	0	0.0
Caulerpa racemosa	1.77	4	7.8	0.7	50.4	22.5	20.75	3	5.9	1	2.0	1	2.0
Scyphozoa	1.58	2	3.9	1.8	78.8	40.3	54.43	1	2.0	1	2.0	1	2.0
Caulerpa cupressoides	1.52	8	15.7	0.2	27.7	9.7	9.72	4	7.8	1	2.0	0	0.0
Sand	1.43	16	31.4	0.2	35.1	4.6	8.80	3	5.9	1	2.0	0	0.0
Hypnea spp.	1.42	19	37.3	0.2	22.3	3.8	6.61	4	7.8	0	0.0	0	0.0
Coelothrix irregularis	1.18	11	21.6	0.3	18.8	5.5	5.39	4	7.8	0	0.0	0	0.0
Mollusk Egg Casing	1.01	5	9.8	0.7	31.2	10.3	12.08	3	5.9	1	2.0	0	0.0
Physalia sp.	0.90	9	17.6	0.2	30.0	5.1	9.45	1	2.0	1	2.0	0	0.0
Amphiroa spp.	0.78	9	17.6	0.3	18.0	4.4	5.81	2	3.9	0	0.0	0	0.0
Hypnea pannosa	0.77	11	21.6	0.3	18.0	3.6	5.96	2	3.9	0	0.0	0	0.0
Acanthophora specifera	0.74	5	9.8	0.3	33.9	7.6	14.74	1	2.0	1	2.0	0	0.0
Tolypiocladia glomerulata	0.66	8	15.7	0.1	19.9	4.2	6.65	2	3.9	0	0.0	0	0.0
Hypnea sp.	0.65	11	21.6	0.2	22.3	3.0	6.50	1	2.0	0	0.0	0	0.0
Gelidiella pannosa	0.59	1	2.0	30.3	30.3	30.3	-	1	2.0	1	2.0	0	0.0
Lomentaria corallicola	0.53	6	11.8	0.3	16.0	4.5	5.91	1	2.0	0	0.0	0	0.0

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Halimeda sp. #1	0.27	19	37.3	0.1	2.2	0.7	0.58	0	0.0	0	0.0	0	0.0
Dictyosphaeria sp.	0.25	9	17.6	0.2	3.9	1.4	1.24	0	0.0	0	0.0	0	0.0
Chondria sp.	0.24	2	3.9	2.9	9.1	6.0	4.42	1	2.0	0	0.0	0	0.0
Champia parvula	0.21	24	47.1	0.2	1.3	0.5	0.33	0	0.0	0	0.0	0	0.0
Padina sp.	0.20	2	3.9	3.3	6.9	5.1	2.55	1	2.0	0	0.0	0	0.0
Mollusk Fragments	0.19	5	9.8	0.2	4.2	1.9	1.62	0	0.0	0	0.0	0	0.0
Spyridia filamentosa	0.19	1	2.0	9.4	9.4	9.4	-	1	2.0	0	0.0	0	0.0
Caulerpa sp.	0.17	6	11.8	0.5	3.0	1.5	0.86	0	0.0	0	0.0	0	0.0
Galaxaura subfruticulosa	0.17	2	3.9	0.3	8.1	4.2	5.48	1	2.0	0	0.0	0	0.0
Polysiphonia spp.	0.12	1	2.0	6.2	6.2	6.2	-	1	2.0	0	0.0	0	0.0
Animal Flesh	0.12	5	9.8	0.1	2.3	1.2	1.00	0	0.0	0	0.0	0	0.0
Mollusk Eggs	0.12	5	9.8	0.3	3.8	1.2	1.50	0	0.0	0	0.0	0	0.0
Caulerpa nummularia	0.10	8	15.7	0.2	2.0	0.6	0.70	0	0.0	0	0.0	0	0.0
Octocoral	0.10	1	2.0	5.1	5.1	5.1	-	1	2.0	0	0.0	0	0.0
Rhodophyta Unknown	0.09	11	21.6	0.1	0.8	0.4	0.24	0	0.0	0	0.0	0	0.0
Laurencia succisa	0.09	6	11.8	0.2	1.8	0.8	0.73	0	0.0	0	0.0	0	0.0
Chlorophyta Unknown	0.05	2	3.9	0.2	2.3	1.2	1.48	0	0.0	0	0.0	0	0.0
Valonia sp.	0.05	2	3.9	0.4	2.0	1.2	1.13	0	0.0	0	0.0	0	0.0
Cladophora sp.	0.04	3	5.9	0.2	1.6	0.8	0.74	0	0.0	0	0.0	0	0.0
Laurencia parvipapillata	0.04	5	9.8	0.1	0.8	0.4	0.22	0	0.0	0	0.0	0	0.0
Dictyota bartayressi	0.04	2	3.9	0.2	1.7	0.9	1.13	0	0.0	0	0.0	0	0.0
Algae Unidentifiable	0.02	1	2.0	1.2	1.2	1.2	-	0	0.0	0	0.0	0	0.0
Centroceras sp.	0.02	2	3.9	0.3	0.8	0.6	0.34	0	0.0	0	0.0	0	0.0
Caulerpa lentillifera	0.02	2	3.9	0.4	0.6	0.5	0.14	0	0.0	0	0.0	0	0.0
Polychaete WormTube	0.02	2	3.9	0.3	0.5	0.4	0.13	0	0.0	0	0.0	0	0.0
Amphipod	0.01	2	3.9	0.3	0.4	0.3	0.04	0	0.0	0	0.0	0	0.0
Phaeophyta Unknown	0.01	1	2.0	0.4	0.4	0.4	-	0	0.0	0	0.0	0	0.0
Sand-Rubble	0.01	2	3.9	0.2	0.2	0.2	0.01	0	0.0	0	0.0	0	0.0
Ceramium sp.	0.01	1	2.0	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Porifera	0.01	1	2.0	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Chlorodesmis fastigiata	0.01	2	3.9	0.1	0.2	0.2	0.01	0	0.0	0	0.0	0	0.0
Osteichthyes Scale	0.00	1	2.0	0.2	0.2	0.2	-	0	0.0	0	0.0	0	0.0

App. Table 6.10-Diet composition of green turtles captured within the study site, March 1989, Heron Reef, Queensland. Data are arranged alphabetically within each division. Means and ranges refer only to those lavage samples in which the species was present. Data include animals of all age classes and both sexes. When individuals were recaptured during the sampling session, only the data from the first capture were used in the calculations below. Generic names followed by "spp" represent values for all species of that genus. Data are based upon the volume contribution of the diet item. Data include turtles feeding in monogeneric stands and or algal turf. (n=63)

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Chlorophyta													
Caulerpa cupressoides	2.48	5	7.9	0.9	96.1	31.2	38.96	4	6.3	2	3.2	1	1.6
Caulerpa nummularia	0.52	12	19.0	0.1	16.5	2.7	4.47	1	1.6	0	0.0	0	0.0
Caulerpa racemosa	1.65	17	27.0	0.2	31.7	6.1	9.87	5	7.9	2	3.2	0	0.0
Caulerpa sertularioides	0.00	1	1.6	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Caulerpa webbiana	0.02	2	3.2	0.4	0.6	0.5	0.11	0	0.0	0	0.0	0	0.0
Caulerpa sp.	0.15	8	12.7	0.3	2.5	1.2	0.75	0	0.0	0	0.0	0	0.0
Caulerpa spp.	4.82	29	46.0	0.2	96.1	10.5	19.47	11	17.5	4	6.3	1	1.6
Chlorodesmis fastigiata	0.01	2	3.2	0.2	0.5	0.3	0.22	0	0.0	0	0.0	0	0.0
Codium spp.	15.08	22	34.9	0.3	98.8	43.2	36.05	15	23.8	13	20.6	10	15.9
Dictyosphaeria sp.	0.48	17	27.0	0.3	5.6	1.8	1.56	1	1.6	0	0.0	0	0.0
Halimeda cylindracea	0.04	1	1.6	2.2	2.2	2.2	-	0	0.0	0	0.0	0	0.0
Halimeda sp.	0.29	22	34.9	0.1	4.3	0.8	0.95	0	0.0	0	0.0	0	0.0
Halimeda sp. #1	0.19	16	25.4	0.1	3.0	0.8	0.69	0	0.0	0	0.0	0	0.0
Halimeda spp.	0.52	31	49.2	0.1	4.6	1.1	1.04	0	0.0	0	0.0	0	0.0
Total Chlorophyta	20.91	48	76.2	0.3	98.8	27.4	32.23	30	47.6	17	27.0	13	20.6
Phaeophyta													
Lobophora variegata	8.62	44	69.8	0.1	58.6	12.3	16.17	22	34.9	8	12.7	3	4.8
Sargassum spp.	1.51	30	47.6	0.1	20.6	3.2	4.19	5	7.9	0	0.0	0	0.0
Turbinaria ornata	19.65	43	68.3	0.1	99.7	28.8	34.10	27	42.9	17	27.0	10	15.9
Total Phaeophyta	29.78	54	85.7	0.1	100.0	34.7	31.54	43	68.3	29	46.0	15	23.8
Rhodophyta													
Amansia glomerata	0.06	2	3.2	0.6	3.3	2.0	1.93	0	0.0	0	0.0	0	0.0
Amphiroa spp.	0.03	5	7.9	0.2	0.6	0.4	0.20	0	0.0	0	0.0	0	0.0
Champia parvula	0.06	12	19.0	0.2	0.9	0.3	0.21	0	0.0	0	0.0	0	0.0
Chondrococcus hornemannii	0.00	1	1.6	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Coelothrix irregularis	2.37	32	50.8	0.1	20.4	4.7	5.46	13	20.6	0	0.0	0	0.0
Eucheuma denticulatum	0.08	3	4.8	0.3	3.1	1.6	1.42	0	0.0	0	0.0	0	0.0
Gelidiella acerosa	14.99	39	61.9	0.3	87.3	24.2	23.43	29	46.0	17	27.0	6	9.5
Gelidiella sp.	3.01	18	28.6	0.1	46.8	10.5	14.81	8	12.7	3	4.8	0	0.0
Gelidiella spp.	17.99	56	88.9	0.1	87.3	20.2	21.95	37	58.7	20	31.7	6	9.5
Hypnea pannosa	1.01	12	19.0	0.1	59.6	5.3	17.10	1	1.6	1	1.6	1	1.6
Hypnea spinella	0.64	1	1.6	40.3	40.3	40.3	-	1	1.6	1	1.6	0	0.0
Hypnea spp.	1.65	13	20.6	0.1	59.6	8.0	19.04	2	3.2	2	3.2	1	1.6
Hypoglossum spathulatum	0.00	1	1.6	0.2	0.2	0.2	-	0	0.0	0	0.0	0	0.0
Laurencia intricata	4.32	7	11.1	0.6	85.6	38.8	36.18	5	7.9	4	6.3	3	4.8
Laurencia parvipapillata	0.95	5	7.9	0.3	55.3	12.0	24.22	1	1.6	1	1.6	1	1.6
Laurencia sp.	19.08	52	82.5	0.1	90.3	23.1	27.36	31	49.2	19	30.2	11	17.5
Laurencia spp.	24.35	55	87.3	0.1	90.3	27.9	30.07	36	57.1	24	38.1	15	23.8
Polysiphonia spp.	0.01	3	4.8	0.2	0.5	0.3	0.18	0	0.0	0	0.0	0	0.0
Tolypiocladia glomerulata	0.74	5	7.9	0.2	45.1	9.3	19.48	1	1.6	1	1.6	0	0.0
Total Rhodophyta	47.36	62	98.4	0.3	98.7	48.1	35.35	52	82.5	40	63.5	31	49.2
Miscellaneous													
Amphipod	0.00	1	1.6	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Animal flesh	0.02	2	3.2	0.2	0.9	0.5	0.52	0	0.0	0	0.0	0	0.0
Foraminiferan	0.00	1	1.6	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Mollusk Eggs	1.52	1	1.6	95.5	95.5	95.5	-	1	1.6	1	1.6	1	1.6
Mollusk Egg Casing	0.23	2	3.2	1.8	13.0	7.4	7.93	1	1.6	0	0.0	0	0.0
Mollusk Fragments	0.05	4	6.3	0.2	1.6	0.8	0.62	0	0.0	0	0.0	0	0.0
Polychaete Worm Tube	0.00	1	1.6	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Sand-Rubble	0.11	11	17.5	0.1	3.4	0.7	0.96	0	0.0	0	0.0	0	0.0
Animal Matter Total	1.83	11	17.5	0.2	95.5	10.5	28.46	2	3.2	1	1.6	1	1.6
Total Micellaneous	1.94	21	33.3	0.1	95.5	5.8	20.75	2	3.2	1	1.6	1	1.6

App. Table 6.11-Diet composition of green turtles captured within the study site, March 1989, Heron Reef, Queensland. Data are arranged in order of descending contribution to the pooled diet. Means and ranges refer only to those lavage samples in which the species was present. Data include animals of all age classes and both sexes. When individuals were recaptured during the sampling session, only the data from the first capture were used in the calculations below. Generic names followed by "spp" represent values for all species of that genus. Data are based upon the volume contribution of the diet item. Data include turtles feeding in monogeneric stands and or algal turf. (n=63)

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Chlorophyta													
Codium spp.	15.08	22	34.9	0.3	98.8	43.2	36.05	15	23.8	13	20.6	10	15.9
Caulerpa spp.	4.82	29	46.0	0.2	96.1	10.5	19.47	11	17.5	4	6.3	1	1.6
Caulerpa cupressoides	2.48	5	7.9	0.9	96.1	31.2	38.96	4	6.3	2	3.2	1	1.6
Caulerpa racemosa	1.65	17	27.0	0.2	31.7	6.1	9.87	5	7.9	2	3.2	0	0.0
Caulerpa nummularia	0.52	12	19.0	0.1	16.5	2.7	4.47	1	1.6	0	0.0	0	0.0
Halimeda spp.	0.52	31	49.2	0.1	4.6	1.1	1.04	0	0.0	0	0.0	0	0.0
Dictyosphaeria sp.	0.48	17	27.0	0.3	5.6	1.8	1.56	1	1.6	0	0.0	0	0.0
Halimeda sp.	0.29	22	34.9	0.1	4.3	0.8	0.95	0	0.0	0	0.0	0	0.0
Halimeda sp. #1	0.19	16	25.4	0.1	3.0	0.8	0.69	0	0.0	0	0.0	0	0.0
Caulerpa sp.	0.15	8	12.7	0.3	2.5	1.2	0.75	0	0.0	0	0.0	0	0.0
Halimeda cylindracea	0.04	1	1.6	2.2	2.2	2.2	-	0	0.0	0	0.0	0	0.0
Caulerpa webbiana	0.02	2	3.2	0.4	0.6	0.5	0.11	0	0.0	0	0.0	0	0.0
Chlorodesmis fastigiata	0.01	2	3.2	0.2	0.5	0.3	0.22	0	0.0	0	0.0	0	0.0
Caulerpa sertularioides	0.00	1	1.6	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Total Chlorophyta	20.91	48	76.2	0.3	98.8	27.4	32.23	30	47.6	17	27.0	13	20.6
Phaeophyta													
Turbinaria ornata	19.65	43	68.3	0.1	99.7	28.8	34.10	27	42.9	17	27.0	10	15.9
Lobophora variegata	8.62	44	69.8	0.1	58.6	12.3	16.17	22	34.9	8	12.7	3	4.8
Sargassum spp.	1.51	30	47.6	0.1	20.6	3.2	4.19	5	7.9	0	0.0	0	0.0
Total Phaeophyta	29.78	54	85.7	0.1	100.0	34.7	31.54	43	68.3	29	46.0	15	23.8
Rhodophyta													
Laurencia spp.	24.35	55	87.3	0.1	90.3	27.9	30.07	36	57.1	24	38.1	15	23.8
Laurencia sp.	19.08	52	82.5	0.1	90.3	23.1	27.36	31	49.2	19	30.2	11	17.5
Gelidiella spp.	17.99	56	88.9	0.1	87.3	20.2	21.95	37	58.7	20	31.7	6	9.5
Gelidiella acerosa	14.99	39	61.9	0.3	87.3	24.2	23.43	29	46.0	17	27.0	6	9.5

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Laurencia intricata	4.32	7	11.1	0.6	85.6	38.8	36.18	5	7.9	4	6.3	3	4.8
Gelidiella sp.	3.01	18	28.6	0.1	46.8	10.5	14.81	8	12.7	3	4.8	0	0.0
Coelothrix irregularis	2.37	32	50.8	0.1	20.4	4.7	5.46	13	20.6	0	0.0	0	0.0
Hypnea spp.	1.65	13	20.6	0.1	59.6	8.0	19.04	2	3.2	2	3.2	1	1.6
Hypnea pannosa	1.01	12	19.0	0.1	59.6	5.3	17.10	1	1.6	1	1.6	1	1.6
Laurencia parvipapillata	0.95	5	7.9	0.3	55.3	12.0	24.22	1	1.6	1	1.6	1	1.6
Tolypiocladia glomerulata	0.74	5	7.9	0.2	45.1	9.3	19.48	1	1.6	1	1.6	0	0.0
Hypnea spinella	0.64	1	1.6	40.3	40.3	40.3	-	1	1.6	1	1.6	0	0.0
Eucheuma denticulatum	0.08	3	4.8	0.3	3.1	1.6	1.42	0	0.0	0	0.0	0	0.0
Champia parvula	0.06	12	19.0	0.2	0.9	0.3	0.21	0	0.0	0	0.0	0	0.0
Amansia glomerata	0.06	2	3.2	0.6	3.3	2.0	1.93	0	0.0	0	0.0	0	0.0
Amphiroa spp.	0.03	5	7.9	0.2	0.6	0.4	0.20	0	0.0	0	0.0	0	0.0
Polysiphonia spp.	0.01	3	4.8	0.2	0.5	0.3	0.18	0	0.0	0	0.0	0	0.0
Chondrococcus hornemannii	0.00	1	1.6	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Hypoglossum spathulatum	0.00	1	1.6	0.2	0.2	0.2	-	0	0.0	0	0.0	0	0.0
Total Rhodophyta	47.36	62	98.4	0.3	98.7	48.1	35.35	52	82.5	40	63.5	31	49.2
Miscellaneous													
Animal Matter Total	1.83	11	17.5	0.2	95.5	10.5	28.46	2	3.2	1	1.6	1	1.6
Mollusk Eggs	1.52	1	1.6	95.5	95.5	95.5	-	1	1.6	1	1.6	1	1.6
Mollusk Egg Casing	0.23	2	3.2	1.8	13.0	7.4	7.93	1	1.6	0	0.0	0	0.0
Sand-Rubble	0.11	11	17.5	0.1	3.4	0.7	0.96	0	0.0	0	0.0	0	0.0
Mollusk Fragments	0.05	4	6.3	0.2	1.6	0.8	0.62	0	0.0	0	0.0	0	0.0
Animal flesh	0.02	2	3.2	0.2	0.9	0.5	0.52	0	0.0	0	0.0	0	0.0
Foraminiferan	0.00	1	1.6	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Amphipod	0.00	1	1.6	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Polychaete Worm Tube	0.00	1	1.6	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Total Micellaneous	1.94	21	33.3	0.1	95.5	5.8	20.75	2	3.2	1	1.6	1	1.6

App. Table 6.12-Diet composition of green turtles captured within the study site, March 1989, Heron Reef, Queensland. Data are arranged by descending contribution to the pooled diet. Means and ranges refer only to those lavage samples in which the species was present. Data include animals of all age classes and both sexes. When individuals were recaptured during the sampling session, only the data from the first capture were used in the calculations below. Genus names followed by "spp" represent values for all species of that genus. Data are based upon the volume contribution of the diet item. Data include turtles feeding in monogeneric stands and or algal turf. (n=63)

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Total Rhodophyta	47.36	62	98.4	0.3	98.7	48.1	35.35	52	82.5	40	63.5	31	49.2
Total Phaeophyta	29.78	54	85.7	0.1	100.0	34.7	31.54	43	68.3	29	46.0	15	23.8
Laurencia spp.	24.35	55	87.3	0.1	90.3	27.9	30.07	36	57.1	24	38.1	15	23.8
Total Chlorophyta	20.91	48	76.2	0.3	98.8	27.4	32.23	30	47.6	17	27.0	13	20.6
Turbinaria ornata	19.65	43	68.3	0.1	99.7	28.8	34.10	27	42.9	17	27.0	10	15.9
Laurencia sp.	19.08	52	82.5	0.1	90.3	23.1	27.36	31	49.2	19	30.2	11	17.5
Gelidiella spp.	17.99	56	88.9	0.1	87.3	20.2	21.95	37	58.7	20	31.7	6	9.5
Codium spp.	15.08	22	34.9	0.3	98.8	43.2	36.05	15	23.8	13	20.6	10	15.9
Gelidiella acerosa	14.99	39	61.9	0.3	87.3	24.2	23.43	29	46.0	17	27.0	6	9.5
Lobophora variegata	8.62	44	69.8	0.1	58.6	12.3	16.17	22	34.9	8	12.7	3	4.8
Caulerpa spp.	4.82	29	46.0	0.2	96.1	10.5	19.47	11	17.5	4	6.3	1	1.6
Laurencia intricata	4.32	7	11.1	0.6	85.6	38.8	36.18	5	7.9	4	6.3	3	4.8
Gelidiella sp.	3.01	18	28.6	0.1	46.8	10.5	14.81	8	12.7	3	4.8	0	0.0
Caulerpa cupressoides	2.48	5	7.9	0.9	96.1	31.2	38.96	4	6.3	2	3.2	1	1.6
Coelothrix irregularis	2.37	32	50.8	0.1	20.4	4.7	5.46	13	20.6	0	0.0	0	0.0
Total Micellaneous	1.94	21	33.3	0.1	95.5	5.8	20.75	2	3.2	1	1.6	1	1.6
Animal Matter Total	1.83	11	17.5	0.2	95.5	10.5	28.46	2	3.2	1	1.6	1	1.6
Caulerpa racemosa	1.65	17	27.0	0.2	31.7	6.1	9.87	5	7.9	2	3.2	0	0.0
Hypnea spp.	1.65	13	20.6	0.1	59.6	8.0	19.04	2	3.2	2	3.2	1	1.6
Mollusk Eggs	1.52	1	1.6	95.5	95.5	95.5	-	1	1.6	1	1.6	1	1.6
Sargassum spp.	1.51	30	47.6	0.1	20.6	3.2	4.19	5	7.9	0	0.0	0	0.0
Hypnea pannosa	1.01	12	19.0	0.1	59.6	5.3	17.10	1	1.6	1	1.6	1	1.6
Laurencia parvipapillata	0.95	5	7.9	0.3	55.3	12.0	24.22	1	1.6	1	1.6	1	1.6
Tolypiocladia glomerulata	0.74	5	7.9	0.2	45.1	9.3	19.48	1	1.6	1	1.6	0	0.0
Hypnea spinella	0.64	1	1.6	40.3	40.3	40.3	-	1	1.6	1	1.6	0	0.0
Caulerpa nummularia	0.52	12	19.0	0.1	16.5	2.7	4.47	1	1.6	0	0.0	0	0.0
Halimeda spp.	0.52	31	49.2	0.1	4.6	1.1	1.04	0	0.0	0	0.0	0	0.0
Dictyosphaeria sp.	0.48	17	27.0	0.3	5.6	1.8	1.56	1	1.6	0	0.0	0	0.0

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Halimeda sp.	0.29	22	34.9	0.1	4.3	0.8	0.95	0	0.0	0	0.0	0	0.0
Mollusk Egg Casing	0.23	2	3.2	1.8	13.0	7.4	7.93	1	1.6	0	0.0	0	0.0
Halimeda sp. #1	0.19	16	25.4	0.1	3.0	0.8	0.69	0	0.0	0	0.0	0	0.0
Caulerpa sp.	0.15	8	12.7	0.3	2.5	1.2	0.75	0	0.0	0	0.0	0	0.0
Sand-Rubble	0.11	11	17.5	0.1	3.4	0.7	0.96	0	0.0	0	0.0	0	0.0
Eucheuma denticulatum	0.08	3	4.8	0.3	3.1	1.6	1.42	0	0.0	0	0.0	0	0.0
Champia parvula	0.06	12	19.0	0.2	0.9	0.3	0.21	0	0.0	0	0.0	0	0.0
Amansia glomerata	0.06	2	3.2	0.6	3.3	2.0	1.93	0	0.0	0	0.0	0	0.0
Mollusk Fragments	0.05	4	6.3	0.2	1.6	0.8	0.62	0	0.0	0	0.0	0	0.0
Halimeda cylindracea	0.04	1	1.6	2.2	2.2	2.2	-	0	0.0	0	0.0	0	0.0
Amphiroa spp.	0.03	5	7.9	0.2	0.6	0.4	0.20	0	0.0	0	0.0	0	0.0
Animal flesh	0.02	2	3.2	0.2	0.9	0.5	0.52	0	0.0	0	0.0	0	0.0
Caulerpa webbiana	0.02	2	3.2	0.4	0.6	0.5	0.11	0	0.0	0	0.0	0	0.0
Polysiphonia spp.	0.01	3	4.8	0.2	0.5	0.3	0.18	0	0.0	0	0.0	0	0.0
Chlorodesmis fastigiata	0.01	2	3.2	0.2	0.5	0.3	0.22	0	0.0	0	0.0	0	0.0
Chondrococcus hornemannii	0.00	1	1.6	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Foraminiferan	0.00	1	1.6	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Amphipod	0.00	1	1.6	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Polychaete Worm Tube	0.00	1	1.6	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Caulerpa sertularioides	0.00	1	1.6	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Hypoglossum spathulatum	0.00	1	1.6	0.2	0.2	0.2	-	0	0.0	0	0.0	0	0.0

App. Table 6.13-Diet composition of green turtles captured within the study site, May 1989, Heron Reef, Queensland. Data are arranged alphabetically within each division. Means and ranges refer only to those lavage samples in which the species was present. Data include animals of all age classes and both sexes. When individuals were recaptured during the sampling session, only the data from the first capture were used in the calculations below. Generic names followed by "spp" represent values for all species of that genus. Data are based upon the volume contribution of the diet item. Data include turtles feeding in monogeneric stands and or algal turf. (n=51)

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Chlorophyta													
Caulerpa brachypus	0.01	1	2.0	0.6	0.6	0.6	-	0	0.0	0	0.0	0	0.0
Caulerpa cupressoides	2.27	17	33.3	0.1	43.7	6.8	11.73	5	9.8	2	3.9	0	0.0
Caulerpa lentillifera	0.20	3	5.9	0.2	4.9	3.3	2.75	0	0.0	0	0.0	0	0.0
Caulerpa nummularia	0.06	3	5.9	0.3	1.9	0.9	0.83	0	0.0	0	0.0	0	0.0
Caulerpa racemosa	1.38	8	15.7	0.2	27.4	8.8	11.69	3	5.9	2	3.9	0	0.0
Caulerpa sp.	0.01	2	3.9	0.1	0.2	0.2	0.01	0	0.0	0	0.0	0	0.0
Caulerpa spp.	3.92	29	56.9	0.1	43.7	6.9	10.80	8	15.7	4	7.8	0	0.0
Cladophora spp.	0.03	1	2.0	1.5	1.5	1.5	-	0	0.0	0	0.0	0	0.0
Chlorodesmis fastigiata	0.56	3	5.9	0.9	23.9	9.6	12.49	1	2.0	0	0.0	0	0.0
Chlorophyta Unknown	0.18	7	13.7	0.1	6.3	1.3	2.21	1	2.0	0	0.0	0	0.0
Codium spp.	4.39	10	19.6	4.5	84.7	22.4	23.83	9	17.6	3	5.9	1	2.0
Enteromorpha spp.	0.36	4	7.8	0.3	12.0	4.7	5.27	1	2.0	0	0.0	0	0.0
Halimeda sp.	0.04	5	9.8	0.1	0.6	0.4	0.18	0	0.0	0	0.0	0	0.0
Halimeda sp. #1	0.08	9	17.6	0.2	1.2	0.5	0.32	0	0.0	0	0.0	0	0.0
Halimeda spp.	0.12	13	25.5	0.2	1.2	0.5	0.28	0	0.0	0	0.0	0	0.0
Total Chlorophyta	9.57	40	78.4	0.1	86.2	12.2	17.80	17	33.3	7	13.7	2	3.9
Phaeophyta													
Lobophora variegata	3.93	37	72.5	0.1	48.2	5.4	9.18	12	23.5	1	2.0	0	0.0
Phaeophyta Unknown	0.01	2	3.9	0.3	0.3	0.3	0.01	0	0.0	0	0.0	0	0.0
Sargassum spp.	0.59	3	5.9	0.1	27.7	10.0	15.34	1	2.0	1	2.0	0	0.0
Turbinaria ornata	41.83	47	92.2	0.1	99.4	45.4	32.69	43	84.3	30	58.8	21	41.2
Total Phaeophyta	46.37	47	92.2	0.6	99.7	50.3	32.25	43	84.3	34	66.7	23	45.1
Rhodophyta													
Centroceras apiculatum	0.01	1	2.0	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Champia parvula	0.02	4	7.8	0.2	0.6	0.3	0.21	0	0.0	0	0.0	0	0.0
Champia sp.	0.00	1	2.0	0.2	0.2	0.2	-	0	0.0	0	0.0	0	0.0
Champia spp.	0.03	5	9.8	0.2	0.6	0.3	0.19	0	0.0	0	0.0	0	0.0
Chondria minutula	0.81	6	11.8	0.2	17.6	6.8	8.32	2	3.9	0	0.0	0	0.0

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Chondria sp.	0.02	3	5.9	0.2	0.9	0.4	0.43	0	0.0	0	0.0	0	0.0
Chondria spp.	0.83	9	17.6	0.2	17.6	4.7	7.33	2	3.9	0	0.0	0	0.0
Galaxaura subfruticulosa	0.16	2	3.9	0.5	7.7	4.1	5.11	1	2.0	0	0.0	0	0.0
Gelidiella acerosa	3.70	18	35.3	0.1	45.7	10.5	14.01	8	15.7	3	5.9	0	0.0
Gelidiella pannosa	0.04	3	5.9	0.2	1.2	0.6	0.53	0	0.0	0	0.0	0	0.0
Gelidiella sp.	0.41	16	31.4	0.1	5.5	1.3	1.82	2	3.9	0	0.0	0	0.0
Gelidiella spp.	4.14	27	52.9	0.1	45.7	7.8	12.55	9	17.6	3	5.9	0	0.0
Hypnea pannosa	0.24	15	29.4	0.2	4.5	0.8	1.15	0	0.0	0	0.0	0	0.0
Hypnea spinella	0.00	1	2.0	0.2	0.2	0.2	-	0	0.0	0	0.0	0	0.0
Hypnea sp.	1.77	17	33.3	0.1	27.8	5.3	8.52	4	7.8	1	2.0	0	0.0
Hypnea spp.	2.02	27	52.9	0.1	27.8	3.8	7.02	4	7.8	1	2.0	0	0.0
Laurencia intricata	2.88	8	15.7	2.4	44.4	18.3	14.99	6	11.8	3	5.9	0	0.0
Laurencia sp.	4.48	27	52.9	0.1	91.5	8.5	21.72	4	7.8	3	5.9	3	5.9
Laurencia spp.	7.36	32	62.7	0.1	91.5	11.7	21.37	10	19.6	6	11.8	3	5.9
Polysiphonia infestans	26.50	27	52.9	2.4	97.8	50.1	27.79	25	49.0	21	41.2	13	25.5
Polysiphonia sp.	0.24	2	3.9	1.1	11.1	6.1	7.08	1	2.0	0	0.0	0	0.0
Polysiphonia spp.	26.74	28	54.9	2.4	97.8	48.7	28.21	26	51.0	21	41.2	13	25.5
Rhodophyta Unknown	0.11	4	7.8	0.2	4.2	1.4	1.88	0	0.0	0	0.0	0	0.0
Tolypiocladia glomerulata	0.05	7	13.7	0.1	0.8	0.4	0.23	0	0.0	0	0.0	0	0.0
Total Rhodophyta	41.44	49	96.1	0.1	99.0	43.1	34.49	39	76.5	29	56.9	22	43.1
Miscellaneous													
Animal flesh	1.19	9	17.6	0.2	51.9	6.8	16.96	1	2.0	1	2.0	1	2.0
Arthropod fragments	0.00	1	2.0	0.1	0.1	0.1	-	0	0.0	0	0.0	0	0.0
Halophila decipiens	0.06	1	2.0	3.1	3.1	3.1	-	0	0.0	0	0.0	0	0.0
Halophila ovalis	0.33	3	5.9	0.3	15.2	5.6	8.37	1	2.0	0	0.0	0	0.0
Halophila spp.	0.39	3	5.9	0.3	18.3	6.6	10.14	1	2.0	0	0.0	0	0.0
Mollusk Fragments	0.16	15	29.4	0.1	3.3	0.6	0.79	0	0.0	0	0.0	0	0.0
Octocoral	0.16	1	2.0	8.2	8.2	8.2	-	1	2.0	0	0.0	0	0.0
Polychaete Worm Tube	0.64	21	41.2	0.1	9.2	1.5	1.91	1	2.0	0	0.0	0	0.0
Sand	0.08	13	25.5	0.1	0.9	0.3	0.22	0	0.0	0	0.0	0	0.0
Animal Matter Total	2.16	34	66.7	0.1	51.9	3.2	8.84	3	5.9	1	2.0	1	2.0
Total Miscellaneous	2.62	37	72.5	0.1	51.9	3.6	8.83	4	7.8	1	2.0	1	2.0

App. Table 6.14-Diet composition of green turtles captured within the study site, May 1989, Heron Reef, Queensland. Data are arranged in order of descending contribution to the pooled diet within each division. Means and ranges refer only to those lavage samples in which the species was present. Data include animals of all age classes and both sexes. When individuals were recaptured during the sampling session, only the data from the first capture were used in the calculations Generic names followed by "spp" represent values for all species of that genus. Data are based upon the volume contribution of the diet item. Data include turtles feeding in monogeneric stands and or algal turf. (n=51)

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Chlorophyta													
Codium spp.	4.39	10	19.6	4.5	84.7	22.4	23.83	9	17.6	3	5.9	1	2.0
Caulerpa spp.	3.92	29	56.9	0.1	43.7	6.9	10.80	8	15.7	4	7.8	0	0.0
Caulerpa cupressoides	2.27	17	33.3	0.1	43.7	6.8	11.73	5	9.8	2	3.9	0	0.0
Caulerpa racemosa	1.38	8	15.7	0.2	27.4	8.8	11.69	3	5.9	2	3.9	0	0.0
Chlorodesmis fastigiata	0.56	3	5.9	0.9	23.9	9.6	12.49	1	2.0	0	0.0	0	0.0
Enteromorpha spp.	0.36	4	7.8	0.3	12.0	4.7	5.27	1	2.0	0	0.0	0	0.0
Caulerpa lentillifera	0.20	3	5.9	0.2	4.9	3.3	2.75	0	0.0	0	0.0	0	0.0
Chlorophyta Unknown	0.18	7	13.7	0.1	6.3	1.3	2.21	1	2.0	0	0.0	0	0.0
Halimeda spp.	0.12	13	25.5	0.2	1.2	0.5	0.28	0	0.0	0	0.0	0	0.0
Halimeda sp. #1	0.08	9	17.6	0.2	1.2	0.5	0.32	0	0.0	0	0.0	0	0.0
Caulerpa nummularia	0.06	3	5.9	0.3	1.9	0.9	0.83	0	0.0	0	0.0	0	0.0
Halimeda sp.	0.04	5	9.8	0.1	0.6	0.4	0.18	0	0.0	0	0.0	0	0.0
Cladophora spp.	0.03	1	2.0	1.5	1.5	1.5	-	0	0.0	0	0.0	0	0.0
Caulerpa brachypus	0.01	1	2.0	0.6	0.6	0.6	-	0	0.0	0	0.0	0	0.0
Caulerpa sp.	0.01	2	3.9	0.1	0.2	0.2	0.01	0	0.0	0	0.0	0	0.0
Total Chlorophyta	9.57	40	78.4	0.1	86.2	12.2	17.80	17	33.3	7	13.7	2	3.9
Phaeophyta													
Turbinaria ornata	41.83	47	92.2	0.1	99.4	45.4	32.69	43	84.3	30	58.8	21	41.2
Lobophora variegata	3.93	37	72.5	0.1	48.2	5.4	9.18	12	23.5	1	2.0	0	0.0
Sargassum spp.	0.59	3	5.9	0.1	27.7	10.0	15.34	1	2.0	1	2.0	0	0.0
Phaeophyta Unknown	0.01	2	3.9	0.3	0.3	0.3	0.01	0	0.0	0	0.0	0	0.0
Total Phaeophyta	46.37	47	92.2	0.6	99.7	50.3	32.25	43	84.3	34	66.7	23	45.1
Rhodophyta													
Polysiphonia spp.	26.74	28	54.9	2.4	97.8	48.7	28.21	26	51.0	21	41.2	13	25.5
Polysiphonia infestans	26.50	27	52.9	2.4	97.8	50.1	27.79	25	49.0	21	41.2	13	25.5
Laurencia spp.	7.36	32	62.7	0.1	91.5	11.7	21.37	10	19.6	6	11.8	3	5.9
Laurencia sp.	4.48	27	52.9	0.1	91.5	8.5	21.72	4	7.8	3	5.9	3	5.9
Gelidiella spp.	4.14	27	52.9	0.1	45.7	7.8	12.55	9	17.6	3	5.9	0	0.0

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Gelidiella acerosa	3.70	18	35.3	0.1	45.7	10.5	14.01	8	15.7	3	5.9	0	0.0
Laurencia intricata	2.88	8	15.7	2.4	44.4	18.3	14.99	6	11.8	3	5.9	0	0.0
Hypnea spp.	2.02	27	52.9	0.1	27.8	3.8	7.02	4	7.8	1	2.0	0	0.0
Hypnea sp.	1.77	17	33.3	0.1	27.8	5.3	8.52	4	7.8	1	2.0	0	0.0
Chondria spp.	0.83	9	17.6	0.2	17.6	4.7	7.33	2	3.9	0	0.0	0	0.0
Chondria minutula	0.81	6	11.8	0.2	17.6	6.8	8.32	2	3.9	0	0.0	0	0.0
Gelidiella sp.	0.41	16	31.4	0.1	5.5	1.3	1.82	2	3.9	0	0.0	0	0.0
Hypnea pannosa	0.24	15	29.4	0.2	4.5	0.8	1.15	0	0.0	0	0.0	0	0.0
Polysiphonia sp.	0.24	2	3.9	1.1	11.1	6.1	7.08	1	2.0	0	0.0	0	0.0
Galaxaura subfruticulosa	0.16	2	3.9	0.5	7.7	4.1	5.11	1	2.0	0	0.0	0	0.0
Rhodophyta Unknown	0.11	4	7.8	0.2	4.2	1.4	1.88	0	0.0	0	0.0	0	0.0
Tolypiocladia glomerulata	0.05	7	13.7	0.1	0.8	0.4	0.23	0	0.0	0	0.0	0	0.0
Gelidiella pannosa	0.04	3	5.9	0.2	1.2	0.6	0.53	0	0.0	0	0.0	0	0.0
Champia spp.	0.03	5	9.8	0.2	0.6	0.3	0.19	0	0.0	0	0.0	0	0.0
Champia parvula	0.02	4	7.8	0.2	0.6	0.3	0.21	0	0.0	0	0.0	0	0.0
Chondria sp.	0.02	3	5.9	0.2	0.9	0.4	0.43	0	0.0	0	0.0	0	0.0
Centroceras apiculatum	0.01	1	2.0	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Hypnea spinella	0.00	1	2.0	0.2	0.2	0.2	-	0	0.0	0	0.0	0	0.0
Champia sp.	0.00	1	2.0	0.2	0.2	0.2	-	0	0.0	0	0.0	0	0.0
Total Rhodophyta	41.44	49	96.1	0.1	99.0	43.1	34.49	39	76.5	29	56.9	22	43.1
Miscellaneous													
Animal Matter Total	2.16	34	66.7	0.1	51.9	3.2	8.84	3	5.9	1	2.0	1	2.0
Animal flesh	1.19	9	17.6	0.2	51.9	6.8	16.96	1	2.0	1	2.0	1	2.0
Polychaete Worm Tube	0.64	21	41.2	0.1	9.2	1.5	1.91	1	2.0	0	0.0	0	0.0
Halophila spp.	0.39	3	5.9	0.3	18.3	6.6	10.14	1	2.0	0	0.0	0	0.0
Halophila ovalis	0.33	3	5.9	0.3	15.2	5.6	8.37	1	2.0	0	0.0	0	0.0
Mollusk Fragments	0.16	15	29.4	0.1	3.3	0.6	0.79	0	0.0	0	0.0	0	0.0
Octocoral	0.16	1	2.0	8.2	8.2	8.2	-	1	2.0	0	0.0	0	0.0
Sand	0.08	13	25.5	0.1	0.9	0.3	0.22	0	0.0	0	0.0	0	0.0
Halophila decipiens	0.06	1	2.0	3.1	3.1	3.1	-	0	0.0	0	0.0	0	0.0
Arthropod fragments	0.00	1	2.0	0.1	0.1	0.1	-	0	0.0	0	0.0	0	0.0
Total Miscellaneous	2.62	37	72.5	0.1	51.9	3.6	8.83	4	7.8	1	2.0	1	2.0

App. Table 6.15-Diet composition of green turtles captured within the study site, May 1989, Heron Reef, Queensland. Data are arranged by descending contribution to the pooled diet. Means and ranges refer only to those lavage samples in which the species was present. Data include animals of all age classes and both sexes. When individuals were recaptured during the sampling session, only the data from the first capture were used in the calculations below. Generic names followed by "spp" represent values for all species of that genus. Data are based upon the volume contribution of the diet item. Data include turtles feeding in monogeneric stands and or algal turf. (n=51)

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Total Phaeophyta	46.37	47	92.2	0.6	99.7	50.3	32.25	43	84.3	34	66.7	23	45.1
Turbinaria ornata	41.83	47	92.2	0.1	99.4	45.4	32.69	43	84.3	30	58.8	21	41.2
Total Rhodophyta	41.44	49	96.1	0.1	99.0	43.1	34.49	39	76.5	29	56.9	22	43.1
Polysiphonia spp.	26.74	28	54.9	2.4	97.8	48.7	28.21	26	51.0	21	41.2	13	25.5
Polysiphonia infestans	26.50	27	52.9	2.4	97.8	50.1	27.79	25	49.0	21	41.2	13	25.5
Total Chlorophyta	9.57	40	78.4	0.1	86.2	12.2	17.80	17	33.3	7	13.7	2	3.9
Laurencia spp.	7.36	32	62.7	0.1	91.5	11.7	21.37	10	19.6	6	11.8	3	5.9
Laurencia sp.	4.48	27	52.9	0.1	91.5	8.5	21.72	4	7.8	3	5.9	3	5.9
Codium spp.	4.39	10	19.6	4.5	84.7	22.4	23.83	9	17.6	3	5.9	1	2.0
Gelidiella spp.	4.14	27	52.9	0.1	45.7	7.8	12.55	9	17.6	3	5.9	0	0.0
Lobophora variegata	3.93	37	72.5	0.1	48.2	5.4	9.18	12	23.5	1	2.0	0	0.0
Caulerpa spp.	3.92	29	56.9	0.1	43.7	6.9	10.80	8	15.7	4	7.8	0	0.0
Gelidiella acerosa	3.70	18	35.3	0.1	45.7	10.5	14.01	8	15.7	3	5.9	0	0.0
Laurencia intricata	2.88	8	15.7	2.4	44.4	18.3	14.99	6	11.8	3	5.9	0	0.0
Total Miscellaneous	2.62	37	72.5	0.1	51.9	3.6	8.83	4	7.8	1	2.0	1	2.0
Caulerpa cupressoides	2.27	17	33.3	0.1	43.7	6.8	11.73	5	9.8	2	3.9	0	0.0
Animal Matter Total	2.16	34	66.7	0.1	51.9	3.2	8.84	3	5.9	1	2.0	1	2.0
Hypnea spp.	2.02	27	52.9	0.1	27.8	3.8	7.02	4	7.8	1	2.0	0	0.0
Hypnea sp.	1.77	17	33.3	0.1	27.8	5.3	8.52	4	7.8	1	2.0	0	0.0
Caulerpa racemosa	1.38	8	15.7	0.2	27.4	8.8	11.69	3	5.9	2	3.9	0	0.0
Animal flesh	1.19	9	17.6	0.2	51.9	6.8	16.96	1	2.0	1	2.0	1	2.0
Chondria spp.	0.83	9	17.6	0.2	17.6	4.7	7.33	2	3.9	0	0.0	0	0.0
Chondria minutula	0.81	6	11.8	0.2	17.6	6.8	8.32	2	3.9	0	0.0	0	0.0
Polychaete Worm Tube	0.64	21	41.2	0.1	9.2	1.5	1.91	1	2.0	0	0.0	0	0.0
Sargassum spp.	0.59	3	5.9	0.1	27.7	10.0	15.34	1	2.0	1	2.0	0	0.0
Chlorodesmis fastigiata	0.56	3	5.9	0.9	23.9	9.6	12.49	1	2.0	0	0.0	0	0.0
Gelidiella sp.	0.41	16	31.4	0.1	5.5	1.3	1.82	2	3.9	0	0.0	0	0.0
Halophila spp.	0.39	3	5.9	0.3	18.3	6.6	10.14	1	2.0	0	0.0	0	0.0
Enteromorpha spp.	0.36	4	7.8	0.3	12.0	4.7	5.27	1	2.0	0	0.0	0	0.0
Halophila ovalis	0.33	3	5.9	0.3	15.2	5.6	8.37	1	2.0	0	0.0	0	0.0
Hypnea pannosa	0.24	15	29.4	0.2	4.5	0.8	1.15	0	0.0	0	0.0	0	0.0

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Polysiphonia sp.	0.24	2	3.9	1.1	11.1	6.1	7.08	1	2.0	0	0.0	0	0.0
Caulerpa lentillifera	0.20	3	5.9	0.2	4.9	3.3	2.75	0	0.0	0	0.0	0	0.0
Chlorophyta Unknown	0.18	7	13.7	0.1	6.3	1.3	2.21	1	2.0	0	0.0	0	0.0
Mollusk Fragments	0.16	15	29.4	0.1	3.3	0.6	0.79	0	0.0	0	0.0	0	0.0
Octocoral	0.16	1	2.0	8.2	8.2	8.2	-	1	2.0	0	0.0	0	0.0
Galaxaura subfruticulosa	0.16	2	3.9	0.5	7.7	4.1	5.11	1	2.0	0	0.0	0	0.0
Halimeda spp.	0.12	13	25.5	0.2	1.2	0.5	0.28	0	0.0	0	0.0	0	0.0
Rhodophyta Unknown	0.11	4	7.8	0.2	4.2	1.4	1.88	0	0.0	0	0.0	0	0.0
Halimeda sp. #1	0.08	9	17.6	0.2	1.2	0.5	0.32	0	0.0	0	0.0	0	0.0
Sand	0.08	13	25.5	0.1	0.9	0.3	0.22	0	0.0	0	0.0	0	0.0
Halophila decipiens	0.06	1	2.0	3.1	3.1	3.1	-	0	0.0	0	0.0	0	0.0
Caulerpa nummularia	0.06	3	5.9	0.3	1.9	0.9	0.83	0	0.0	0	0.0	0	0.0
Tolypiocladia glomerulata	0.05	7	13.7	0.1	0.8	0.4	0.23	0	0.0	0	0.0	0	0.0
Halimeda sp.	0.04	5	9.8	0.1	0.6	0.4	0.18	0	0.0	0	0.0	0	0.0
Gelidiella pannosa	0.04	3	5.9	0.2	1.2	0.6	0.53	0	0.0	0	0.0	0	0.0
Cladophora spp.	0.03	1	2.0	1.5	1.5	1.5	-	0	0.0	0	0.0	0	0.0
Champia spp.	0.03	5	9.8	0.2	0.6	0.3	0.19	0	0.0	0	0.0	0	0.0
Champia parvula	0.02	4	7.8	0.2	0.6	0.3	0.21	0	0.0	0	0.0	0	0.0
Chondria sp.	0.02	3	5.9	0.2	0.9	0.4	0.43	0	0.0	0	0.0	0	0.0
Phaeophyta Unknown	0.01	2	3.9	0.3	0.3	0.3	0.01	0	0.0	0	0.0	0	0.0
Caulerpa brachypus	0.01	1	2.0	0.6	0.6	0.6	-	0	0.0	0	0.0	0	0.0
Centroceras apiculatum	0.01	1	2.0	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Caulerpa sp.	0.01	2	3.9	0.1	0.2	0.2	0.01	0	0.0	0	0.0	0	0.0
Hypnea spinella	0.00	1	2.0	0.2	0.2	0.2	-	0	0.0	0	0.0	0	0.0
Champia sp.	0.00	1	2.0	0.2	0.2	0.2	-	0	0.0	0	0.0	0	0.0
Arthropod fragments	0.00	1	2.0	0.1	0.1	0.1	-	0	0.0	0	0.0	0	0.0

App. Table 6.16-Diet composition of green turtles captured within the study site, July 1989, Heron Reef, Queensland. Data are arranged alphabetically within in the division. Means and ranges refer only to those lavage samples in which the species was present. Data include animals of all age classes and both sexes. When individuals were recaptured during the sampling session, only the data from the first capture were used in the calculations below. Generic names followed by "spp" represent values for all species of that genus. Data are based upon the volume contribution of the diet item. Data include turtles feeding in monogeneric stands and or algal turf. (n=67)

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Chlorophyta													
Caulerpa sertularioides	0.03	2	3.0	0.3	1.5	0.9	0.84	0	0.0	0	0.0	0	0.0
Chlorodesmis fastigiata	1.04	4	6.0	0.1	43.8	17.4	21.23	2	3.0	2	3.0	0	0.0
Enteromorpha spp.	79.65	65	97.0	34.5	100.0	82.1	17.47	65	97.0	65	97.0	59	88.1
Halimeda sp.	0.01	2	3.0	0.1	0.3	0.2	0.10	0	0.0	0	0.0	0	0.0
Halimeda sp. #1	0.03	1	1.5	2.0	2.0	2.0	-	0	0.0	0	0.0	0	0.0
Halimeda spp.	0.04	3	4.5	0.1	2.0	0.8	1.00	0	0.0	0	0.0	0	0.0
Total Chlorophyta	80.76	67	100.0	2.0	100.0	80.8	19.64	66	98.5	66	98.5	60	89.6
Phaeophyta													
Dictyota bartayressi	0.02	3	4.5	0.1	0.6	0.3	0.23	0	0.0	0	0.0	0	0.0
Hydroclathrus clathratus	0.16	14	20.9	0.3	1.5	0.8	0.40	0	0.0	0	0.0	0	0.0
Lobophora variegata	0.34	1	1.5	22.5	22.5	22.5	-	1	1.5	0	0.0	0	0.0
Phaeophyta Unknown	0.01	1	1.5	0.6	0.6	0.6	-	0	0.0	0	0.0	0	0.0
Sargassum spp.	0.04	5	7.5	0.3	0.9	0.6	0.21	0	0.0	0	0.0	0	0.0
Turbinaria ornata	1.52	9	13.4	0.3	53.3	11.3	17.59	3	4.5	1	1.5	1	1.5
Total Phaeophyta	2.09	23	34.3	0.3	53.3	6.1	12.31	4	6.0	1	1.5	1	1.5
Rhodophyta													
Ceramium sp.	0.06	9	13.4	0.1	1.2	0.4	0.31	0	0.0	0	0.0	0	0.0
Champia parvula	0.14	15	22.4	0.1	1.8	0.6	0.48	0	0.0	0	0.0	0	0.0
Chondria sp.	1.07	30	44.8	0.3	14.6	2.4	3.03	3	4.5	0	0.0	0	0.0
Coelothrix irregularis	0.16	3	4.5	0.1	10.4	3.7	5.85	1	1.5	0	0.0	0	0.0
Gelidiella acerosa	0.21	3	4.5	0.3	12.1	4.7	6.40	1	1.5	0	0.0	0	0.0
Hypnea pannosa	0.20	8	11.9	0.2	4.8	1.7	1.75	0	0.0	0	0.0	0	0.0
Hypnea spinella	0.40	4	6.0	0.3	19.0	6.6	8.60	2	3.0	0	0.0	0	0.0
Hypnea sp.	0.44	33	49.3	0.1	2.8	0.9	0.81	0	0.0	0	0.0	0	0.0
Hypnea spp.	1.03	41	61.2	0.1	19.0	1.7	3.07	2	3.0	0	0.0	0	0.0

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Laurencia spp.	1.19	22	32.8	0.1	51.8	3.6	11.05	2	3.0	1	1.5	1	1.5
Polysiphonia spp.	12.49	54	80.6	0.1	56.3	15.5	16.07	33	49.3	12	17.9	4	6.0
Rhodophyta Unknown	0.00	1	1.5	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Spyridia filamentosa	0.21	3	4.5	0.3	12.2	4.8	6.49	1	1.5	0	0.0	0	0.0
Tolypiocladia glomerulata	0.30	18	26.9	0.1	8.0	1.1	2.01	1	1.5	0	0.0	0	0.0
Total Rhodophyta	16.87	65	97.0	0.1	74.9	17.4	18.05	44	65.7	16	23.9	6	9.0
Miscellaneous													
Mollusk Fragments	0.01	2	3.0	0.1	0.3	0.2	0.13	0	0.0	0	0.0	0	0.0
Polychaete Worm Tube	0.10	11	16.4	0.1	1.2	0.6	0.33	0	0.0	0	0.0	0	0.0
Sand	0.05	7	10.4	0.1	0.9	0.4	0.28	0	0.0	0	0.0	0	0.0
Sand-Rubble	0.14	18	26.9	0.1	1.8	0.5	0.47	0	0.0	0	0.0	0	0.0
Animal Matter Total	0.11	11	16.4	0.1	1.2	0.7	0.31	0	0.0	0	0.0	0	0.0
Total Miscellaneous	0.29	32	47.8	0.1	1.8	0.6	0.41	0	0.0	0	0.0	0	0.0

App. Table 6.17-Diet composition of green turtles captured within the study site, July 1989, Heron Reef, Queensland. Data are arranged in order of descending contribution to the pooled diet within each division. Means and ranges refer only to those lavage samples in which the species was present. Data include animals of all age classes and both sexes. When individuals were recaptured during the sampling session, only the data from the first capture were used in the calculations below. Generic names followed by "spp" represent values for all species of that genus. Data are based upon the volume contribution of the diet item. Data include turtles feeding in monogeneric stands and or algal turf. (n=67)

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Chlorophyta													
Enteromorpha spp.	79.65	65	97.0	34.5	100.0	82.1	17.47	65	97.0	65	97.0	59	88.1
Chlorodesmis fastigiata	1.04	4	6.0	0.1	43.8	17.4	21.23	2	3.0	2	3.0	0	0.0
Halimeda spp.	0.04	3	4.5	0.1	2.0	0.8	1.00	0	0.0	0	0.0	0	0.0
Halimeda sp. #1	0.03	1	1.5	2.0	2.0	2.0	-	0	0.0	0	0.0	0	0.0
Caulerpa sertularioides	0.03	2	3.0	0.3	1.5	0.9	0.84	0	0.0	0	0.0	0	0.0
Halimeda sp.	0.01	2	3.0	0.1	0.3	0.2	0.10	0	0.0	0	0.0	0	0.0
Total Chlorophyta	80.76	67	100.0	2.0	100.0	80.8	19.64	66	98.5	66	98.5	60	89.6
Phaeophyta													
Turbinaria ornata	1.52	9	13.4	0.3	53.3	11.3	17.59	3	4.5	1	1.5	1	1.5
Lobophora variegata	0.34	1	1.5	22.5	22.5	22.5	-	1	1.5	0	0.0	0	0.0
Hydroclathrus clathratus	0.16	14	20.9	0.3	1.5	0.8	0.40	0	0.0	0	0.0	0	0.0
Sargassum spp.	0.04	5	7.5	0.3	0.9	0.6	0.21	0	0.0	0	0.0	0	0.0
Dictyota bartayressi	0.02	3	4.5	0.1	0.6	0.3	0.23	0	0.0	0	0.0	0	0.0
Phaeophyta Unknown	0.01	1	1.5	0.6	0.6	0.6	-	0	0.0	0	0.0	0	0.0
Total Phaeophyta	2.09	23	34.3	0.3	53.3	6.1	12.31	4	6.0	1	1.5	1	1.5
Rhodophyta													
Polysiphonia spp.	12.49	54	80.6	0.1	56.3	15.5	16.07	33	49.3	12	17.9	4	6.0
Laurencia spp.	1.19	22	32.8	0.1	51.8	3.6	11.05	2	3.0	1	1.5	1	1.5
Chondria sp.	1.07	30	44.8	0.3	14.6	2.4	3.03	3	4.5	0	0.0	0	0.0
Hypnea spp.	1.03	41	61.2	0.1	19.0	1.7	3.07	2	3.0	0	0.0	0	0.0
Hypnea sp.	0.44	33	49.3	0.1	2.8	0.9	0.81	0	0.0	0	0.0	0	0.0
Hypnea spinella	0.40	4	6.0	0.3	19.0	6.6	8.60	2	3.0	0	0.0	0	0.0
Tolypiocladia glomerulata	0.30	18	26.9	0.1	8.0	1.1	2.01	1	1.5	0	0.0	0	0.0
Spyridia filamentosa	0.21	3	4.5	0.3	12.2	4.8	6.49	1	1.5	0	0.0	0	0.0
Gelidiella acerosa	0.21	3	4.5	0.3	12.1	4.7	6.40	1	1.5	0	0.0	0	0.0

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Hypnea pannosa	0.20	8	11.9	0.2	4.8	1.7	1.75	0	0.0	0	0.0	0	0.0
Coelothrix irregularis	0.16	3	4.5	0.1	10.4	3.7	5.85	1	1.5	0	0.0	0	0.0
Champia parvula	0.14	15	22.4	0.1	1.8	0.6	0.48	0	0.0	0	0.0	0	0.0
Ceramium sp.	0.06	9	13.4	0.1	1.2	0.4	0.31	0	0.0	0	0.0	0	0.0
Rhodophyta Unknown	0.00	1	1.5	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Total Rhodophyta	16.87	65	97.0	0.1	74.9	17.4	18.05	44	65.7	16	23.9	6	9.0
Miscellaneous													
Sand-Rubble	0.14	18	26.9	0.1	1.8	0.5	0.47	0	0.0	0	0.0	0	0.0
Animal Matter Total	0.11	11	16.4	0.1	1.2	0.7	0.31	0	0.0	0	0.0	0	0.0
Polychaete Worm Tube	0.10	11	16.4	0.1	1.2	0.6	0.33	0	0.0	0	0.0	0	0.0
Sand	0.05	7	10.4	0.1	0.9	0.4	0.28	0	0.0	0	0.0	0	0.0
Mollusk Fragments	0.01	2	3.0	0.1	0.3	0.2	0.13	0	0.0	0	0.0	0	0.0
Total Miscellaneous	0.29	32	47.8	0.1	1.8	0.6	0.41	0	0.0	0	0.0	0	0.0

App. Table 6.18-Diet composition of green turtles captured within the study site, July 1989, Heron Reef, Queensland. Data are arranged by descending contribution to the pooled diet. Means and ranges refer only to those lavage samples in which the species was present. Data include animals of all age classes and both sexes. When individuals were recaptured during the sampling session, only the data from the first capture were used in the calculations below. Generic names followed by "spp" represent values for all species of that genus. Data are based upon the volume contribution of the diet item. Data include turtles feeding in monogeneric stands and or algal turf. (n=67)

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Total Chlorophyta	80.76	67	100.0	2.0	100.0	80.8	19.64	66	98.5	66	98.5	60	89.6
Enteromorpha spp.	79.65	65	97.0	34.5	100.0	82.1	17.47	65	97.0	65	97.0	59	88.1
Total Rhodophyta	16.87	65	97.0	0.1	74.9	17.4	18.05	44	65.7	16	23.9	6	9.0
Polysiphonia spp.	12.49	54	80.6	0.1	56.3	15.5	16.07	33	49.3	12	17.9	4	6.0
Total Phaeophyta	2.09	23	34.3	0.3	53.3	6.1	12.31	4	6.0	1	1.5	1	1.5
Turbinaria ornata	1.52	9	13.4	0.3	53.3	11.3	17.59	3	4.5	1	1.5	1	1.5
Laurencia spp.	1.19	22	32.8	0.1	51.8	3.6	11.05	2	3.0	1	1.5	1	1.5
Chondria sp.	1.07	30	44.8	0.3	14.6	2.4	3.03	3	4.5	0	0.0	0	0.0
Chlorodesmis fastigiata	1.04	4	6.0	0.1	43.8	17.4	21.23	2	3.0	2	3.0	0	0.0
Hypnea spp.	1.03	41	61.2	0.1	19.0	1.7	3.07	2	3.0	0	0.0	0	0.0
Hypnea sp.	0.44	33	49.3	0.1	2.8	0.9	0.81	0	0.0	0	0.0	0	0.0
Hypnea spinella	0.40	4	6.0	0.3	19.0	6.6	8.60	2	3.0	0	0.0	0	0.0
Lobophora variegata	0.34	1	1.5	22.5	22.5	22.5	-	1	1.5	0	0.0	0	0.0
Tolypiocladia glomerulata	0.30	18	26.9	0.1	8.0	1.1	2.01	1	1.5	0	0.0	0	0.0
Total Miscellaneous	0.29	32	47.8	0.1	1.8	0.6	0.41	0	0.0	0	0.0	0	0.0
Spyridia filamentosa	0.21	3	4.5	0.3	12.2	4.8	6.49	1	1.5	0	0.0	0	0.0
Gelidiella acerosa	0.21	3	4.5	0.3	12.1	4.7	6.40	1	1.5	0	0.0	0	0.0
Hypnea pannosa	0.20	8	11.9	0.2	4.8	1.7	1.75	0	0.0	0	0.0	0	0.0
Coelothrix irregularis	0.16	3	4.5	0.1	10.4	3.7	5.85	1	1.5	0	0.0	0	0.0
Hydroclathrus clathratus	0.16	14	20.9	0.3	1.5	0.8	0.40	0	0.0	0	0.0	0	0.0
Champia parvula	0.14	15	22.4	0.1	1.8	0.6	0.48	0	0.0	0	0.0	0	0.0
Sand-Rubble	0.14	18	26.9	0.1	1.8	0.5	0.47	0	0.0	0	0.0	0	0.0
Animal Matter Total	0.11	11	16.4	0.1	1.2	0.7	0.31	0	0.0	0	0.0	0	0.0
Polychaete Worm Tube	0.10	11	16.4	0.1	1.2	0.6	0.33	0	0.0	0	0.0	0	0.0
Ceramium sp.	0.06	9	13.4	0.1	1.2	0.4	0.31	0	0.0	0	0.0	0	0.0
Sand	0.05	7	10.4	0.1	0.9	0.4	0.28	0	0.0	0	0.0	0	0.0
Sargassum spp.	0.04	5	7.5	0.3	0.9	0.6	0.21	0	0.0	0	0.0	0	0.0
Halimeda spp.	0.04	3	4.5	0.1	2.0	0.8	1.00	0	0.0	0	0.0	0	0.0

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Halimeda sp. #1	0.03	1	1.5	2.0	2.0	2.0	-	0	0.0	0	0.0	0	0.0
Caulerpa sertularioides	0.03	2	3.0	0.3	1.5	0.9	0.84	0	0.0	0	0.0	0	0.0
Dictyota bartayressi	0.02	3	4.5	0.1	0.6	0.3	0.23	0	0.0	0	0.0	0	0.0
Phaeophyta Unknown	0.01	1	1.5	0.6	0.6	0.6	-	0	0.0	0	0.0	0	0.0
Mollusk Fragments	0.01	2	3.0	0.1	0.3	0.2	0.13	0	0.0	0	0.0	0	0.0
Halimeda sp.	0.01	2	3.0	0.1	0.3	0.2	0.10	0	0.0	0	0.0	0	0.0
Rhodophyta Unknown	0.00	1	1.5	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0

App. Table 6.19-Diet composition of green turtles captured within the study site, March 1990, Heron Reef, Queensland. Data are arranged alphabetically within each division. Means and ranges refer only to those lavage samples in which the species was present. Data include animals of all age classes and both sexes. When individuals were recaptured during the sampling session, only the data from the first capture were used in the calculations below. Generic names followed by "spp" represent values for all species of that genus. Data are based upon the volume contribution of the diet item. Data include turtles feeding in monogeneric stands and or algal turf. (n=68)

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Chlorophyta													
Caulerpa brachypus	0.04	1	1.5	3.0	3.0	3.0	-	0	0.0	0	0.0	0	0.0
Caulerpa cupressoides	0.15	4	5.9	1.4	4.8	2.6	1.55	0	0.0	0	0.0	0	0.0
Caulerpa lentillifera	2.38	4	5.9	0.5	89.7	40.5	46.30	2	2.9	2	2.9	2	2.9
Caulerpa nummularia	0.14	7	10.3	0.1	3.6	1.4	1.27	0	0.0	0	0.0	0	0.0
Caulerpa racemosa	13.71	40	58.8	0.3	97.0	23.3	29.54	27	39.7	10	14.7	7	10.3
Caulerpa sertularioides	0.01	2	2.9	0.3	0.5	0.4	0.11	0	0.0	0	0.0	0	0.0
Caulerpa sp.	0.01	1	1.5	0.4	0.4	0.4	-	0	0.0	0	0.0	0	0.0
Caulerpa spp.	16.45	46	67.6	0.1	97.0	24.3	30.79	31	45.6	13	19.1	9	13.2
Chlorodesmis fastigiata	0.12	5	7.4	0.1	6.2	1.6	2.58	1	1.5	0	0.0	0	0.0
Codium spp.	16.32	44	64.7	0.1	96.4	25.2	26.08	30	44.1	20	29.4	5	7.4
Dictyosphaeria sp.	0.14	10	14.7	0.1	2.7	0.9	0.75	0	0.0	0	0.0	0	0.0
Halimeda sp.	0.19	20	29.4	0.1	1.8	0.7	0.49	0	0.0	0	0.0	0	0.0
Halimeda sp. #1	0.25	16	23.5	0.1	4.2	1.1	1.25	0	0.0	0	0.0	0	0.0
Halimeda spp.	0.44	29	42.6	0.1	4.2	1.0	1.01	0	0.0	0	0.0	0	0.0
Total Chlorophyta	33.47	64	94.1	0.9	97.6	35.6	31.23	51	75.0	35	51.5	18	26.5
Phaeophyta													
Dictyota bartayressi	0.00	1	1.5	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Lobophora variegata	2.11	34	50.0	0.2	31.2	4.2	7.17	6	8.8	2	2.9	0	0.0
Phaeophyta Unknown	0.01	1	1.5	0.4	0.4	0.4	-	0	0.0	0	0.0	0	0.0
Sargassum spp.	4.05	28	41.2	0.2	93.3	9.8	22.25	8	11.8	3	4.4	2	2.9
Turbinaria ornata	35.19	60	88.2	0.1	98.5	39.9	35.55	45	66.2	32	47.1	23	33.8
Total Phaeophyta	41.36	68	100.0	0.3	100.0	41.4	35.32	55	80.9	38	55.9	27	39.7
Rhodophyta													
Acanthophora specifera	0.00	1	1.5	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Amphiroa spp.	0.03	4	5.9	0.3	0.6	0.5	0.14	0	0.0	0	0.0	0	0.0
Champia parvula	0.04	11	16.2	0.1	0.5	0.2	0.12	0	0.0	0	0.0	0	0.0

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Coelothrix irregularis	0.93	25	36.8	0.0	10.7	2.5	2.85	2	2.9	0	0.0	0	0.0
Galaxaura subfruticulosa	0.06	2	2.9	0.7	3.6	2.2	2.03	0	0.0	0	0.0	0	0.0
Gelidiella acerosa	11.53	32	47.1	0.2	70.4	24.5	24.15	21	30.9	14	20.6	6	8.8
Gelidiella sp.	0.54	9	13.2	0.1	27.0	4.1	8.79	2	2.9	1	1.5	0	0.0
Gelidiella spp.	12.07	38	55.9	0.1	70.4	21.6	23.47	23	33.8	15	22.1	6	8.8
Hypnea pannosa	0.40	13	19.1	0.1	14.6	2.1	4.03	1	1.5	0	0.0	0	0.0
Hypnea sp.	0.08	2	2.9	1.9	3.5	2.7	1.10	0	0.0	0	0.0	0	0.0
Hypnea spp.	0.48	15	22.1	0.1	14.6	2.2	3.75	1	1.5	0	0.0	0	0.0
Laurencia intricata	3.33	17	25.0	0.1	56.5	13.3	17.44	7	10.3	4	5.9	1	1.5
Laurencia parvipapillata	0.05	4	5.9	0.1	1.9	0.8	0.77	0	0.0	0	0.0	0	0.0
Laurencia majusculata	0.39	5	7.4	0.4	18.9	5.3	7.85	2	2.9	0	0.0	0	0.0
Laurencia succisa	0.00	2	2.9	0.1	0.2	0.1	0.003	0	0.0	0	0.0	0	0.0
Laurencia sp.	6.12	49	72.1	0.1	85.8	8.5	18.64	10	14.7	6	8.8	3	4.4
Laurencia spp.	9.89	53	77.9	0.1	91.1	12.7	20.77	19	27.9	11	16.2	4	5.9
Leveillea jungermannioides	0.03	5	7.4	0.1	0.9	0.4	0.31	0	0.0	0	0.0	0	0.0
Plocamium hamatum	0.01	1	1.5	0.9	0.9	0.9	-	0	0.0	0	0.0	0	0.0
Rhodophyta Unknown	0.01	4	5.9	0.0	0.5	0.2	0.19	0	0.0	0	0.0	0	0.0
Tolypiocladia glomerulata	0.00	1	1.5	0.1	0.1	0.1	-	0	0.0	0	0.0	0	0.0
Total Rhodophyta	23.55	59	86.8	0.0	97.5	27.1	30.64	38	55.9	24	35.3	15	22.1
Miscellaneous													
Amphipod	0.00	1	1.5	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Animal flesh	0.17	10	14.7	0.1	8.1	1.1	2.47	1	1.5	0	0.0	0	0.0
Arthropod fragments	0.03	1	1.5	2.0	2.0	2.0	-	0	0.0	0	0.0	0	0.0
Bryozoan	0.01	1	1.5	0.9	0.9	0.9	-	0	0.0	0	0.0	0	0.0
Foraminiferan	0.02	2	2.9	0.3	1.2	0.8	0.62	0	0.0	0	0.0	0	0.0
Halophila ovalis	0.00	1	1.5	0.1	0.1	0.1	-	0	0.0	0	0.0	0	0.0
Holothuroidea	0.00	1	1.5	0.1	0.1	0.1	-	0	0.0	0	0.0	0	0.0
Mollusk Eggs	0.00	2	2.9	0.1	0.2	0.2	0.002	0	0.0	0	0.0	0	0.0
Mollusk Egg Casing	1.10	4	5.9	4.3	30.1	18.8	10.71	3	4.4	1	1.5	0	0.0
Mollusk Fragments	0.05	5	7.4	0.1	2.4	0.7	0.95	0	0.0	0	0.0	0	0.0
Octocoral	0.10	5	7.4	0.3	3.3	1.3	1.21	0	0.0	0	0.0	0	0.0
Physalia sp.	0.00	1	1.5	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Porifera	0.01	1	1.5	0.5	0.5	0.5	-	0	0.0	0	0.0	0	0.0

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Sand	0.01	3	4.4	0.1	0.3	0.2	0.09	0	0.0	0	0.0	0	0.0
Sand-Rubble	0.11	18	26.5	0.1	1.5	0.4	0.39	0	0.0	0	0.0	0	0.0
Animal Matter Total	1.48	23	33.8	0.1	30.5	4.4	8.06	4	5.9	1	1.5	0	0.0
Total Miscellaneous	1.63	38	55.9	0.1	30.6	2.9	6.57	4	5.9	1	1.5	0	0.0

App. Table 6.20-Diet composition of green turtles captured within the study site, March 1990, Heron Reef, Queensland. Data are arranged in order of descending contribution to the pooled diet within each division. Means and ranges refer only to those lavage samples in which the species was present. Data include animals of all age classes and both sexes. When individuals were recaptured during the sampling session, only the data from the first capture were used in the calculations below. Generic names followed by "spp" represent values for all species of that genus. Data are based upon the volume contribution of the diet item. Data include turtles feeding in monogeneric stands and or algal turf. (n=68)

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Chlorophyta													
Caulerpa spp.	16.45	46	67.6	0.1	97.0	24.3	30.79	31	45.6	13	19.1	9	13.2
Codium spp.	16.32	44	64.7	0.1	96.4	25.2	26.08	30	44.1	20	29.4	5	7.4
Caulerpa racemosa	13.71	40	58.8	0.3	97.0	23.3	29.54	27	39.7	10	14.7	7	10.3
Caulerpa lentillifera	2.38	4	5.9	0.5	89.7	40.5	46.30	2	2.9	2	2.9	2	2.9
Halimeda spp.	0.44	29	42.6	0.1	4.2	1.0	1.01	0	0.0	0	0.0	0	0.0
Halimeda sp. #1	0.25	16	23.5	0.1	4.2	1.1	1.25	0	0.0	0	0.0	0	0.0
Halimeda sp.	0.19	20	29.4	0.1	1.8	0.7	0.49	0	0.0	0	0.0	0	0.0
Caulerpa cupressoides	0.15	4	5.9	1.4	4.8	2.6	1.55	0	0.0	0	0.0	0	0.0
Caulerpa nummularia	0.14	7	10.3	0.1	3.6	1.4	1.27	0	0.0	0	0.0	0	0.0
Dictyosphaeria sp.	0.14	10	14.7	0.1	2.7	0.9	0.75	0	0.0	0	0.0	0	0.0
Chlorodesmis fastigiata	0.12	5	7.4	0.1	6.2	1.6	2.58	1	1.5	0	0.0	0	0.0
Caulerpa brachypus	0.04	1	1.5	3.0	3.0	3.0	-	0	0.0	0	0.0	0	0.0
Caulerpa sertularioides	0.01	2	2.9	0.3	0.5	0.4	0.11	0	0.0	0	0.0	0	0.0
Caulerpa sp.	0.01	1	1.5	0.4	0.4	0.4	-	0	0.0	0	0.0	0	0.0
Total Chlorophyta	33.47	64	94.1	0.9	97.6	35.6	31.23	51	75.0	35	51.5	18	26.5
Phaeophyta													
Turbinaria ornata	35.19	60	88.2	0.1	98.5	39.9	35.55	45	66.2	32	47.1	23	33.8
Sargassum spp.	4.05	28	41.2	0.2	93.3	9.8	22.25	8	11.8	3	4.4	2	2.9
Lobophora variegata	2.11	34	50.0	0.2	31.2	4.2	7.17	6	8.8	2	2.9	0	0.0
Phaeophyta Unknown	0.01	1	1.5	0.4	0.4	0.4	-	0	0.0	0	0.0	0	0.0
Dictyota bartayressi	0.00	1	1.5	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Total Phaeophyta	41.36	68	100.0	0.3	100.0	41.4	35.32	55	80.9	38	55.9	27	39.7
Rhodophyta													
Gelidiella spp.	12.07	38	55.9	0.1	70.4	21.6	23.47	23	33.8	15	22.1	6	8.8
Gelidiella acerosa	11.53	32	47.1	0.2	70.4	24.5	24.15	21	30.9	14	20.6	6	8.8
Laurencia spp.	9.89	53	77.9	0.1	91.1	12.7	20.77	19	27.9	11	16.2	4	5.9

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Laurencia sp.	6.12	49	72.1	0.1	85.8	8.5	18.64	10	14.7	6	8.8	3	4.4
Laurencia intricata	3.33	17	25.0	0.1	56.5	13.3	17.44	7	10.3	4	5.9	1	1.5
Coelothrix irregularis	0.93	25	36.8	0.0	10.7	2.5	2.85	2	2.9	0	0.0	0	0.0
Gelidiella sp.	0.54	9	13.2	0.1	27.0	4.1	8.79	2	2.9	1	1.5	0	0.0
Hypnea spp.	0.48	15	22.1	0.1	14.6	2.2	3.75	1	1.5	0	0.0	0	0.0
Hypnea pannosa	0.40	13	19.1	0.1	14.6	2.1	4.03	1	1.5	0	0.0	0	0.0
Laurencia majusculata	0.39	5	7.4	0.4	18.9	5.3	7.85	2	2.9	0	0.0	0	0.0
Hypnea sp.	0.08	2	2.9	1.9	3.5	2.7	1.10	0	0.0	0	0.0	0	0.0
Galaxaura subfruticulosa	0.06	2	2.9	0.7	3.6	2.2	2.03	0	0.0	0	0.0	0	0.0
Laurencia parvipapillata	0.05	4	5.9	0.1	1.9	0.8	0.77	0	0.0	0	0.0	0	0.0
Champia parvula	0.04	11	16.2	0.1	0.5	0.2	0.12	0	0.0	0	0.0	0	0.0
Amphiroa spp.	0.03	4	5.9	0.3	0.6	0.5	0.14	0	0.0	0	0.0	0	0.0
Leveillea jungermannioides	0.03	5	7.4	0.1	0.9	0.4	0.31	0	0.0	0	0.0	0	0.0
Rhodophyta Unknown	0.01	4	5.9	0.0	0.5	0.2	0.19	0	0.0	0	0.0	0	0.0
Plocamium hamatum	0.01	1	1.5	0.9	0.9	0.9	-	0	0.0	0	0.0	0	0.0
Acanthophora specifera	0.00	1	1.5	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Laurencia succisa	0.00	2	2.9	0.1	0.2	0.1	0.003	0	0.0	0	0.0	0	0.0
Tolypiocladia glomerulata	0.00	1	1.5	0.1	0.1	0.1	-	0	0.0	0	0.0	0	0.0
Total Rhodophyta	23.55	59	86.8	0.0	97.5	27.1	30.64	38	55.9	24	35.3	15	22.1
Miscellaneous													
Animal Matter Total	1.48	23	33.8	0.1	30.5	4.4	8.06	4	5.9	1	1.5	0	0.0
Mollusk Egg Casing	1.10	4	5.9	4.3	30.1	18.8	10.71	3	4.4	1	1.5	0	0.0
Animal flesh	0.17	10	14.7	0.1	8.1	1.1	2.47	1	1.5	0	0.0	0	0.0
Sand-Rubble	0.11	18	26.5	0.1	1.5	0.4	0.39	0	0.0	0	0.0	0	0.0
Octocoral	0.10	5	7.4	0.3	3.3	1.3	1.21	0	0.0	0	0.0	0	0.0
Mollusk Fragments	0.05	5	7.4	0.1	2.4	0.7	0.95	0	0.0	0	0.0	0	0.0
Arthropod fragments	0.03	1	1.5	2.0	2.0	2.0	-	0	0.0	0	0.0	0	0.0
Foraminiferan	0.02	2	2.9	0.3	1.2	0.8	0.62	0	0.0	0	0.0	0	0.0
Bryozoan	0.01	1	1.5	0.9	0.9	0.9	-	0	0.0	0	0.0	0	0.0
Sand	0.01	3	4.4	0.1	0.3	0.2	0.09	0	0.0	0	0.0	0	0.0
Porifera	0.01	1	1.5	0.5	0.5	0.5	-	0	0.0	0	0.0	0	0.0
Amphipod	0.00	1	1.5	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Physalia sp.	0.00	1	1.5	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Mollusk Eggs	0.00	2	2.9	0.1	0.2	0.2	0.002	0	0.0	0	0.0	0	0.0
Holothuroidea	0.00	1	1.5	0.1	0.1	0.1	-	0	0.0	0	0.0	0	0.0
Halophila ovalis	0.00	1	1.5	0.1	0.1	0.1	-	0	0.0	0	0.0	0	0.0
Total Miscellaneous	1.63	38	55.9	0.1	30.6	2.9	6.57	4	5.9	1	1.5	0	0.0

App. Table 6.21-Diet composition of green turtles captured within the study site, March 1990, Heron Reef, Queensland. Data are arranged by descending contribution to the pooled diet. Means and ranges refer only to those lavage samples in which the species was present. Data include animals of all age classes and both sexes. When individuals were recaptured during the sampling session, only the data from the first capture were used in the calculations below. Generic names followed by "spp" represent values for all species of that genus. Data are based upon the volume contribution of the diet item. Data include turtles feeding in monogeneric stands and or algal turf. (n=68)

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Total Phaeophyta	41.36	68	100.0	0.3	100.0	41.4	35.32	55	80.9	38	55.9	27	39.7
Turbinaria ornata	35.19	60	88.2	0.1	98.5	39.9	35.55	45	66.2	32	47.1	23	33.8
Total Chlorophyta	33.47	64	94.1	0.9	97.6	35.6	31.23	51	75.0	35	51.5	18	26.5
Total Rhodophyta	23.55	59	86.8	0.0	97.5	27.1	30.64	38	55.9	24	35.3	15	22.1
Caulerpa spp.	16.45	46	67.6	0.1	97.0	24.3	30.79	31	45.6	13	19.1	9	13.2
Codium spp.	16.32	44	64.7	0.1	96.4	25.2	26.08	30	44.1	20	29.4	5	7.4
Caulerpa racemosa	13.71	40	58.8	0.3	97.0	23.3	29.54	27	39.7	10	14.7	7	10.3
Gelidiella spp.	12.07	38	55.9	0.1	70.4	21.6	23.47	23	33.8	15	22.1	6	8.8
Gelidiella acerosa	11.53	32	47.1	0.2	70.4	24.5	24.15	21	30.9	14	20.6	6	8.8
Laurencia spp.	9.89	53	77.9	0.1	91.1	12.7	20.77	19	27.9	11	16.2	4	5.9
Laurencia sp.	6.12	49	72.1	0.1	85.8	8.5	18.64	10	14.7	6	8.8	3	4.4
Sargassum spp.	4.05	28	41.2	0.2	93.3	9.8	22.25	8	11.8	3	4.4	2	2.9
Laurencia intricata	3.33	17	25.0	0.1	56.5	13.3	17.44	7	10.3	4	5.9	1	1.5
Caulerpa lentillifera	2.38	4	5.9	0.5	89.7	40.5	46.30	2	2.9	2	2.9	2	2.9
Lobophora variegata	2.11	34	50.0	0.2	31.2	4.2	7.17	6	8.8	2	2.9	0	0.0
Total Miscellaneous	1.63	38	55.9	0.1	30.6	2.9	6.57	4	5.9	1	1.5	0	0.0
Animal Matter Total	1.48	23	33.8	0.1	30.5	4.4	8.06	4	5.9	1	1.5	0	0.0
Mollusk Egg Casing	1.10	4	5.9	4.3	30.1	18.8	10.71	3	4.4	1	1.5	0	0.0
Coelothrix irregularis	0.93	25	36.8	0.0	10.7	2.5	2.85	2	2.9	0	0.0	0	0.0
Gelidiella sp.	0.54	9	13.2	0.1	27.0	4.1	8.79	2	2.9	1	1.5	0	0.0
Hypnea spp.	0.48	15	22.1	0.1	14.6	2.2	3.75	1	1.5	0	0.0	0	0.0
Halimeda spp.	0.44	29	42.6	0.1	4.2	1.0	1.01	0	0.0	0	0.0	0	0.0
Hypnea pannosa	0.40	13	19.1	0.1	14.6	2.1	4.03	1	1.5	0	0.0	0	0.0
Laurencia majusculata	0.39	5	7.4	0.4	18.9	5.3	7.85	2	2.9	0	0.0	0	0.0
Halimeda sp. #1	0.25	16	23.5	0.1	4.2	1.1	1.25	0	0.0	0	0.0	0	0.0
Halimeda sp.	0.19	20	29.4	0.1	1.8	0.7	0.49	0	0.0	0	0.0	0	0.0
Animal flesh	0.17	10	14.7	0.1	8.1	1.1	2.47	1	1.5	0	0.0	0	0.0
Caulerpa cupressoides	0.15	4	5.9	1.4	4.8	2.6	1.55	0	0.0	0	0.0	0	0.0
Caulerpa nummularia	0.14	7	10.3	0.1	3.6	1.4	1.27	0	0.0	0	0.0	0	0.0

Diet Item	Contribution to Pooled Diet (% Vol.)	Contribution to Individual Diets						Frequency of Indiv. Diets w/ ≥5.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥25.0% of Diet Item by Vol.	Rel. Freq. (%)	Frequency of Indiv. Diets w/ ≥50.0% of Diet Item by Vol.	Rel. Freq. (%)
		Frequency	Relative Frequency (%)	Minimum (% Vol.)	Maximum (% Vol.)	Mean (% Vol.)	Std. Dev. (%)						
Dictyosphaeria sp.	0.14	10	14.7	0.1	2.7	0.9	0.75	0	0.0	0	0.0	0	0.0
Chlorodesmis fastigiata	0.12	5	7.4	0.1	6.2	1.6	2.58	1	1.5	0	0.0	0	0.0
Sand-Rubble	0.11	18	26.5	0.1	1.5	0.4	0.39	0	0.0	0	0.0	0	0.0
Octocoral	0.10	5	7.4	0.3	3.3	1.3	1.21	0	0.0	0	0.0	0	0.0
Hypnea sp.	0.08	2	2.9	1.9	3.5	2.7	1.10	0	0.0	0	0.0	0	0.0
Galaxaura subfruticulosa	0.06	2	2.9	0.7	3.6	2.2	2.03	0	0.0	0	0.0	0	0.0
Mollusk Fragments	0.05	5	7.4	0.1	2.4	0.7	0.95	0	0.0	0	0.0	0	0.0
Laurencia parvipapillata	0.05	4	5.9	0.1	1.9	0.8	0.77	0	0.0	0	0.0	0	0.0
Caulerpa brachypus	0.04	1	1.5	3.0	3.0	3.0	-	0	0.0	0	0.0	0	0.0
Champia parvula	0.04	11	16.2	0.1	0.5	0.2	0.12	0	0.0	0	0.0	0	0.0
Amphiroa spp.	0.03	4	5.9	0.3	0.6	0.5	0.14	0	0.0	0	0.0	0	0.0
Arthropod fragments	0.03	1	1.5	2.0	2.0	2.0	-	0	0.0	0	0.0	0	0.0
Leveillea jungermannioides	0.03	5	7.4	0.1	0.9	0.4	0.31	0	0.0	0	0.0	0	0.0
Foraminiferan	0.02	2	2.9	0.3	1.2	0.8	0.62	0	0.0	0	0.0	0	0.0
Rhodophyta Unknown	0.01	4	5.9	0.0	0.5	0.2	0.19	0	0.0	0	0.0	0	0.0
Plocamium hamatum	0.01	1	1.5	0.9	0.9	0.9	-	0	0.0	0	0.0	0	0.0
Bryozoan	0.01	1	1.5	0.9	0.9	0.9	-	0	0.0	0	0.0	0	0.0
Caulerpa sertularioides	0.01	2	2.9	0.3	0.5	0.4	0.11	0	0.0	0	0.0	0	0.0
Sand	0.01	3	4.4	0.1	0.3	0.2	0.09	0	0.0	0	0.0	0	0.0
Porifera	0.01	1	1.5	0.5	0.5	0.5	-	0	0.0	0	0.0	0	0.0
Caulerpa sp.	0.01	1	1.5	0.4	0.4	0.4	-	0	0.0	0	0.0	0	0.0
Phaeophyta Unknown	0.01	1	1.5	0.4	0.4	0.4	-	0	0.0	0	0.0	0	0.0
Amphipod	0.00	1	1.5	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Acanthophora specifera	0.00	1	1.5	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Physalia sp.	0.00	1	1.5	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Mollusk Eggs	0.00	2	2.9	0.1	0.2	0.2	0.002	0	0.0	0	0.0	0	0.0
Dictyota bartayressi	0.00	1	1.5	0.3	0.3	0.3	-	0	0.0	0	0.0	0	0.0
Laurencia succisa	0.00	2	2.9	0.1	0.2	0.1	0.003	0	0.0	0	0.0	0	0.0
Holothuroidea	0.00	1	1.5	0.1	0.1	0.1	-	0	0.0	0	0.0	0	0.0
Tolypiocladia glomerulata	0.00	1	1.5	0.1	0.1	0.1	-	0	0.0	0	0.0	0	0.0
Halophila ovalis	0.00	1	1.5	0.1	0.1	0.1	-	0	0.0	0	0.0	0	0.0

App. Table 6.22- Multivariate and univariate tests of significance for occasion*age class. Only algal diet components and the first capture of a sampling occasion were used in these data. (n=384)

Multivariate Tests (S=12, M=0, N=174 1/2)

Test Name	Value	Approx. F	Hypothesis DF	Error DF	Sig. of F
Pillais	0.60586	1.48065	156.00	4344.00	0.000
Hotellings	0.67370	1.50791	156.00	4190.00	0.000
Wilkes	0.52823	1.49873	156.00	3140.53	0.000
Roys	0.16444				

Univariate Tests (12, 363 D.F.)

Variable	Hypothesis SS	Error SS	Hypothesis MS	Error MS	F	Sig. of F
Codium spp.	6.8155	324.9100	0.5680	0.8951	0.6345	0.813
Enteromorpha spp.	12.8159	86.0912	1.0680	0.2372	4.5032	0.000
Caulerpa spp.	10.3321	293.1530	0.8610	0.8076	1.0662	0.388
Halimeda spp.	3.5979	81.2011	0.2998	0.2237	1.3404	0.193
Lobophora variegata	8.0140	185.1809	0.6678	0.5101	1.3091	0.211
Turbinaria ornata	19.0913	253.1122	1.5909	0.6973	2.2816	0.008
Sargassum spp.	3.2569	209.3622	0.2714	0.5768	0.4706	0.931
Coelothrix irregularis	7.3761	129.2259	0.6147	0.3560	1.7267	0.059
Champia spp.	1.6438	40.4878	0.1370	0.1115	1.2281	0.261
Gelidiella spp.	15.6812	191.1903	1.3068	0.5267	2.4811	0.004
Hypnea spp.	7.8026	156.1850	0.6502	0.4303	1.5112	0.118
Laurencia spp.	20.7318	294.4000	1.7277	0.8110	2.1302	0.015
Polysiphonia spp.	20.2477	224.4358	1.6873	0.6183	2.7290	0.001

App. Table 6.23- Multivariate and univariate tests of significance for age class. Only algal diet components and the first capture of a sampling occasion were used in these data. (n=384)

Multivariate Tests (S=2, M=5, N=174 1/2)

Test Name	Value	Approx. F	Hypothesis DF	Error DF	Sig. of F
Pillais	0.46067	8.10322	26.00	704.00	0.000
Hotellings	0.65111	8.76495	26.00	700.00	0.000
Wilkes	0.58064	8.43332	26.00	702.00	0.000
Roys	0.33872				

Univariate Tests (2, 363 D.F.)

Variable	Hypothesis SS	Error SS	Hypothesis MS	Error MS	F	Sig. of F
Codium spp.	2.5405	324.9100	1.2702	0.8951	1.4191	0.243
Enteromorpha spp.	3.5787	86.0912	1.7894	0.2372	7.5448	0.001
Caulerpa spp.	6.7817	293.1530	3.3909	0.8076	4.1988	0.016
Halimeda spp.	1.5155	81.2011	0.7577	0.2237	3.3874	0.035
Lobophora variegata	14.7992	185.1809	7.3996	0.5101	14.5051	0.000
Turbinaria ornata	31.5698	253.1122	15.7849	0.6973	22.6378	0.000
Sargassum spp.	0.0310	209.3622	0.0155	0.5768	0.0268	0.974
Coelothrix irregularis	6.9537	129.2259	3.4769	0.3560	9.7666	0.000
Champia spp.	0.3753	40.4878	0.1877	0.1115	1.6825	0.187
Gelidiella spp.	53.5331	191.1903	26.7666	0.5267	50.8198	0.000
Hypnea spp.	5.8255	156.1850	2.9128	0.4303	6.7698	0.001
Laurencia spp.	6.1459	294.4000	3.0730	0.8110	3.7890	0.024
Polysiphonia spp.	4.3935	224.4358	2.1968	0.6183	3.5530	0.030

App. Table 6.24- Multivariate and univariate tests of significance for occasion. Only algal diet components and the first capture of a sampling occasion were used in these data. (n=384)

Multivariate Tests (S=6, M=3, N=174 1/2)

Test Name	Value	Approx. F	Hypothesis DF	Error DF	Sig. of F
Pillais	1.16095	6.56989	78.00	2136.00	0.000
Hotellings	1.69341	7.58415	78.00	2096.00	0.000
Wilkes	0.25013	7.11206	78.00	194.39	0.000
Roys	0.44012				

Univariate Tests (6, 363 D.F.)

Variable	Hypothesis SS	Error SS	Hypothesis MS	Error MS	F	Sig. of F
Codium spp.	36.1235	324.9100	6.0206	0.8951	6.7264	0.000
Enteromorpha spp.	38.6339	86.0912	6.4390	0.2372	27.1497	0.000
Caulerpa spp.	38.8040	293.1530	6.4673	0.8076	8.0082	0.000
Halimeda spp.	4.3287	81.2011	0.7215	0.2237	3.2252	0.004
Lobophora variegata	29.4978	185.1809	4.9163	0.5101	9.6372	0.000
Turbinaria ornata	40.2580	253.1122	6.7097	0.6973	9.6226	0.000
Sargassum spp.	16.1086	209.3622	2.6848	0.5768	4.6549	0.000
Coelothrix irregularis	5.7348	129.2259	0.9558	0.3560	2.6849	0.015
Champia spp.	6.0368	40.4878	1.0061	0.1115	9.0206	0.000
Gelidiella spp.	10.8087	191.1903	1.8015	0.5267	3.4203	0.003
Hypnea spp.	21.7052	156.1850	3.6175	0.4303	8.4078	0.000
Laurencia spp.	24.0068	294.4000	4.0011	0.8110	4.9335	0.000
Polysiphonia spp.	72.0951	224.4358	12.0159	0.6183	19.4343	0.000

App.Table 6.25- Multivariate and univariate tests of significance for occasion*age class for diets of turtles captured repeatedly. Only algal diet components and the first capture of a sampling occasion were used in these data. (n=130)

Multivariate Tests (S=10, M=1, N=19)

Test Name	Value	Approx. F	Hypothesis DF	Error DF	Sig. of F
Pillais	2.19037	1.05716	130.00	490.00	0.335
Hotellings	3.46080	1.01694	130.00	382.00	0.444
Wilkes	0.06656	1.04191	130.00	336.00	0.381
Roys	0.52044				

Univariate Tests (10, 52 D.F.)

Variable	Hypothesis SS	Error SS	Hypothesis MS	Error MS	F	Sig. of F
Codium spp.	4.7034	44.8660	0.4703	0.8628	0.5451	0.850
Enteromorpha spp.	1.8751	11.1662	0.1875	0.2147	0.8732	0.563
Caulerpa spp.	6.6513	34.4512	0.6651	0.6625	1.0039	0.453
Halimeda spp.	1.9930	10.4496	0.1993	0.2010	0.9918	0.462
Lobophora variegata	6.4736	18.6669	0.6474	0.3590	1.8033	0.083
Turbinaria ornata	8.2698	28.4263	0.8270	0.5467	1.5128	0.161
Sargassum spp.	7.8954	19.6536	0.7895	0.3780	2.0890	0.042
Coelothrix irregularis	1.9991	21.1958	0.1999	0.4076	0.4905	0.889
Champia spp.	1.2876	5.6174	0.1288	0.1080	1.1919	0.318
Gelidiella spp.	5.6486	28.4014	0.5649	0.5462	1.0342	0.429
Hypnea spp.	7.1941	24.1337	0.7194	0.4641	1.5501	0.149
Laurencia spp.	2.7213	37.8910	0.2721	0.7287	0.3735	0.953
Polysiphonia spp.	3.3843	35.0173	0.3384	0.6734	0.5026	0.880

App. Table 6.26- Multivariate and univariate tests of significance for occasion for diets of turtles captured repeatedly. Only algal diet components and the first capture of a sampling occasion were used in these data. (n=130)

Multivariate Tests (S=6, M=3, N=19)

Test Name	Value	Approx. F	Hypothesis DF	Error DF	Sig. of F
Pillais	3.08208	3.65629	78.00	270.00	0.000
Hotellings	18.17480	8.93206	78.00	230.00	0.000
Wilkes	0.00287	5.49339	78.00	226.65	0.000
Roys	0.92728				

Univariate Tests (6, 52 D.F.)

Variable	Hypothesis SS	Error SS	Hypothesis MS	Error MS	F	Sig. of F
Codium spp.	10.1900	44.8660	1.8033	0.8628	2.0901	0.070
Enteromorpha spp.	96.7479	11.1662	16.1247	0.2147	75.0910	0.000
Caulerpa spp.	12.2835	34.4512	2.0473	0.6625	3.0901	0.012
Halimeda spp.	6.4576	10.4496	1.0763	0.2010	5.3558	0.000
Lobophora variegata	34.9591	18.6669	5.8265	0.3590	16.2308	0.000
Turbinaria ornata	41.8861	28.4263	6.9810	0.5467	12.7703	0.000
Sargassum spp.	11.9249	19.6536	1.9875	0.3178	5.2585	0.000
Coelothrix irregularis	12.3882	21.1958	2.0647	0.4076	5.0654	0.000
Champia spp.	5.0062	5.6174	0.8344	0.1080	7.7237	0.000
Gelidiella spp.	30.4182	28.4014	5.0697	0.5462	9.2821	0.000
Hypnea spp.	23.0482	24.1337	3.8414	0.4641	8.2769	0.000
Laurencia spp.	32.4759	37.8910	5.4127	0.7287	7.4281	0.000
Polysiphonia spp.	66.5841	35.0173	11.0974	0.6734	16.4793	0.000

App. Table 6.27- Multivariate and univariate tests of significance for age class for diets of turtles captured repeatedly. Only algal diet components and the first capture of a sampling occasion were used in these data. (n=130)

Multivariate Tests (S=2, M=5, N=19)

Test Name	Value	Approx. F	Hypothesis DF	Error DF	Sig. of F
Pillais	1.21540	4.88554	26.00	82.00	0.000
Hotellings	3.89015	5.83523	26.00	78.00	0.000
Wilkes	0.13321	5.35630	26.00	80.00	0.000
Roys	0.75155				

Univariate Tests (2, 52 D.F.)

Variable	Hypothesis SS	Error SS	Hypothesis MS	Error MS	F	Sig. of F
Codium spp.	8.2683	44.8660	4.1342	0.8628	4.7915	0.012
Enteromorpha spp.	0.4711	11.1662	0.2356	0.2147	1.0969	0.341
Caulerpa spp.	2.0981	34.4512	1.0490	0.6625	1.5834	0.215
Halimeda spp.	1.8167	10.4496	0.9084	0.2010	4.5202	0.015
Lobophora variegata	8.0207	18.6669	4.0104	0.3590	11.1716	0.000
Turbinaria ornata	23.3653	28.4263	11.6826	0.5467	21.3710	0.000
Sargassum spp.	1.4758	19.6536	0.7379	0.3780	1.9523	0.152
Coelothrix irregularis	3.2091	21.1958	1.6046	0.4076	3.9365	0.026
Champia spp.	0.2638	5.6174	0.1319	0.1080	1.2210	0.303
Gelidiella spp.	25.7321	28.4014	12.8660	0.5462	23.5563	0.000
Hypnea spp.	5.7658	24.1337	2.8829	0.4641	6.2116	0.004
Laurencia spp.	0.3387	37.8910	0.1694	0.7287	0.2324	0.793
Polysiphonia spp.	0.3409	35.0173	0.1705	0.6734	0.2531	0.777

App. Table 6.28- Multivariate and univariate tests of significance for diets of turtles captured repeatedly. Only algal diet components and the first capture of a sampling occasion were used in these data. (n=130)

Multivariate Tests (S=13, M=22 1/2, N=19)

Test Name	Value	Approx. F	Hypothesis DF	Error DF	Sig. of F
Pillais	7.33526	1.14127	767.00	676.00	0.039
Hotellings	22.89245	1.13877	767.00	496.00	0.057
Wilkes	0.00001	1.14433	767.00	563.96	0.044
Roys	0.83255				

Univariate Tests (59, 52 D.F.)

Variable	Hypothesis SS	Error SS	Hypothesis MS	Error MS	F	Sig. of F
Codium spp.	58.7459	44.8660	0.9957	0.8628	1.1540	0.300
Enteromorpha spp.	16.2143	11.1662	0.2748	0.2147	1.2798	0.183
Caulerpa spp.	51.2935	34.4512	0.8694	0.6625	1.3122	0.160
Halimeda spp.	14.8514	10.4496	0.2517	0.2010	1.2526	0.205
Lobophora variegata	43.4207	18.6669	0.7359	0.3590	2.0501	0.005
Turbinaria ornata	39.5527	28.4263	0.6704	0.5467	1.2263	0.227
Sargassum spp.	28.1674	19.6536	0.4774	0.3780	1.2632	0.196
Coelothrix irregularis	29.7585	21.1958	0.5044	0.4076	1.2374	0.218
Champia spp.	8.1884	5.6174	0.1388	0.1080	1.2847	0.179
Gelidiella spp.	42.7702	28.4014	0.7249	0.5462	1.3273	0.150
Hypnea spp.	31.4070	24.1337	0.5323	0.4641	1.1470	0.308
Laurencia spp.	52.2661	37.8910	0.8859	0.7287	1.2175	0.237
Polysiphonia spp.	50.3645	35.0173	0.8536	0.6734	1.2676	0.192

App. Table 6.29- Maximum contribution to the diet (vol.) of a single algal species and number of genera in the diet of green turtles captured repeatedly on Heron Reef.

Animal I.D. #	Max Contrib. (%) of a Single Alga	# Algae Genera in Sample	Sex	Age Class	Capture Date (D/M/Y)
T1085	27	13	F	J	16/3/88
	33	13	F	J	23/3/89
	92	6	F	J	2/4/89
T11943	39	8	F	SA	1/2/89
	36	9	F	SA	8/4/90
T11955	27	15	F	SA	31/10/88
	83	4	F	SA	31/5/89
T12920	92	3	M	SA	28/7/89
	73	7	M	SA	3/4/90
T15335	67	11	F	SA	11/4/88
	70	7	F	SA	18/1/89
	28	8	F	SA	9/4/89
T15344	35	10	M	J	9/3/88
	54	8	M	J	29/3/89
T15689	24	8	F	SA	18/1/89
	28	9	F	SA	30/5/89
	28	5	F	SA	8/4/90
T16316	88	7	M	SA	23/3/88
	90	5	M	J	30/5/89
T17830	95	5	M	A	17/1/89
	58	6	M	A	29/5/89
	72	6	M	A	6/4/90
T17927	65	11	M	J	26/3/88
	61	6	M	J	27/3/88
	35	8	M	J	21/3/89
	56	8	M	J	16/4/89
T17960	56	8	F	SA	27/3/88
	46	5	F	SA	1/6/89
	59	5	F	SA	1/4/90
T19202	92	5	F	J	4/4/88
	59	5	F	J	7/4/89
T21096	32	10	M	J	21/1/89
	42	8	M	J	1/6/89
	46	6	M	J	31/5/89
T23040	63	8	F	J	27/3/88
	68	9	F	J	27/3/89
T23048	43	13	F	SA	26/3/88
	21	17	F	SA	10/11/88
	45	6	F	SA	20/3/89
T23544	69	6	F	SA	22/3/88
	50	4	F	SA	3/4/90
T23554	56	11	M	A	25/3/88
	94	4	M	A	2/2/89
T31970	78	4	F	SA	16/3/88
	46	4	F	SA	9/4/90
T34711	62	4	M	A	18/3/89
	97	2	M	A	10/4/90
T35137	80	6	M	J	7/4/89
	47	6	M	J	24/3/89
	85	6	M	J	30/7/89
	75	5	M	J	30/7/89
	69	8	M	J	5/4/90
T35150	86	5	F	SA	12/3/88
	72	10	F	SA	9/11/88
T35674	51	3	M	A	23/3/88
	98	4	M	A	3/8/89
T36001	62	8	I	SA	31/10/88
	86	5	I	SA	23/7/89
T36047	81	15	I	SA	4/11/88
	79	8	I	SA	31/5/89

App. Table 6.29 (cont.)

Animal I.D. #	Max Contrib. (%) of a Single Alga	# Algae Genera in Sample	Sex	Age Class	Capture Date (D/M/Y)
T36462	80	8	M	SA	22/3/89
	98	2	M	SA	29/7/89
T36802	35	7	F	J	20/3/89
	45	10	F	J	16/4/89
T36816	53	8	F	SA	29/1/89
	91	5	F	SA	22/3/89
T36904	42	10	F	J	31/1/89
	34	9	F	J	17/1/89
	49	10	F	J	26/3/89
	42	10	F	J	14/4/89
	52	8	F	J	19/3/89
T36907	91	8	M	J	18/1/89
	54	9	M	J	30/3/89
	53	10	M	J	21/3/89
T37430	96	4	F	SA	29/3/89
	77	4	F	SA	25/7/89
T38037	58	6	I	SA	31/5/89
	99	2	I	SA	23/7/89
T38042	54	6	I	SA	31/5/89
	51	4	I	SA	29/7/89
T38048	96	4	I	SA	6/6/89
	75	3	I	SA	1/6/89
T38068	98	3	F	A	6/6/89
	91	5	F	A	11/4/90
T38075	96	3	M	A	6/6/89
	53	3	M	A	23/7/89
T38076	91	8	M	SP	23/7/89
	50	3	M	SP	26/7/89
T38085	83	4	I	SA	29/7/89
	97	3	I	SA	24/7/89
T38174	94	4	F	A	1/8/89
	97	4	F	SP	5/4/90
T4373	40	6	F	J	17/1/89
	92	6	F	J	29/3/90
	64	7	F	J	6/4/90
T4418	100	2	M	SA	24/7/89
	72	8	M	SA	1/8/89
T4510	34	9	F	J	12/3/88
	51	12	F	J	3/4/88
	40	9	F	J	18/3/89
T4524	35	10	F	SA	4/11/88
	89	3	F	SA	31/5/89
	88	7	F	SA	30/7/89
T4533	50	13	M	SA	12/3/88
	40	12	M	SA	26/3/88
	53	7	M	SA	1/6/89
	47	7	M	SA	5/4/90
T45434	36	9	M	J	8/4/90
	51	8	M	J	30/3/90
T4764	35	15	M	SA	14/11/88
	73	7	M	SA	5/11/88
	26	7	M	SA	20/3/89
	70	3	M	SA	29/7/89
T4767	93	4	F	SA	27/3/88
	79	10	F	SA	5/11/88
T5064	48	12	F	J	1/4/88
	78	4	F	J	30/5/89
	94	3	F	J	29/7/89
T5275	62	5	F	J	4/4/90
	88	4	F	J	5/4/90
X13351	20	19	F	SA	12/3/88
	25	18	F	SA	17/1/89
X13438	93	5	F	SA	24/7/89
	66	8	F	SA	6/4/90

App. Table 6.29 (cont.)

Animal I.D. #	Max Contrib. (%) of a Single Alga	# Algae Genera in Sample	Sex	Age Class	Capture Date (D/M/Y)
T39001	47	8	F	J	18/3/89
	70	7	F	J	11/4/90
T4268	57	3	M	A	31/3/90
	97	3	M	A	10/4/90
T4291	77	3	F	A	1/6/89
	97	5	F	A	29/7/89
X13479	74	12	M	SA	14/11/88
	79	6	M	SA	26/3/89
X13753	38	4	F	SA	30/5/89
	65	6	F	SA	23/7/89
X13884	55	5	M	SA	26/3/88
	60	9	M	SA	4/4/90
X13887	23	16	F	SA	3/11/88
	18	9	F	SA	17/1/89
X15673	95	7	F	SA	28/1/89
	33	14	F	SA	21/3/89
X19887	43	14	F	SA	30/10/88
	57	10	F	SA	5/4/90
X22019	30	8	F	J	28/1/89
	40	6	F	J	1/6/89
X2202	59	10	M	A	26/3/88
	67	4	M	A	27/1/89
X2222	44	8	M	A	30/3/88
	91	5	M	A	3/4/90
X22675	23	9	F	SA	31/3/88
	42	13	F	SA	30/10/88
X2271	63	2	M	SA	12/3/88
	80	4	M	SA	26/3/88
X22813	96	5	M	SA	28/3/89
	59	3	M	SA	8/4/90
X2795	23	15	F	SA	24/1/89
	45	12	F	SA	19/3/89
X2830	63	12	F	SA	28/10/88
	57	9	F	SA	1/6/89
X2842	67	7	F	SA	10/3/88
	88	6	F	SA	31/3/88
X38284	25	9	M	SA	14/3/88
	82	5	M	SA	21/3/89
X38286	72	5	F	SA	28/3/88
	43	13	F	SA	9/11/88
X38694	36	13	F	SA	27/3/88
	84	5	F	SA	29/5/89
	64	10	F	SA	7/4/90
	84	12	M	SA	23/3/88
	59	8	M	SA	3/6/89
X9098	58	8	F	J	2/4/88
	50	9	F	SA	22/3/90

Appendix Table 6.30- Tests of significance for the contribution (% by vol.) of total animal material to the diet of green turtles. Only the first capture of a sampling occasion is used in these data. Data were arcsine square root transformed. Occasion and age class were treated as fixed factors and total animal matter (% by vol.) was the response. (n=384)

Source of Variation	SS	DF	MS	F	Sig. of F
Within + Residual	6.12	363	0.02		
Occasion	0.25	6	0.04	2.48	0.023
Age Class	0.04	2	0.02	1.22	0.296
Occasion by Age Class	0.17	12	0.01	0.83	0.622
(Model)	0.62	20	0.03	1.83	0.017
(Total)	6.74	383	0.02		

R-Squared=0.092
Adj. R-Squared=0.042

App. Table 6.31- Preference of diet components of green turtles captured in the study site, November 1988. Test of Ho: All components consumed are equally preferred. Waller-Duncan critical value W=3.19 with K=100 (alpha approximating 0.05). F (7,3)= 31.47, crit value=8.89 (0.05), n=10. Data include animals of all age classes and both sexes. Only the first capture of a sampling session is used in the data set. C=Chlorophyta, P=Phaeophyta, R=Rhodophyta.

Mean difference in ranks of diet components

Algae and Division	Rank	Tbar
Gelidiella spp. (R)	1	-3.000
Sargassum spp. (P)	2	-2.450
Hypnea spp. (R)	3	-1.700
Turbinaria ornata (P)	4	-0.950
Caulerpa spp. (C)	5	-0.400
Laurencia spp. (R)	6	0.550
Lobophora variegata (P)	7	3.400
Hydroclathrus clathratus (P)	8	4.550

Algae present in monogeneric stands but not consumed by turtles of this data set-*Chlorodesmis* (C), *Halimeda* (C).

Waller-Duncan test of significance of preference- Only those diet components with significant differences of preferability are listed. When d1ik < 0 a preference is shown for diet item "i" over "k". When d1ik > 0, a preference is shown for diet item "k" over "i". Preferred items are indicated by (*). v1ik=variance/ covariance, d1ik=difference in mean rank, ld1iklsd1ik=absolute standard difference, u1ik=sigma inverse.

i	k	v1ik	d1ik	ld1iklsd1ik	u1ik
Hydroclathrus clathratus	*Caulerpa spp.**	-0.978	4.950	5.132	7.712
Lobophora variegata	*Caulerpa spp.**	-0.794	3.800	3.594	8.154
*Turbinaria ornata**	*Hydroclathrus clathratus*	2.331	-5.500	9.015	4.710
*Turbinaria ornata**	*Lobophora variegata*	-0.661	-4.350	3.980	5.467
*Sargassum spp.**	*Hydroclathrus clathratus*	0.303	-7.000	8.174	4.394
*Sargassum spp.**	*Lobophora variegata*	2.394	-5.850	7.967	4.707
*Gelidiella spp.**	*Hydroclathrus clathratus*	-1.222	-7.550	8.399	11.245
*Gelidiella spp.**	*Lobophora variegata*	-1.972	-6.400	5.886	11.979
*Hypnea spp.**	*Hydroclathrus clathratus*	-0.128	-6.250	9.135	5.084
*Hypnea spp.**	*Lobophora variegata*	-0.744	-5.100	5.647	5.578
*Laurencia spp.**	*Hydroclathrus clathratus*	-1.669	-4.000	4.092	0.000
Laurencia spp.	*Gelidiella spp.**	3.389	3.550	9.261	0.000

App. Table 6.32-Preference of diet components of green turtles captured in the study site, January 1989. Test of Ho: All components consumed are equally preferred. Waller-Duncan critical value W=2.61 with K=100 (alpha approximating 0.05). F (9,4)= 67.73, crit value=6.00 (0.05), n=13. Only the first capture of a samplling session is used in the data set. Data include animals of all age classes and both sexes. C=Chlorophyta, P=Phaeophyta, R=Rhodophyta.

Mean difference in ranks of diet components

Algae and Division	Rank	Tbar
Gelidiella spp. (R)	1	-4.769
Codium spp. (C)	2	-2.692
Turbinaria ornata (P)	3	-2.692
Sargassum spp. (P)	4	-1.808
Lobophora variegata (P)	5	-0.192
Hypnea spp. (R)	6	-0.077
Caulerpa spp. (C)	7	1.346
Laurencia spp. (R)	8	2.615
Halimeda spp. (C)	9	4.000
Chlorodesmis fastigiata (C)	10	4.269

Algae present in monogeneric stands but not consumed by turtles of this data set-*Valonia* (C).

Waller-Duncan test of significance of preference- Only those diet components with significant differences of preferability are listed. When d1ik < 0 a preference is shown for diet item "i" over "k". When d1ik > 0, a preference is shown for diet item "k" over "i". Preferred items are indicated by (*). v1ik=variance/ covariance, d1ik=difference in mean rank, ld1iklsd1ik=absolute standard difference, u1ik=sigma inverse.

i	k	v1ik	d1ik	ld1iklsd1ik	u1ik
*Codium spp.**	*Chlorodesmis fastigiata*	0.744	-6.962	10.766	0.384
*Caulerpa spp.**	*Chlorodesmis fastigiata*	-0.288	-2.923	6.789	1.734
Caulerpa spp.	*Codium spp.**	-0.449	4.038	4.917	0.055
Halimeda spp.	*Codium spp.**	2.167	6.692	8.872	0.280
Halimeda spp.	*Caulerpa spp.**	-1.292	2.654	3.151	0.418
*Lobophora variegata**	*Chlorodesmis fastigiata*	-0.881	-4.462	5.834	2.837
*Lobophora variegata**	*Halimeda spp.*	-2.917	-4.192	3.723	0.862
*Turbinaria ornata**	*Chlorodesmis fastigiata*	-0.006	-6.962	12.788	2.001
*Turbinaria ornata**	*Caulerpa spp.*	0.385	-4.038	7.263	0.168
*Turbinaria ornata**	*Halimeda spp.*	-0.708	-6.692	7.606	0.684
*Turbinaria ornata**	*Lobophora variegata*	-0.561	-2.500	2.862	1.314
*Sargassum spp.**	*Chlorodesmis fastigiata*	0.090	-6.077	10.851	2.367
*Sargassum spp.**	*Caulerpa spp.*	0.449	-3.154	5.479	0.206
*Sargassum spp.**	*Halimeda spp.*	-1.125	-5.808	6.225	0.766
*Gelidiella spp.**	*Chlorodesmis fastigiata*	-0.484	-9.038	13.237	2.887
*Gelidiella spp.**	*Caulerpa spp.*	0.038	-6.115	9.028	0.371
*Gelidiella spp.**	*Halimeda spp.*	1.354	-8.769	11.790	0.397
*Gelidiella spp.**	*Lobophora variegata*	-0.181	-4.577	5.115	0.977
*Gelidiella spp.**	*Sargassum spp.*	-1.423	-2.962	3.175	0.097
*Hypnea spp.**	*Chlorodesmis fastigiata*	-1.228	-4.346	9.962	3.487
Hypnea spp.	*Codium spp.**	-1.329	2.615	2.881	0.608
*Hypnea spp.**	*Caulerpa spp.*	-0.346	-1.423	2.682	0.935
*Hypnea spp.**	*Halimeda spp.*	-0.081	-4.077	5.056	0.732
Hypnea spp.	*Turbinaria ornata**	-0.058	2.615	4.180	1.262
Hypnea spp.	*Sargassum spp.**	-0.026	1.731	2.675	1.207
Hypnea spp.	*Gelidiella spp.**	-1.127	4.692	5.810	1.294
Laurencia spp.	*Codium spp.**	-4.080	5.308	4.272	0.000
Laurencia spp.	*Lobophora variegata**	1.420	2.808	3.583	0.000

Laurencia spp.	*Turbinaria ornata**	1.378	5.308	7.771	0.000
Laurencia spp.	*Sargassum spp.**	0.455	4.423	5.527	0.000
Laurencia spp.	*Gelidiella spp.**	-3.029	7.385	6.629	0.000
Laurencia spp.	*Hypnea spp.**	1.468	2.692	4.815	0.000

App.Table 6.33-Preference of diet components of green turtles captured in the study site, March 1989. Test of Ho: All components consumed are equally preferred. Waller-Duncan critical value W=2.11 with K=100 (alpha approximating 0.05). F (8,11)=19.20, crit value=2.95 (0.05), n=19. Data include animals of all age classes and both sexes. Only the first capture of a sampling session is used in the data set. C=Chlorophyta, P=Phaeophyta, R=Rhodophyta.

Mean difference in ranks of diet components

Algae and Division	Rank	Tbar
Gelidiella spp. (R)	1	-4.237
Codium spp. (C)	2	-2.289
Sargassum spp. (P)	3	-1.289
Hypnea spp. (R)	4	-0.789
Turbinaria ornata (P)	5	0.237
Caulerpa spp. (C)	6	0.289
Laurencia spp. (R)	7	2.105
Lobophora variegata (P)	8	2.184
Halimeda spp. (C)	9	3.789

Algae present in monogeneric stands but not consumed by turtles of this data set-*Chlorodesmis* (C), *Valonia* (C), *Amphiroa* (R), *Chnoospora* (R), *Plocamium* (R).

Waller-Duncan test of significance of preference- Only those diet components with significant differences of preferability are listed. When d1ik < 0 a preference is shown for diet item "i" over "k". When d1ik > 0, a preference is shown for diet item "k" over "i". Preferred items are indicated by (*). v1ik=variance/ covariance, d1ik=difference in mean rank, ld1iklsd1ik=absolute standard difference, u1ik=sigma inverse.

i	k	v1ik	d1ik	ld1iklsd1ik	u1ik
Caulerpa spp.	*Codium spp.**	-0.550	2.579	3.215	0.430
Halimeda spp.	*Codium spp.**	-1.495	6.079	7.059	0.436
Halimeda spp.	*Caulerpa spp.**	2.148	3.500	8.463	0.360
Lobophora variegata	*Codium spp.**	-2.152	4.474	4.755	0.411
Lobophora variegata	*Caulerpa spp.**	-2.876	1.895	2.153	0.812
Turbinaria ornata	*Codium spp.**	-1.761	2.526	2.681	0.290
*Turbinaria ornata**	*Halimeda spp.*	-2.420	-3.553	4.052	0.507
*Turbinaria ornata**	*Lobophora variegata*	2.357	-1.947	3.337	0.257
*Sargassum spp.**	*Caulerpa spp.*	-1.287	-1.579	2.322	0.525
*Sargassum spp.**	*Halimeda spp.*	-1.453	-5.079	7.343	0.441
*Sargassum spp.**	*Lobophora variegata*	0.279	-3.474	5.706	0.396
*Sargassum spp.**	*Turbinaria ornata*	0.864	-1.526	2.569	0.183
*Gelidiella spp.**	*Codium spp.*	0.678	-1.947	2.677	0.240
*Gelidiella spp.**	*Caulerpa spp.*	0.031	-4.526	7.068	0.449
*Gelidiella spp.**	*Halimeda spp.*	-0.233	-8.026	12.150	0.418
*Gelidiella spp.**	*Lobophora variegata*	-0.815	-6.421	8.490	0.339
*Gelidiella spp.**	*Turbinaria ornata*	-2.121	-4.474	5.153	0.357
*Gelidiella spp.**	*Sargassum spp.*	-0.100	-2.947	4.966	0.231
Hypnea spp.	*Codium spp.**	-0.102	1.500	2.257	0.362
*Hypnea spp.**	*Halimeda spp.*	-0.439	-4.579	8.527	0.439
*Hypnea spp.**	*Lobophora variegata*	0.612	-2.974	5.922	0.553
Hypnea spp.	*Gelidiella spp.**	-0.545	3.447	6.136	0.560
Laurencia spp.	*Codium spp.**	-2.579	4.395	4.674	0.000
Laurencia spp.	*Caulerpa spp.**	1.593	1.816	3.577	0.000
*Laurencia spp.**	*Halimeda spp.*	1.898	-1.684	3.559	0.000
Laurencia spp.	*Turbinaria ornata**	-1.624	1.868	2.124	0.000
Laurencia spp.	*Sargassum spp.**	-1.579	3.395	4.708	0.000
Laurencia spp.	*Gelidiella spp.**	-0.960	6.342	8.622	0.000
Laurencia spp.	*Hypnea spp.**	-0.232	2.895	5.332	0.000

App. Table 6.34-Preference of diet components of green turtles captured in the study site, May 1989. Test of Ho: All components consumed are equally preferred. Waller-Duncan critical value W=2.24 with K=100 (alpha approximating 0.05). F (10,6)=40.39, crit value=4.06 (0.05), n=16. Data include animals of all age classes and both sexes. Only the first capture of the sampling session is used in the data set. C=Chlorophyta, P=Phaeophyta, R=Rhodophyta.

Mean difference in ranks of diet components

Algae and Division	Rank	Tbar
Lobophora variegata (P)	1	-5.813
Gelidiella spp. (R)	2	-3.938
Turbinaria ornata (P)	3	-2.813
Enteromorpha spp. (C)	4	-2.188
Hypnea spp. (R)	5	-1.344
Caulerpa spp. (C)	6	-1.125
Codium spp. (C)	7	1.563
Polysiphonia spp. (R)	8	2.344
Halimeda spp. (C)	9	3.781
Laurencia spp. (R)	10	3.813
Chlorodesmis fastigiata (C)	11	5.719

Algae present in monogeneric stands but not consumed by turtles of this data set-*Plocamium* (R).

Waller-Duncan test of significance of preference- Only those diet components with significant differences of preferability are listed. When d1ik < 0 a preference is shown for diet item "i" over "k". When d1ik > 0, a preference is shown for diet item "k" over "i". Preferred items are indicated by (*). v1ik=variance/ covariance, d1ik=difference in mean rank, ld1iklsd1ik=absolute standard difference, u1ik=sigma inverse.

i	k	v1ik	d1ik	ld1iklsd1ik	u1ik
*Codium spp.**	*Chlorodesmis fastigiata*	-0.048	-4.156	6.646	0.411
*Enteromorpha spp.**	*Chlorodesmis fastigiata*	0.560	-7.906	18.038	-0.266
*Enteromorpha spp.**	*Codium spp.*	-0.188	-3.750	6.536	-0.109
*Caulerpa spp.**	*Chlorodesmis fastigiata*	-0.788	-6.844	8.372	0.206
*Caulerpa spp.**	*Codium spp.*	0.542	-2.688	3.639	-0.055
*Halimeda spp.**	*Chlorodesmis fastigiata*	-0.982	-1.938	2.669	1.096
Halimeda spp.	*Codium spp.**	0.498	2.219	3.574	0.354
Halimeda spp.	*Enteromorpha spp.**	-1.044	5.969	8.847	0.213
Halimeda spp.	*Caulerpa spp.**	-1.346	4.906	5.484	0.235
*Lobophora variegata**	*Chlorodesmis fastigiata*	-1.160	-11.531	15.333	2.152
*Lobophora variegata**	*Codium spp.*	-0.913	-7.375	9.700	0.692
*Lobophora variegata**	*Enteromorpha spp.*	0.371	-3.625	6.677	-0.538
*Lobophora variegata**	*Caulerpa spp.*	0.625	-4.688	6.206	0.084
*Lobophora variegata**	*Halimeda spp.*	-0.690	-9.594	12.716	1.415
*Turbinaria ornata**	*Chlorodesmis fastigiata*	0.156	-8.531	12.704	-1.290
*Turbinaria ornata**	*Codium spp.*	-0.713	-4.375	5.633	-0.342
*Turbinaria ornata**	*Halimeda spp.*	0.410	-6.594	9.500	-0.851
Turbinaria ornata	*Lobophora variegata**	3.096	3.000	7.442	-2.025
*Gelidiella spp.**	*Chlorodesmis fastigiata*	-0.965	-9.656	12.451	0.482
*Gelidiella spp.**	*Codium spp.*	1.729	-5.500	9.905	-0.043
*Gelidiella spp.**	*Enteromorpha spp.*	-0.954	-1.750	2.425	0.239
*Gelidiella spp.**	*Caulerpa spp.*	-1.408	-2.813	2.989	0.244
*Gelidiella spp.**	*Halimeda spp.*	2.048	-7.719	14.397	0.222
*Hypnea spp.**	*Chlorodesmis fastigiata*	-0.403	-7.063	10.161	0.218
*Hypnea spp.**	*Codium spp.*	-1.344	-2.906	3.621	0.286
*Hypnea spp.**	*Halimeda spp.*	-0.597	-5.125	6.789	0.255
Hypnea spp.	*Lobophora variegata**	-0.081	4.469	6.186	0.244
Hypnea spp.	*Gelidiella spp.**	-0.110	2.594	3.389	0.065
*Laurencia spp.**	*Chlorodesmis fastigiata*	0.660	-1.906	2.387	0.680
Laurencia spp.	*Enteromorpha spp.**	0.746	6.000	8.106	-0.001
Laurencia spp.	*Caulerpa spp.**	-1.208	4.938	4.708	0.138
Laurencia spp.	*Lobophora variegata**	-0.979	9.625	10.025	0.949
Laurencia spp.	*Turbinaria ornata**	0.054	6.625	7.217	-0.504
Laurencia spp.	*Gelidiella spp.**	-3.121	7.750	6.932	0.293
Laurencia spp.	*Hypnea spp.**	-0.702	5.156	5.437	0.185
*Polysiphonia spp.**	*Chlorodesmis fastigiata*	0.236	-3.375	3.786	0.000
Polysiphonia spp.	*Enteromorpha spp.**	0.219	4.531	5.349	0.000

Polysiphonia spp.	*Caulerpa spp.**	-2.021	3.469	3.036	0.000
Polysiphonia spp.	*Lobophora variegata**	-3.002	8.156	7.213	0.000
Polysiphonia spp.	*Turbinaria ornata**	-4.702	5.156	4.154	0.000
Polysiphonia spp.	*Gelidiella spp.**	0.160	6.281	6.466	0.000
Polysiphonia spp.	*Hypnea spp.**	-0.274	3.688	3.784	0.000

App. Table 6.35-Preference of diet components of green turtles captured in the study site, July 1989. Test of Ho: All components consumed are equally preferred. Waller-Duncan critical value W=1.74 (approx.) with K=100 (alpha approximating 0.05). F (9, 31). "ulik" and therefore "F" values could not be determined as the matrix could not beinverted due to the inclusion of many diets with the same rank orders. Data include animals of all age classes and both sexes. Only the first capture of a sampling session is used in the data set. n=40 C=Chlorophyta, P=Phaeophyta, R=Rhodophyta.

Mean difference in ranks of diet components

Algae and Division	Rank	Tbar
Polysiphonia spp. (R)	1	-4.925
Sargassum spp. (P)	2	-2.838
Gelidiella spp. (R)	3	-2.388
Hypnea spp. (R)	4	-1.525
Enteromorpha spp. (C)	5	-1.000
Hydroclathrus clathratus (P)	6	-0.700
Turbinaria ornata (P)	7	1.713
Chlorodesmis fastigiata (C)	8	3.125
Halimeda spp. (C)	9	4.025
Laurencia spp. (R)	10	4.513

Algae present in monogeneric stands but not consumed by turtles of this data set- *Caulerpa* (C), *Lobophora* (P), *Amphiroa* (R), *Plocamium* (R).

Waller-Duncan test of significance of preference- Only those diet components with significant differences of preferability are listed. When d1ik < 0 a preference is shown for diet item "i" over "k". When d1ik > 0, a preference is shown for diet item "k" over "i". Preferred items are indicated by (*). v1ik=variance/ covariance, d1ik=difference in mean rank, ld1iklsd1ik=absolute standard difference, u1ik=sigma inverse.

i	k	v1ik	d1ik	ld1iklsd1ik
*Enteromorpha spp.**	*Chlorodesmis fastigiata*	0.000	-4.125	39.086
Halimeda spp.	*Chlorodesmis fastigiata**	0.407	0.900	9.000
Halimeda spp.	*Enteromorpha spp.**	0.000	5.025	36.251
*Hydroclathrus clathratus**	*Chlorodesmis fastigiata*	-0.410	-3.825	13.038
*Hydroclathrus clathratus**	*Halimeda spp.*	-0.533	-4.725	14.919
*Turbinaria ornata**	*Chlorodesmis fastigiata*	0.011	-1.413	5.581
Turbinaria ornata	*Enteromorpha spp.**	0.000	2.713	11.728
*Turbinaria ornata**	*Halimeda spp.*	-0.070	-2.313	8.378
Turbinaria ornata	*Hydroclathrus clathratus**	0.024	2.413	7.386
*Sargassum spp.**	*Chlorodesmis fastigiata*	-0.155	-5.963	24.137
*Sargassum spp.**	*Enteromorpha spp.*	0.000	-1.838	8.954
*Sargassum spp.**	*Halimeda spp.*	-0.241	-6.863	25.331
*Sargassum spp.**	*Hydroclathrus clathratus*	0.136	-2.138	7.135
*Sargassum spp.**	*Turbinaria ornata*	-0.555	-4.550	12.956
*Gelidiella spp.**	*Chlorodesmis fastigiata*	0.287	-5.513	47.238
*Gelidiella spp.**	*Enteromorpha spp.*	0.000	-1.388	10.698
*Gelidiella spp.**	*Halimeda spp.*	0.247	-6.413	41.670
*Gelidiella spp.**	*Hydroclathrus clathratus*	0.055	-1.688	6.448
*Gelidiella spp.**	*Turbinaria ornata*	0.572	-4.100	20.070
Gelidiella spp.	*Sargassum spp.**	-0.089	0.450	1.787
*Hypnea spp.**	*Chlorodesmis fastigiata*	-0.285	-4.650	13.573
*Hypnea spp.**	*Halimeda spp.*	-0.031	-5.550	16.528
*Hypnea spp.**	*Hydroclathrus clathratus*	-0.524	-0.825	1.986
*Hypnea spp.**	*Turbinaria ornata*	-1.161	-3.238	7.176
Hypnea spp.	*Sargassum spp.**	-0.316	1.313	3.390

Hypnea spp.	*Gelidiella spp.**	-0.747	0.863	2.256
Laurencia spp.	*Chlorodesmis fastigiata**	-0.252	1.388	4.206
Laurencia spp.	*Enteromorpha spp.**	0.000	5.513	18.897
Laurencia spp.	*Hydroclathrus clathratus**	-0.241	5.213	13.389
Laurencia spp.	*Turbinaria ornata**	-0.028	2.800	7.483
Laurencia spp.	*Sargassum spp.**	0.107	7.350	21.055
Laurencia spp.	*Gelidiella spp.**	-0.546	6.900	19.194
Laurencia spp.	*Hypnea spp.**	-1.263	6.038	12.319
*Polysiphonia spp.**	*Chlorodesmis fastigiata*	-0.048	-8.050	24.797
*Polysiphonia spp.**	*Enteromorpha spp.*	0.000	-3.925	12.951
*Polysiphonia spp.**	*Halimeda spp.*	-0.502	-8.950	24.255
*Polysiphonia spp.**	*Hydroclathrus clathratus*	-0.683	-4.225	9.946
*Polysiphonia spp.**	*Polysiphonia spp.*	-0.933	-6.638	15.149
*Polysiphonia spp.**	*Sargassum spp.*	-0.570	-2.088	5.179
*Polysiphonia spp.**	*Gelidiella spp.*	-0.451	-2.538	7.005
*Polysiphonia spp.**	*Hypnea spp.*	0.649	-3.400	8.740
*Polysiphonia spp.**	*Laurencia spp.*	-1.136	-9.438	19.522

App. Table 6.36-Preference of diet components of green turtles captured in the study site, March 1990. Test of Ho: All components consumed are equally preferred. Waller-Duncan critical value W=1.84 with K=100 (alpha approximating 0.05). F (9,12)=139.05, crit value=2.80 (0.05), n=21. Data include animals of all age classes and both sexes. Only the first capture of a sampling session is used in the data set. C=Chlorophyta, P=Phaeophyta, R=Rhodophyta.

Mean difference in ranks of diet components

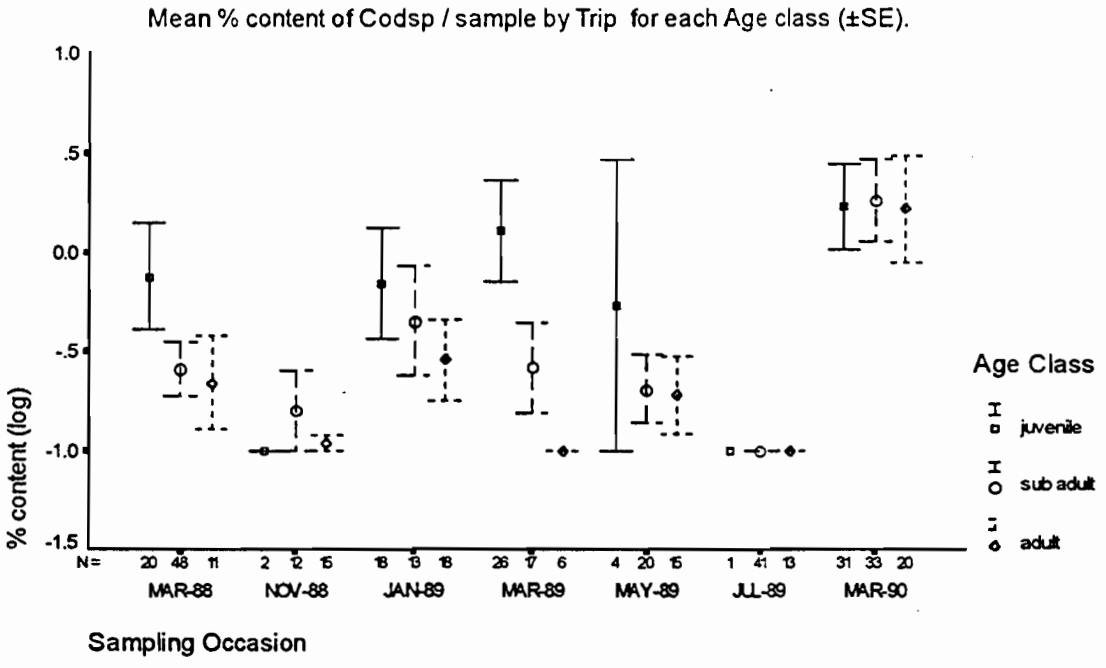
Algae and Division	Rank	Tbar
Caulerpa spp. (C)	1	-4.357
Gelidiella spp. (R)	2	-2.476
Sargassum spp. (P)	3	-2.333
Turbinaria ornata (P)	4	-1.929
Hypnea spp. (R)	5	-1.810
Codium spp. (C)	6	-1.000
Lobophora variegata (P)	7	1.476
Laurencia spp. (R)	8	3.571
Halimeda spp. (C)	9	4.381
Chlorodesmis fastigiata (C)	10	4.476

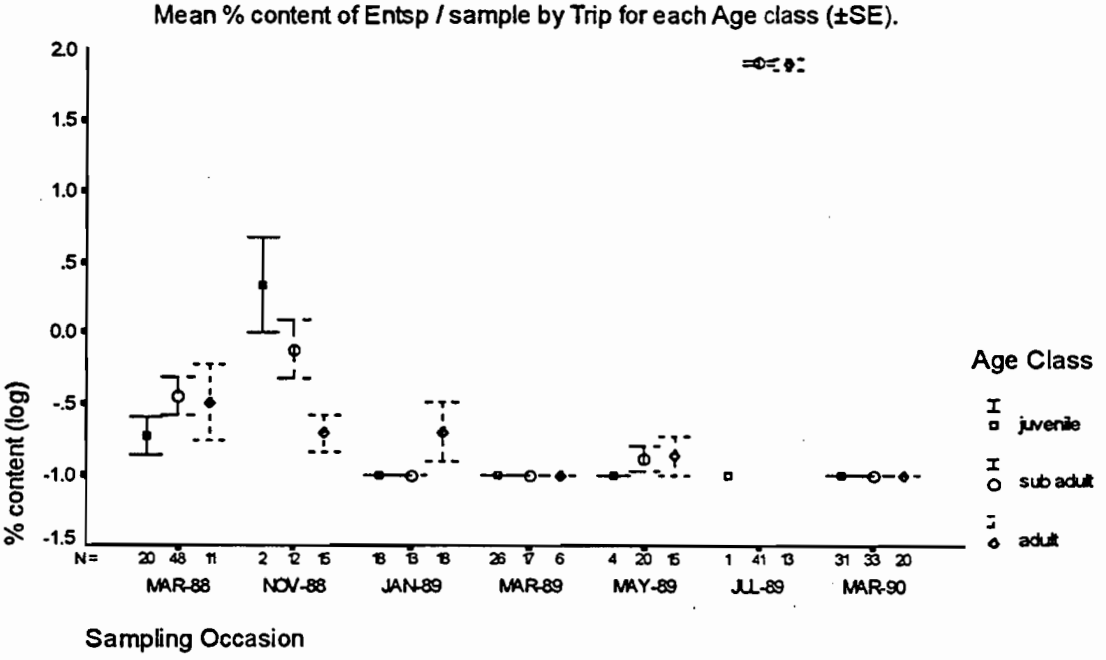
Algae present in monogeneric stands but not consumed by turtles of this data set-*Hydroclathrus (P), Amphiroa* (R).

Waller-Duncan test of significance of preference- Only those diet components with significant differences of preferability are listed. When d1ik < 0 a preference is shown for diet item "i" over "k". When d1ik > 0, a preference is shown for diet item "k" over "i". Preferred items are indicated by (*). v1ik=variance/ covariance, d1ik=difference in mean rank, ld1iklsd1ik=absolute standard difference, u1ik=sigma inverse.

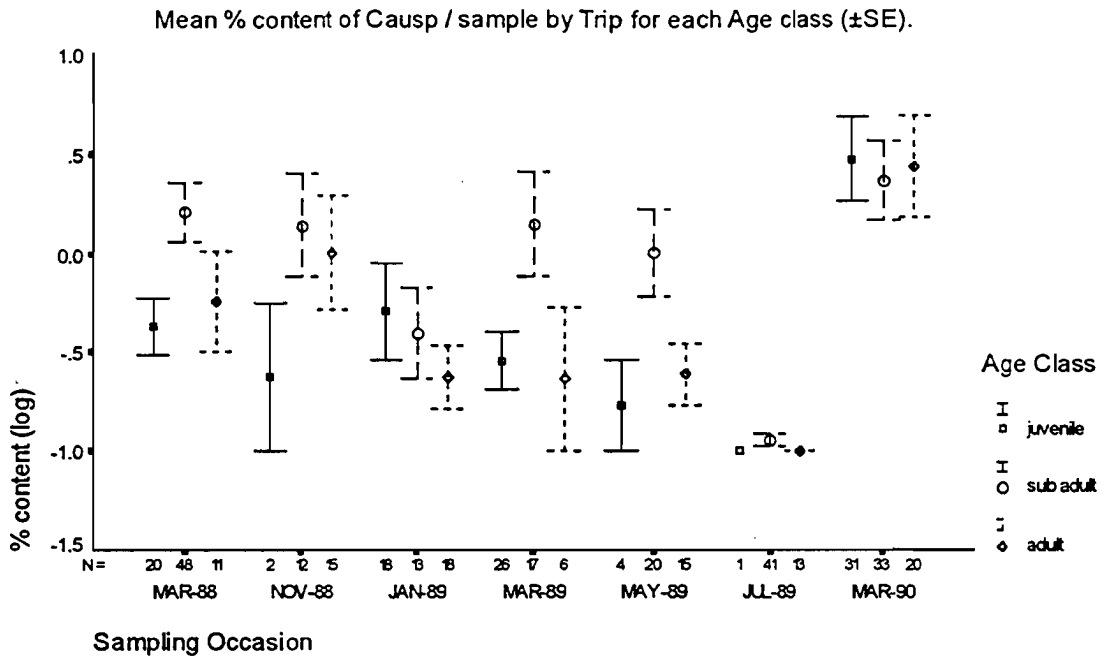
i	k	v1ik	d1ik	ld1iklsd1ik	u1ik
*Codium spp.**	*Chlorodesmis fastigiata*	-0.588	-5.476	8.257	-0.287
*Caulerpa spp.**	*Chlorodesmis fastigiata*	0.179	-8.833	14.372	-0.202
*Caulerpa spp.**	*Codium spp.*	-4.188	-3.357	3.194	0.380
Halimeda spp.	*Codium spp.**	-0.813	5.381	7.003	0.401
Halimeda spp.	*Caulerpa spp.**	1.393	8.738	13.970	0.276
*Lobophora variegata**	*Chlorodesmis fastigiata*	0.537	-3.000	7.904	-0.557
Lobophora variegata	*Codium spp.**	-2.225	2.476	2.921	0.717
Lobophora variegata	*Caulerpa spp.**	1.179	5.833	9.164	0.523
*Lobophora variegata**	*Halimeda spp.*	-0.890	-2.905	4.542	1.140
*Turbinaria ornata**	*Chlorodesmis fastigiata*	0.127	-6.405	14.129	-0.149
Turbinaria ornata	*Caulerpa spp.**	0.014	2.429	3.310	0.379
*Turbinaria ornata**	*Halimeda spp.*	0.734	-6.310	11.994	0.653
*Turbinaria ornata**	*Lobophora variegata*	-0.498	-3.405	5.469	1.134
*Sargassum spp.**	*Chlorodesmis fastigiata*	0.954	-6.810	14.263	-0.717
Sargassum spp.	*Caulerpa spp.**	-1.913	2.024	2.231	0.366
*Sargassum spp.**	*Halimeda spp.*	-1.354	-6.714	8.840	0.506
*Sargassum spp.**	*Lobophora variegata*	-0.446	-3.810	5.476	0.838
*Gelidiella spp.**	*Chlorodesmis fastigiata*	-0.562	-6.952	12.876	0.275
Gelidiella spp.	*Caulerpa spp.**	-0.191	1.881	2.473	0.336
*Gelidiella spp.**	*Halimeda spp.*	-0.472	-6.857	10.682	0.652
*Gelidiella spp.**	*Lobophora variegata*	-0.287	-3.952	6.345	0.995
*Hypnea spp.**	*Chlorodesmis fastigiata*	-0.420	-6.286	12.706	0.292
Hypnea spp.	*Caulerpa spp.**	-2.216	2.548	2.966	0.363
*Hypnea spp.**	*Halimeda spp.*	-1.164	-6.190	9.284	0.924
*Hypnea spp.**	*Lobophora variegata*	-1.645	-3.286	4.723	1.373

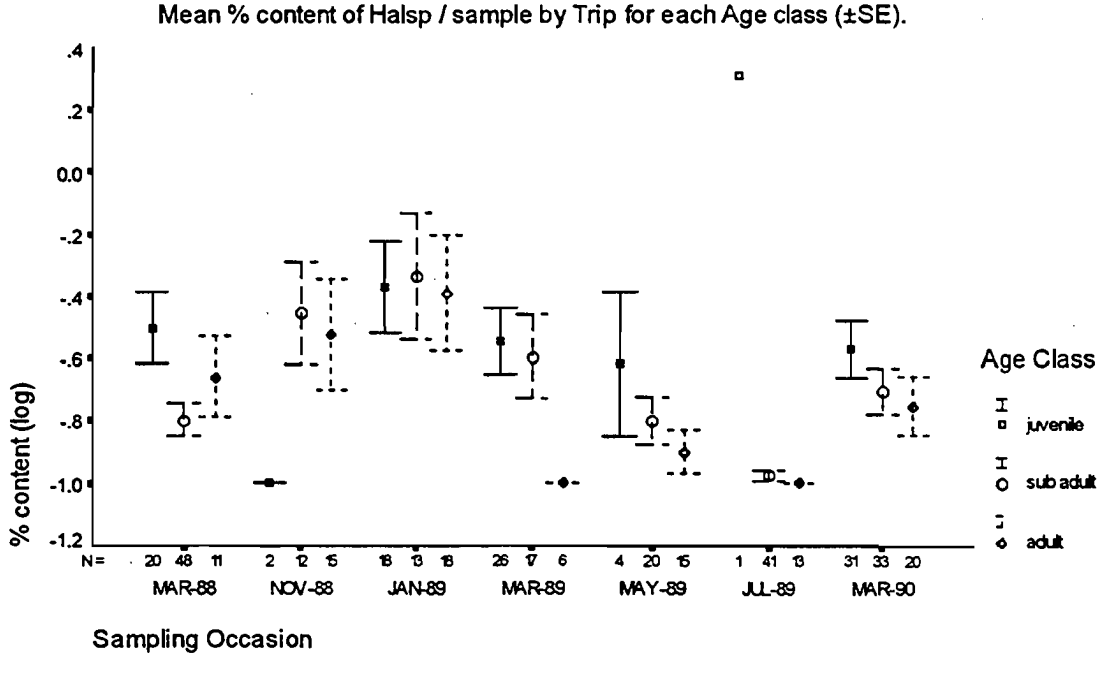
Laurencia spp.	*Codium spp.**	-0.163	4.571	6.058	0.000
Laurencia spp.	*Caulerpa spp.**	-1.786	7.929	9.249	0.000
Laurencia spp.	*Lobophora variegata**	0.939	2.095	3.990	0.000
Laurencia spp.	*Turbinaria ornata**	-0.330	5.500	8.496	0.000
Laurencia spp.	*Sargassum spp.**	-1.750	5.905	7.293	0.000
Laurencia spp.	*Gelidiella spp.**	0.398	6.048	9.941	0.000
Laurencia spp.	*Hypnea spp.**	-0.002	5.381	8.788	0.000

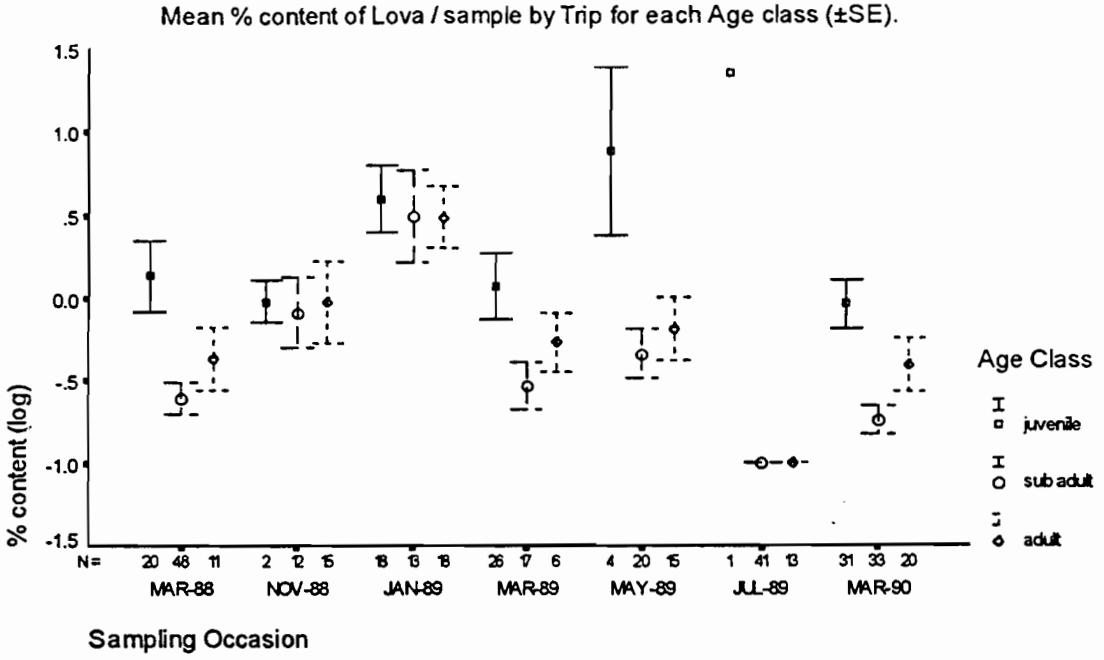


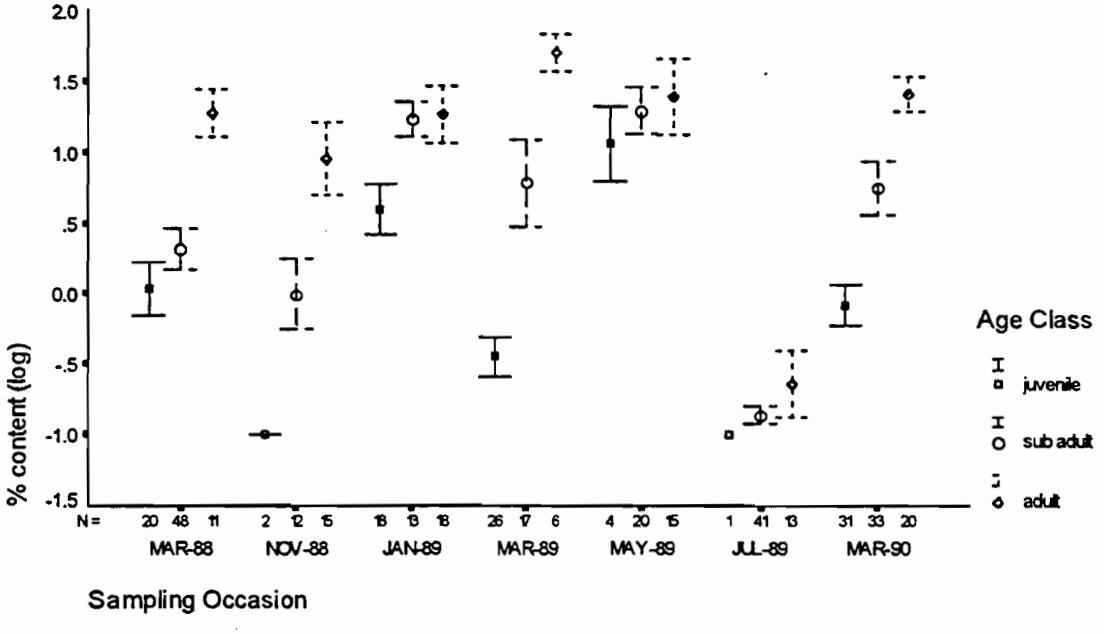


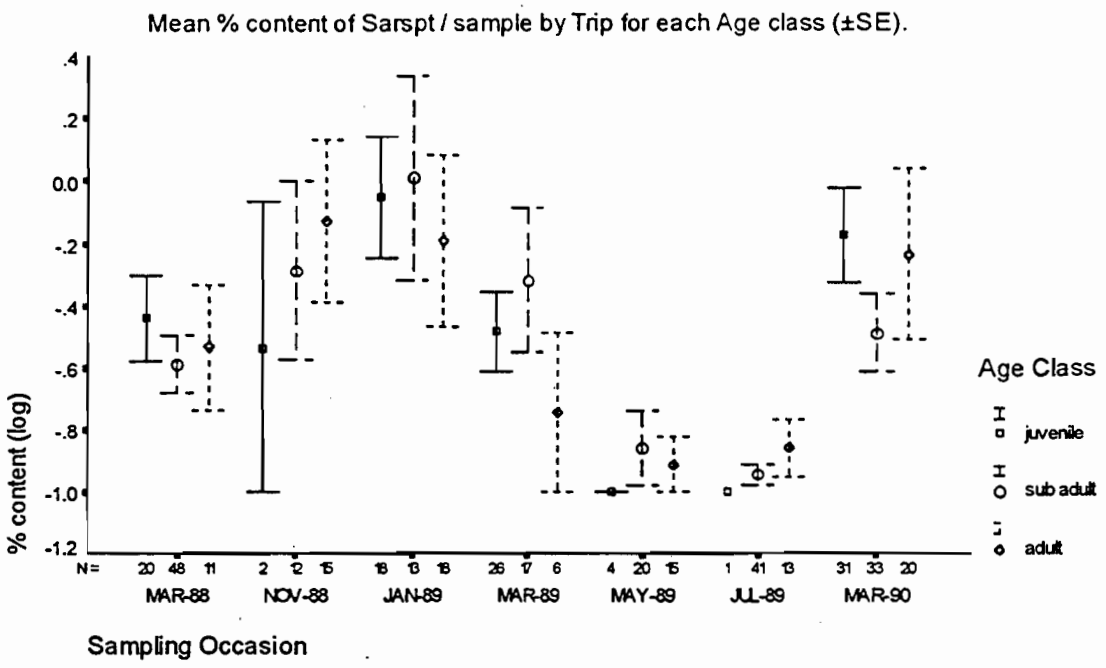
App. Figure. 6.1- Trip * Age error bar graphs for each diet component. (causp=*Caulerpa spp.*, chasp=*Champia spp.*, codsp=*Codium spp.*, coir=*Coelothrix irregularis*, entsp=*Enteromorpha spp.*, gelsp=*Gelidiella spp.*, halsp=*Halimeda sp.*, hypsp=*Hypnea spp.*, lausp=*Laurencia spp.*, lova=*Lobophora spp.*, polsp=*Polysiphonia spp.*, sarspt=*Sargassum spp.*, tuort=*Turbinaria ornata*)

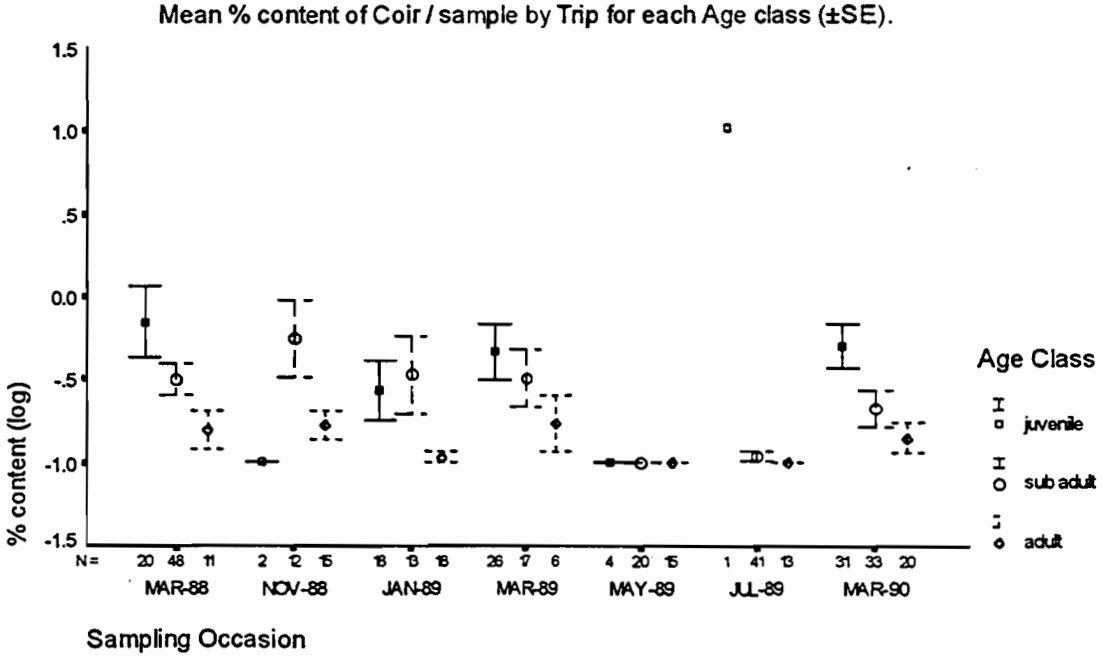

Mean % content of Causp / sample by Trip for each Age class (±SE).
1.0
.5
0.0
-.5
-1.0
-1.5
% content (log)
N= 20 48 11 2 12 15 18 13 18 26 17 6 4 20 15 1 41 13 31 33 20
MAR-88 NOV-88 JAN-89 MAR-89 MAY-89 JUL-89 MAR-90
Sampling Occasion
Age Class
juvenile
sub adult
adult


Mean % content of Halsp / sample by Trip for each Age class (±SE).
.4
.2
0.0
-.2
-.4
-.6
-.8
-1.0
-1.2
% content (log)
N= 20 48 11 2 12 15 18 13 18 26 17 6 4 20 15 1 41 13 31 33 20
MAR-88 NOV-88 JAN-89 MAR-89 MAY-89 JUL-89 MAR-90
Sampling Occasion
Age Class
juvenile
sub adult
adult

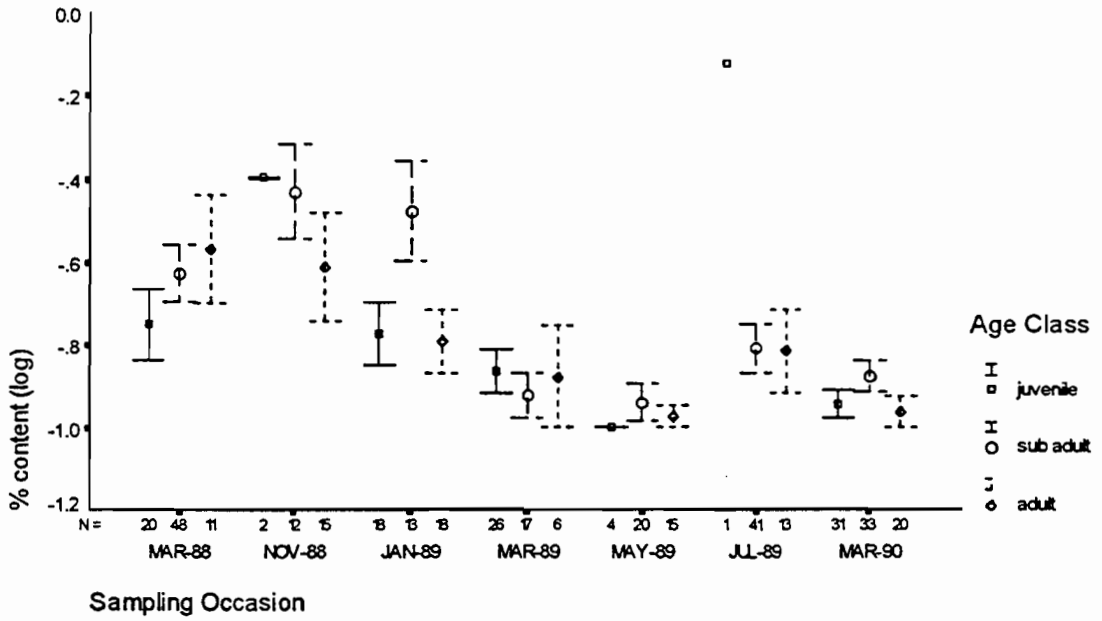

Mean % content of Lova / sample by Trip for each Age class (±SE).
% content (log)
1.5
1.0
.5
0.0
-.5
-1.0
-1.5
N= 20 48 11 2 12 15 18 13 18 26 17 6 4 20 15 1 41 13 31 33 20
MAR-88 NOV-88 JAN-89 MAR-89 MAY-89 JUL-89 MAR-90
Sampling Occasion
Age Class
juvenile
sub adult
adult


Mean % content of Tuort / sample by Trip for each Age class (±SE).
% content (log)
2.0
1.5
1.0
.5
0.0
-.5
-1.0
-1.5
N= 20 48 11 2 12 15 18 13 18 26 17 6 4 20 15 1 41 13 31 33 20
MAR-88 NOV-88 JAN-89 MAR-89 MAY-89 JUL-89 MAR-90
Sampling Occasion
Age Class
juvenile
sub adult
adult

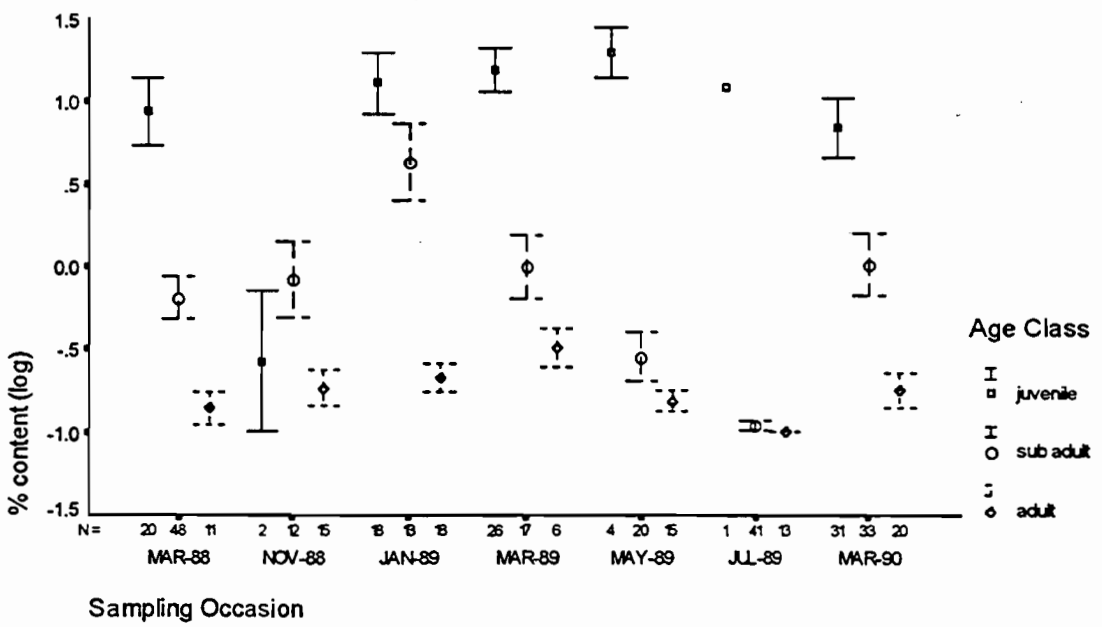

Mean % content of Sarspt / sample by Trip for each Age class (±SE).
% content (log)
.4
.2
0.0
-.2
-.4
-.6
-.8
-1.0
-1.2
N=
20 48 11
2 12 15
18 13 18
26 17 6
4 20 15
1 41 13
31 33 20
MAR-88
NOV-88
JAN-89
MAR-89
MAY-89
JUL-89
MAR-90
Sampling Occasion
Age Class
juvenile
sub adult
adult


Mean % content of Coir / sample by Trip for each Age class (±SE).
% content (log)
1.5
1.0
.5
0.0
-.5
-1.0
-1.5
N=
20 48 11
2 12 15
18 13 18
26 17 6
4 20 15
1 41 13
31 33 20
MAR-88
NOV-88
JAN-89
MAR-89
MAY-89
JUL-89
MAR-90
Sampling Occasion
Age Class
juvenile
sub adult
adult

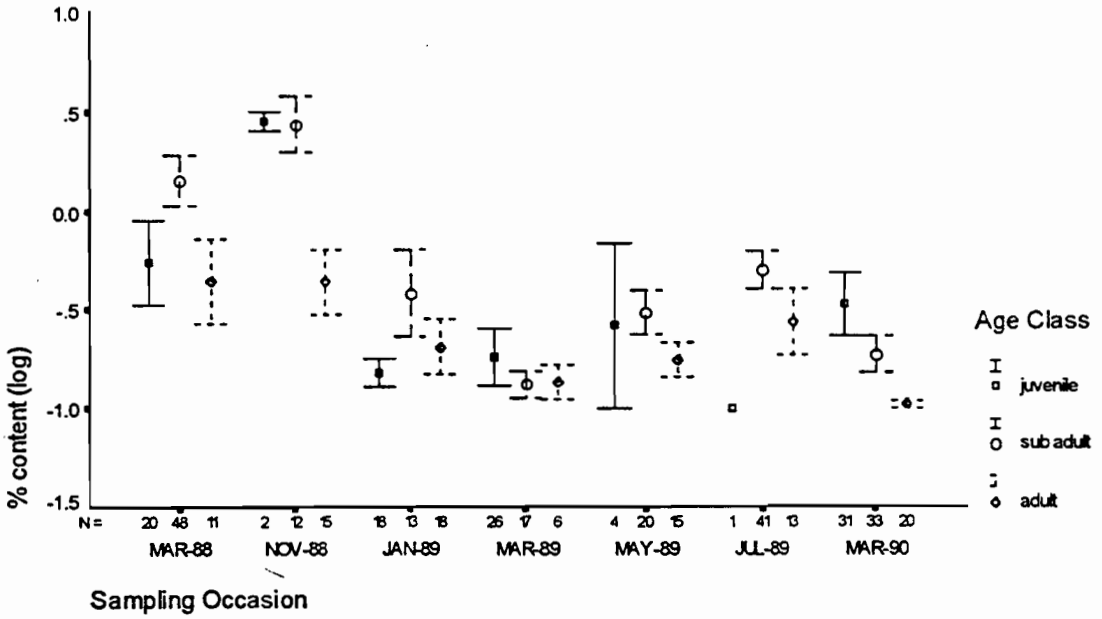
Mean % content of Chasp / sample by Trip for each Age class (±SE).



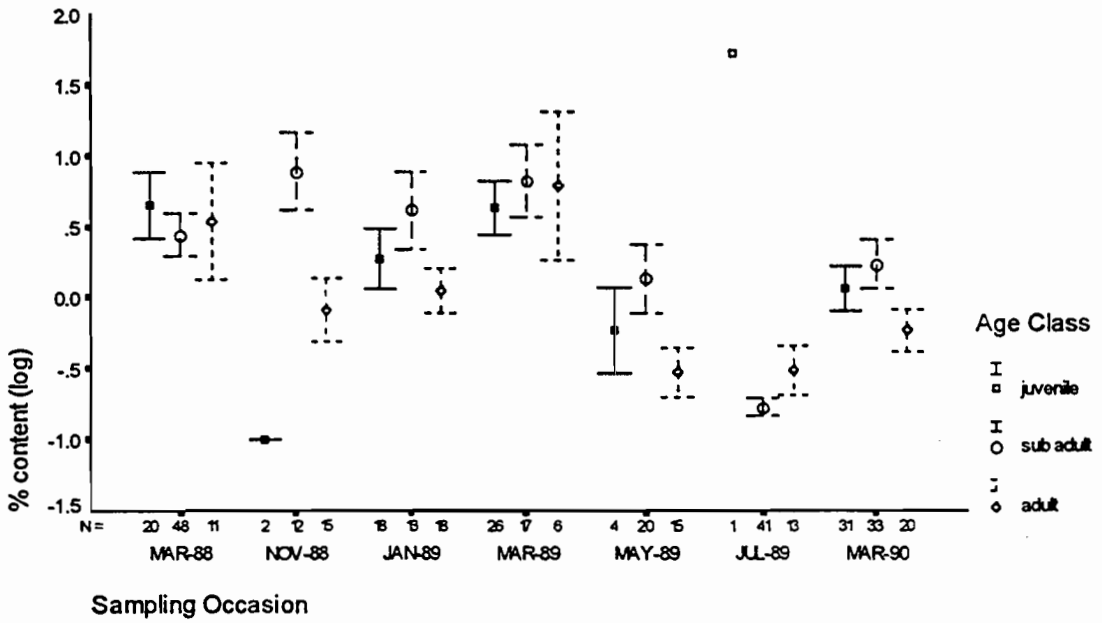
Mean % content of Gelsp / sample by Trip for each Age class (±SE).

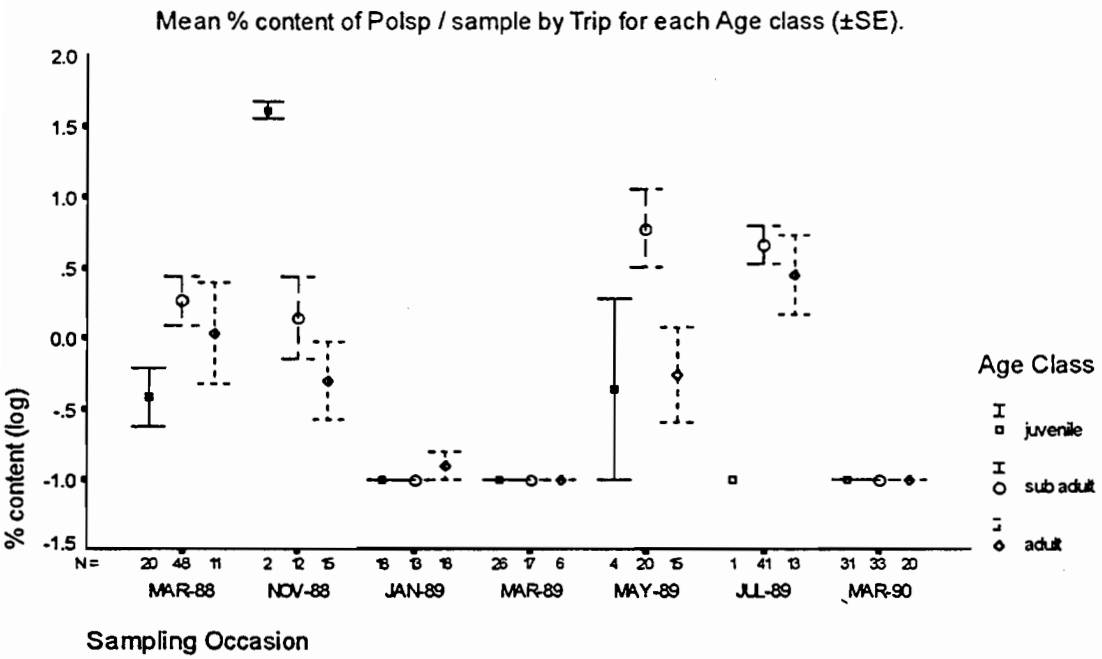


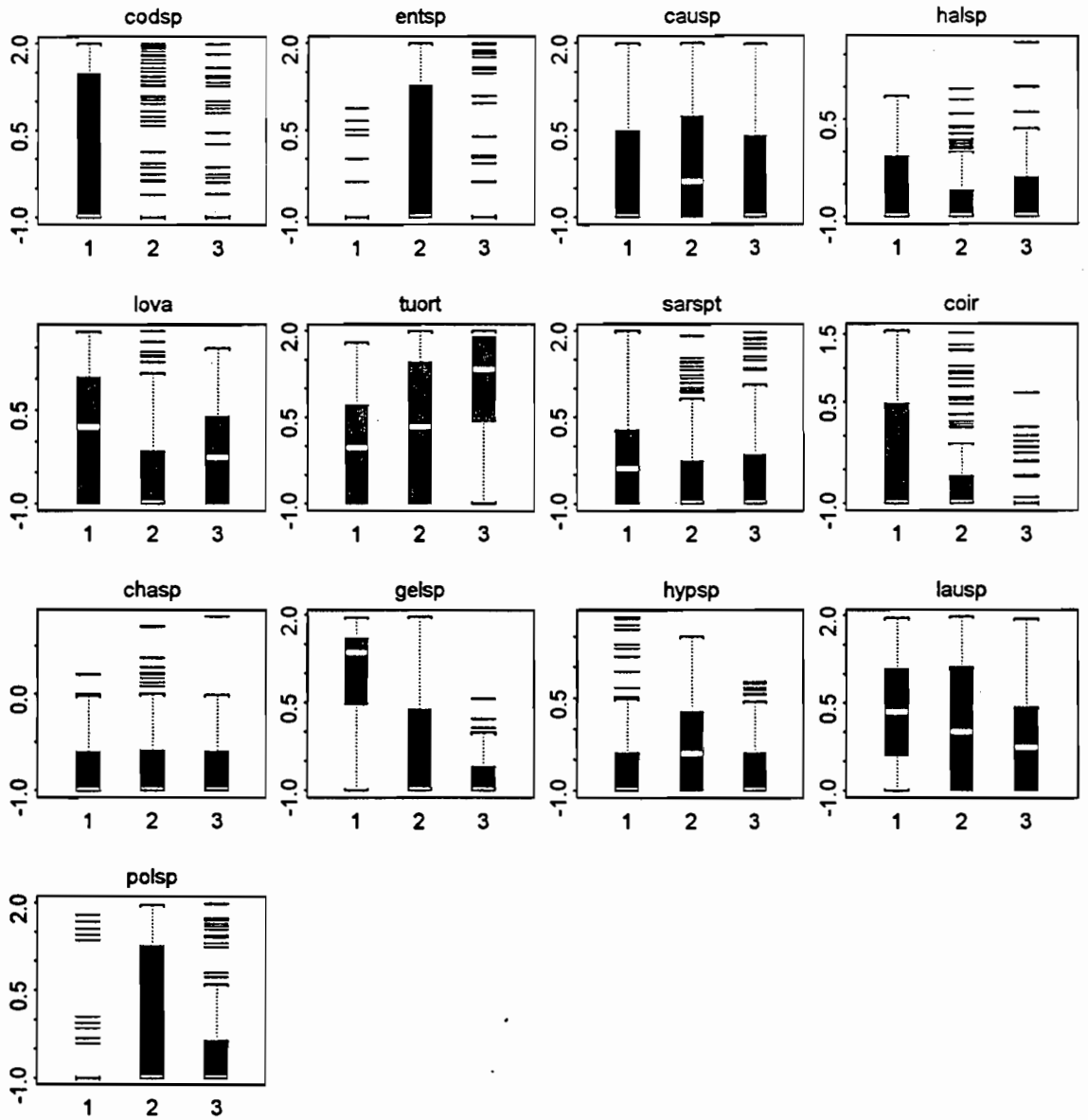
Mean % content of Hypsp / sample by Trip for each Age class (±SE).



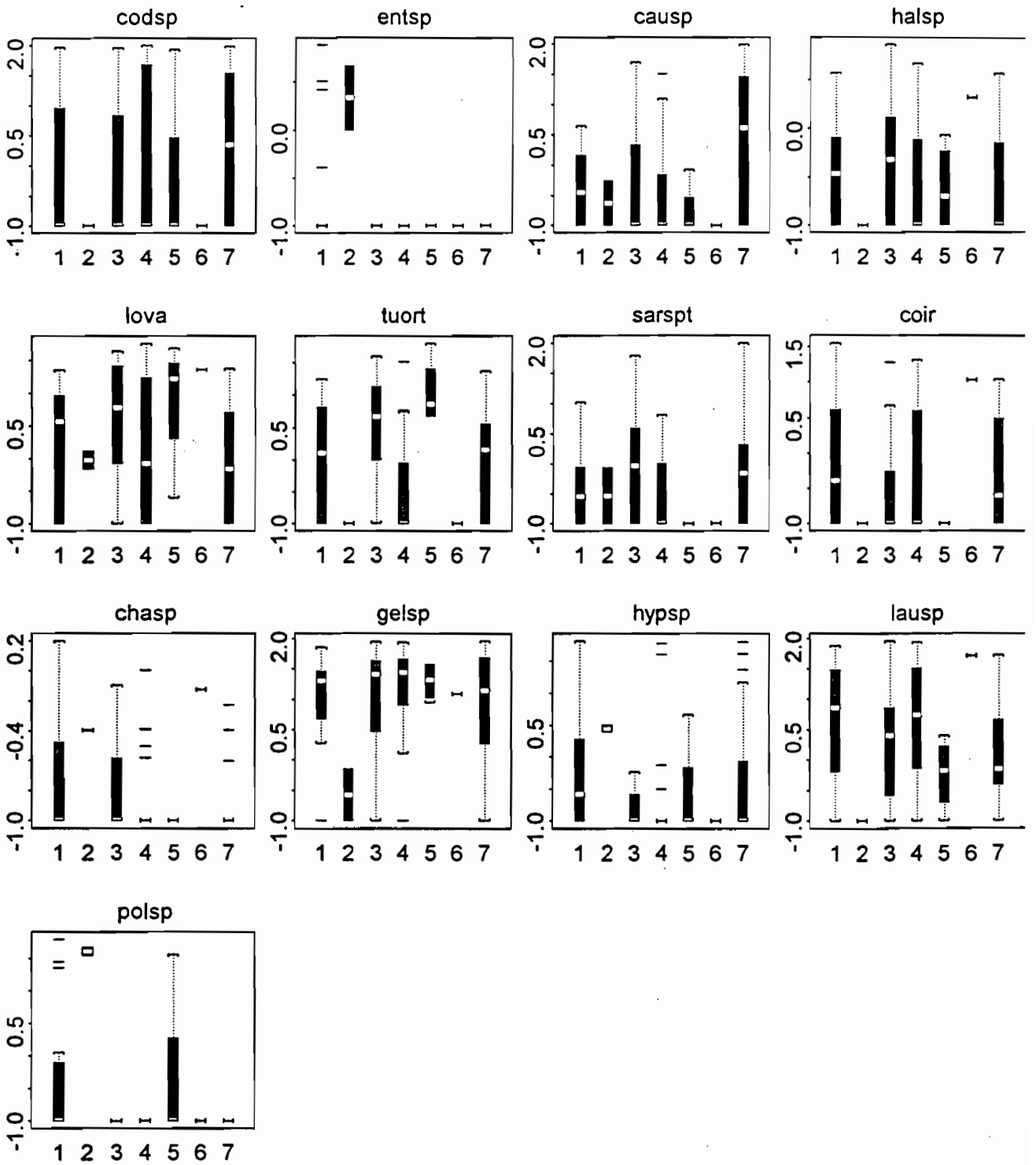
Mean % content of Lausp / sample by Trip for each Age class (±SE).



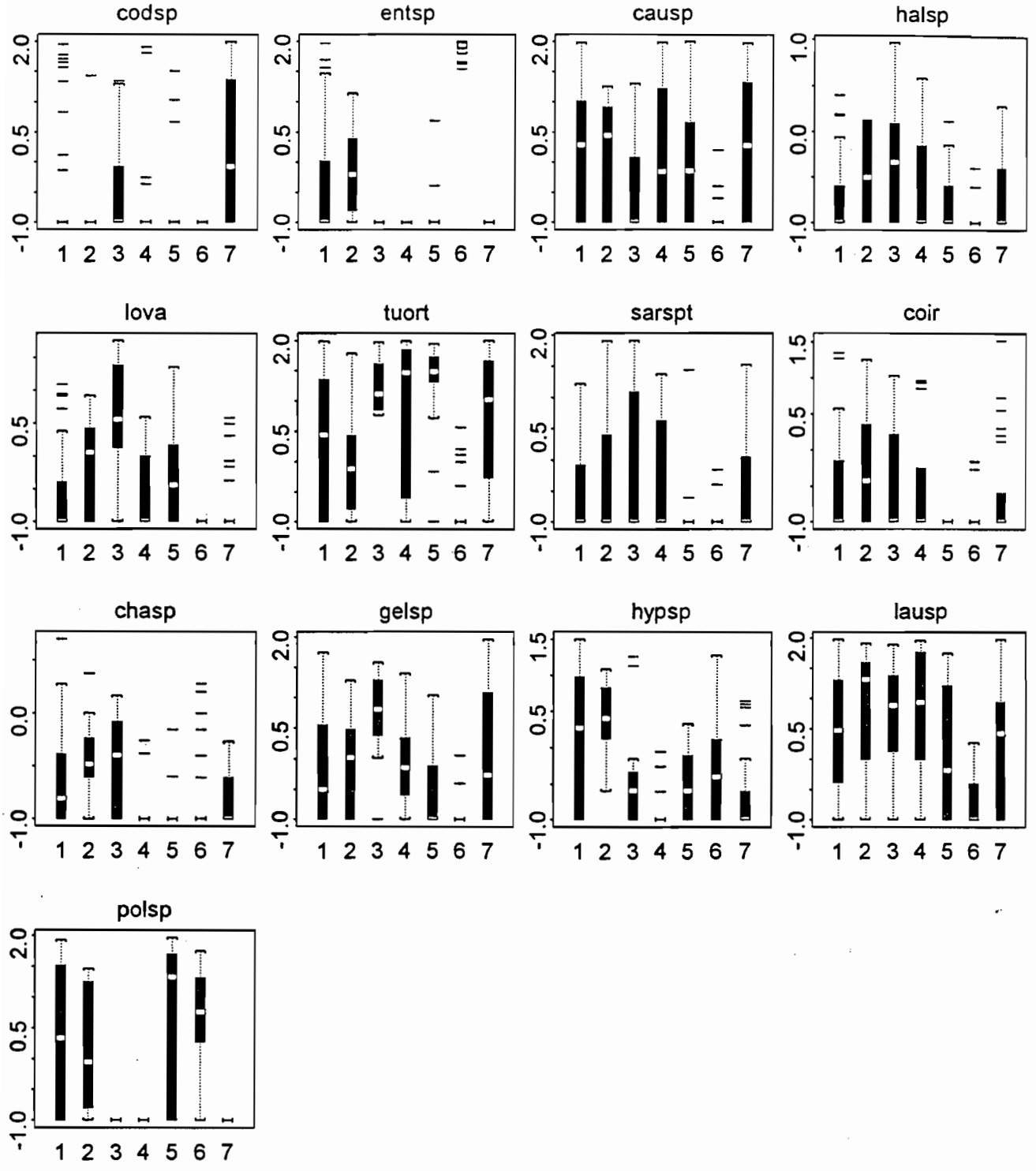

Mean % content of Polsp / sample by Trip for each Age class (±SE).
% content (log)
2.0
1.5
1.0
.5
0.0
-.5
-1.0
-1.5
N=
20 48 11
2 12 15
18 13 18
26 17 6
4 20 15
1 41 13
31 33 20
MAR-88
NOV-88
JAN-89
MAR-89
MAY-89
JUL-89
MAR-90
Sampling Occasion
Age Class
juvenile
sub adult
adult



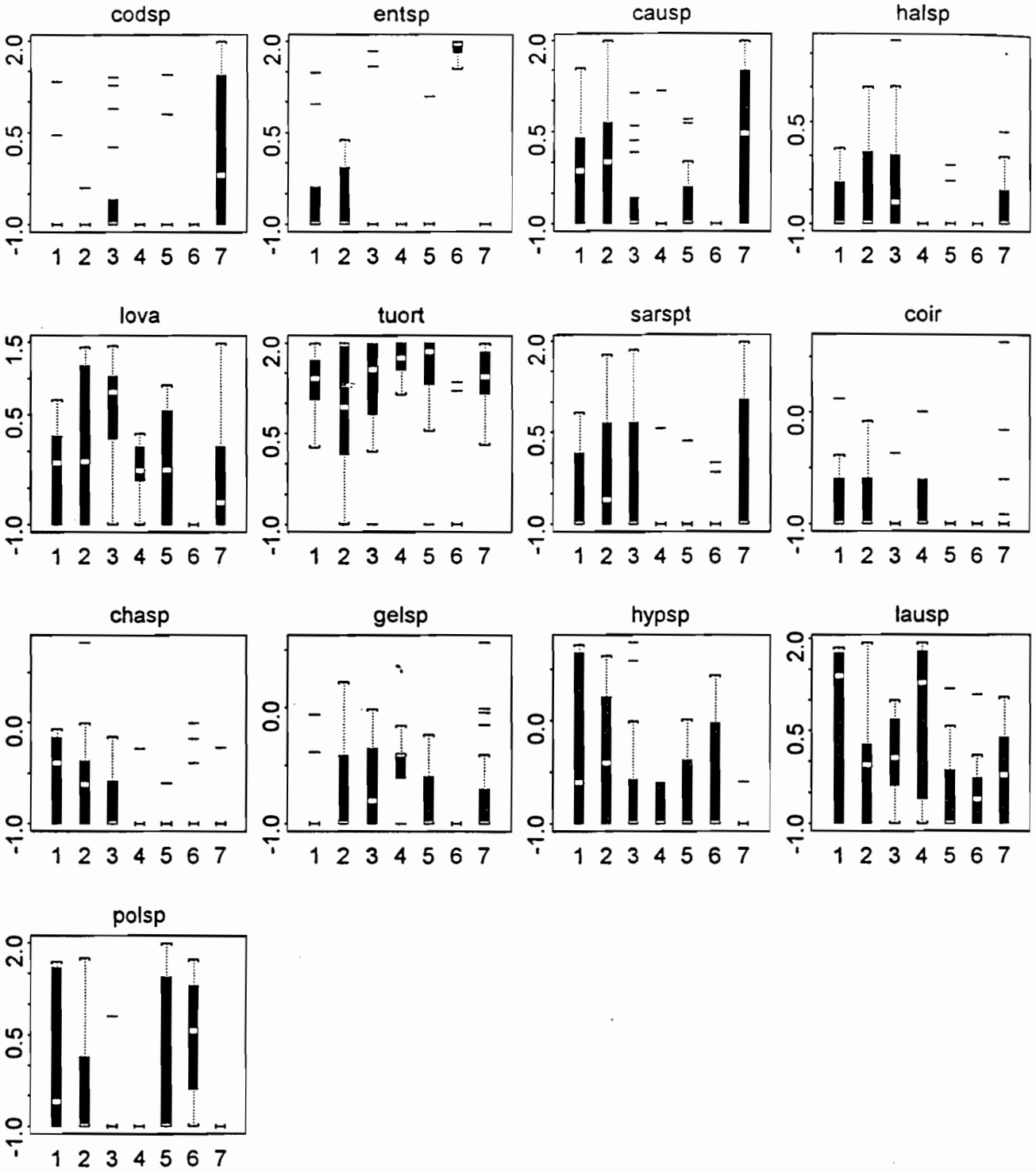
App.Figure 6.2- Boxplots for each diet component by age class. (1=juvenile, 2=subadult, 3=adult) (causp=*Caulerpa spp.*, chasp=*Champia spp.*, codsp=*Codium spp.*, coir=*Coelothrix irregularis*, entsp=*Enteromorpha spp.*, gelsp=*Gelidiella spp.*, halsp=*Halimeda sp.*, hypsp=*Hypnea spp.*, lausp=*Laurencia spp.*, lova=*Lobophora spp.*, polsp=*Polysiphonia spp.*, sarspt=*Sargassum spp.*, tuort=*Turbinaria ornata*)



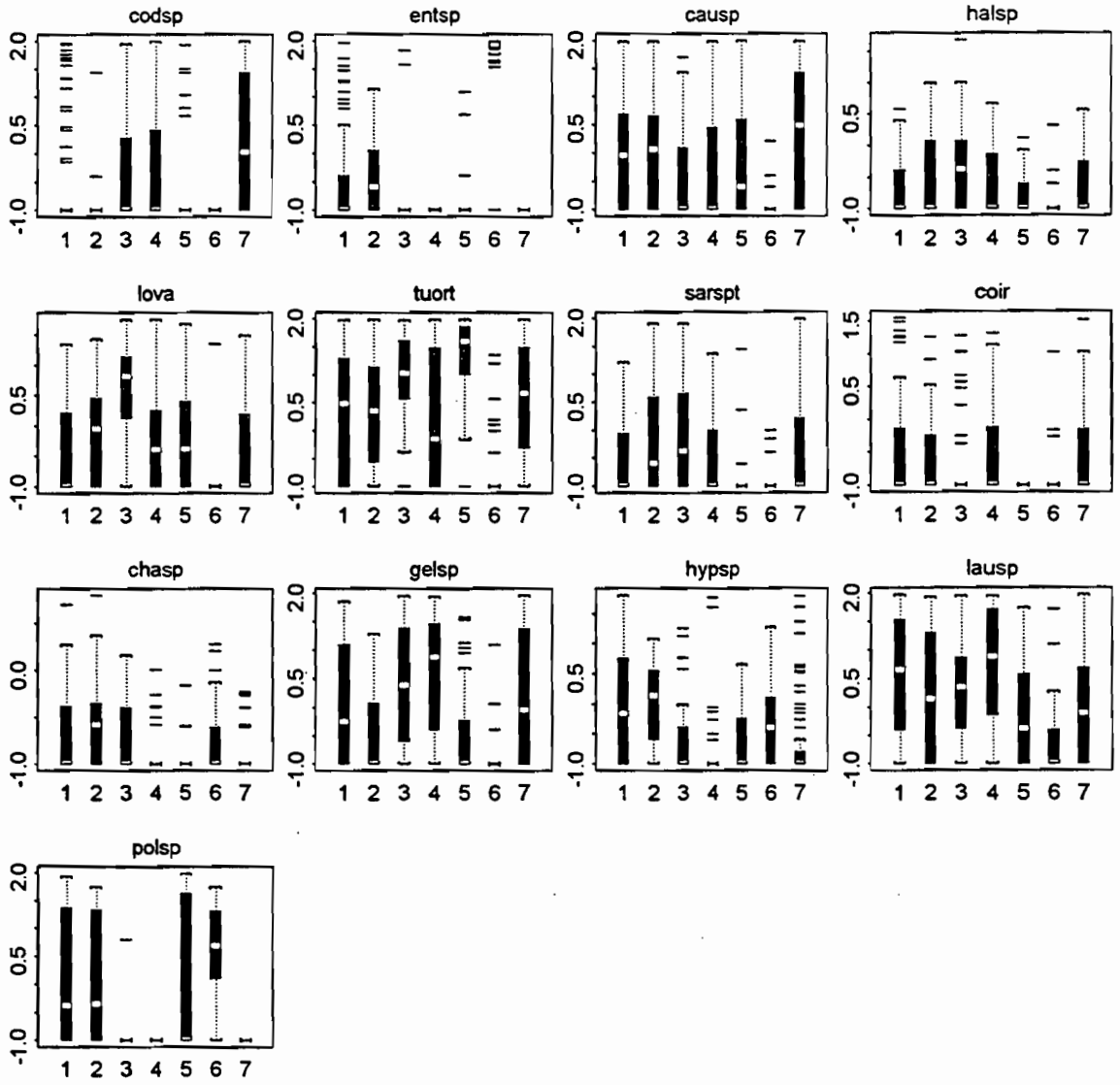
App. Figure 6.3- Boxplots for each diet component for each occasion in diets of juvenile turtles. (1=3/88, 2=11/88, 3=1/89, 4=3/89, 5=5/89, 6=7/89, 7=3/90) (causp=*Caulerpa spp.*, chasp=*Champia spp.*, codsp=*Codium spp.*, coir=*Coelothrix irregularis*, entsp=*Enteromorpha spp.*, gelsp=*Gelidiella spp.*, halsp=*Halimeda sp.*, hypsp=*Hypnea spp.*, lausp=*Laurencia spp.*, lova=*Lobophora spp.*, polsp=*Polysiphonia spp.*, sarspt=*Sargassum spp.*, tuort=*Turbinaria ornata*)



App. Figure 6.4- Boxplots for each diet component for each occasion in diets of subadult turtles. (1=3/88, 2=11/88, 3=1/89, 4=3/89, 5=5/89, 6=7/89, 7=3/90) (causp=*Caulerpa spp.*, chasp=*Champia spp.*, codsp=*Codium spp.*, coir=*Coelothrix irregularis*, entsp=*Enteromorpha spp.*, gelsp=*Gelidiella spp.*, halsp=*Halimeda sp.*, hypsp=*Hypnea spp.*, lausp=*Laurencia spp.*, lova=*Lobophora spp.*, polsp=*Polysiphonia spp.*, sarspt=*Sargassum spp.*, tuort=*Turbinaria ornata*)



App. Figure 6.5- Boxplots for each diet component for each occasion in diets of adult turtles. (1=3/88, 2=11/88, 3=1/89, 4=3/89, 5=5/89, 6=7/89, 7=3/90) (causp=*Caulerpa spp.*, chasp=*Champia spp.*, codsp=*Codium spp.*, coir=*Coelothrix irregularis*, entsp=*Enteromorpha spp.*, gelsp=*Gelidiella spp.*, halsp=*Halimeda sp.*, hypsp=*Hypnea spp.*, lausp=*Laurencia spp.*, lova=*Lobophora spp.*, polsp=*Polysiphonia spp.*, sarspt=*Sargassum spp.*, tuort=*Turbinaria ornata*)



App. Figure 6.6- Boxplots for each diet component by occasion. (1=3/88, 2=11/88, 3=1/89, 4=3/89, 5=5/89, 6=7/89, 7=3/90) (causp=*Caulerpa spp.*, chasp=*Champia spp.*, codsp=*Codium spp.*, coir=*Coelothrix irregularis*, entsp=*Enteromorpha spp.*, gelsp=*Gelidiella spp.*, halsp=*Halimeda sp.*, hypsp=*Hypnea spp.*, lausp=*Laurencia spp.*, lova=*Lobophora spp.*, polsp=*Polysiphonia spp.*, sarspt=*Sargassum spp.*, tuort=*Turbinaria ornata*)

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