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BIOLOGY OF THE EAST PACIFIC GREEN TURTLE,
CHELONIA MYDAS AGASSIZII, AT A WARM TEMPERATE FEEDING AREA
IN THE GULF OF CALIFORNIA, MEXICO.

By

Jeffrey Aleksandr Seminoff

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A Dissertation submitted to the Faculty of the
SCHOOL OF RENEWABLE NATURAL RESOURCES
In Partial Fulfillment of the Requirements
for the Degree of
DOCTOR OF PHILOSOPHY
WITH A MAJOR IN WILDLIFE AND FISHERIES SCIENCE
In the Graduate College
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entitled Biology of the East Pacific green turtle,
Chelonia mydas agassizii, at a warm temperate
feeding area in the Gulf of California, Mexico.

and recommend that it be accepted as fulfilling the dissertation requirement for the Degree of Doctor of Philosophy

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SIGNED: J. M. A. Smith!

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ABSTRACT

I studied the East Pacific green turtle, *Chelonia mydas agassizii*, at the Bahía de los Angeles foraging grounds of the central Gulf of California from July 1995 to October 1999. Entanglement nets were used to capture 153 green turtles among 16 capture sites. Pooled straight carapace length (SCL; mean \pm SE) was 75.1 ± 0.79 cm. Though there was no significant variation in mean SCL among years, there was strong evidence of a difference in mean SCL among capture sites. Most of the population (58%) consisted of immature turtles but did not differ significantly from a 1:1 immature:adult ratio. Pooled adult sex ratio (F:M) was heavily biased toward probable females (2.70:1.00) and differed substantially from a 1:1 ratio. Approximately 5% of the population showed signs of anthropogenic-derived injuries ranging from missing flippers to boat impact scars.

I collected gastric lavage samples from 101 green turtles and fecal samples from a subset of 45 turtles. Digestive tract contents were analyzed from seven stranded carcasses. The primary alga recovered in diet samples was *Gracilariopsis lemaneiformis*. Other major diet items included the green algae *Codium* sp. and *Ulva lactuca*. Animal matter was found in all sample types. Tube worms (Sabellidae), sponges (Porifera), sea hares (*Aplysia vaccaria*), and sea pens (*Ptilosarcus undulatus*) were the most commonly ingested invertebrates.

I studied home range sizes and movement patterns of 23 *C. m. agassizii*. Mean minimum convex polygon (MCP) home range area was 1,801 ha. Kernel density estimates (95%) of home range area had a mean of 1,545 ha. Home range length

averaged 7,548 m. Mean 24-h vagility was 9,535 m. Diurnal and nocturnal movements were evident. Turtles exhibited a bimodal pattern in which they foraged in nearshore marine algae pastures during evening and night hours and moved to offshore and/or insular resting sites by midmorning.

This study indicates that Bahía de los Angeles is an important foraging and developmental habitat for *C. m. agassizii*. Management efforts should focus on reducing human disturbance and limit or phase out the use of entanglement nets in the entire bay. In such efforts it is essential that local inhabitants are provided with appropriate alternatives that encourage sustainable marine resource use and economic progress.

INTRODUCTION

The Problem and its Context. – The East Pacific Green Turtle (*Chelonia mydas agassizii*) is listed as Endangered throughout its range (National Marine Fisheries Service and U. S. Fish and Wildlife Service, 1998). This turtle has experienced drastic declines over the last 30 years due to overharvest of eggs and adults and bycatch in legal drift- and set-net fisheries. Beginning in 1979 on-the-ground conservation started in the form of nesting beach protection at the primary nesting areas in Michoacan, Mexico (Alvarado and Figueroa 1987; 1991). Additional efforts to protect this species came in 1990 when the Mexican government declared a moratorium on the harvest and trade of sea turtles in México (Anonymous 1990). Despite these actions, exploitation of green turtles persists and populations continue to decline (Figueroa et al. 1992, Delgado and Alvarado 2000). Conservation efforts away from nesting areas have been limited and efforts to prevent further declines have been hampered by our lack of knowledge on *C. m. agassizii* in foraging areas, particularly near Baja California. The goals of this research were to characterize the ecology of the East Pacific green turtle at a foraging area in Bahía de los Angeles, Gulf of California, and provide information for future management efforts.

C. m. agassizii was historically abundant throughout the Gulf of California, particularly in the Midriff region and around offshore islands of the Baja California peninsula (Townsend 1916, Felger and Moser 1973, Clifton et al. 1982). Prior to the arrival of Europeans, the Seri Indians of northwestern Sonora were the primary group to utilize East Pacific green sea turtles in the Gulf (Bowen 1976, Felger and Moser 1985); however, the subsistence nature of their harvest prevented dramatic impacts. By the early

1900s, a large scale sea turtle fishery had started in the Gulf of California as sea turtle populations were large enough to support a lucrative industry (Alger 1913, Averett 1920, Craig 1926). Green turtles, exploited primarily for their meat, were commonly shipped to far away destinations in the United States such as Los Angeles and San Francisco (O'Donnell 1974). The abundant sea turtle populations supported this fishery for many decades as both Carr (1961) and Clifton et al. (1982) described the tremendous harvest in the Gulf of California.

In Bahía de los Angeles the turtle fishery was particularly strong and this town was considered the capital of the sea turtle fishery for northern Baja (Caldwell 1962a, 1963). Speaking of the Bahía de los Angeles harvest, Caldwell (1963) wrote, "I saw over 500 landed in a 3-week summer period in 1962 at Los Angeles Bay alone, and a comparable number, considering fishing effort, per week in winter." In total, 186.47 tons of sea turtles were landed that year from Bahía de los Angeles (Márquez 1984). Extraction was so heavy that during their investigations of *C. m. agassizii* in this region, Caldwell and Caldwell (1962) coined this species the 'black steer' of the Gulf of California. By the early 1980s, this population had crashed (Márquez 1984, Clifton et al. 1982). In 1982 only eleven tons of sea turtle were fished from Bahía de los Angeles, a figure representing a 96% drop in catch rate (Márquez 1984, Olguin-Mena 1990). As a result, the sea turtle fishing cooperative of Bahía de los Angeles disbanded in 1982 (Resendiz unpubl. data). Although not quantified, legal fishing continued at low levels near Bahía de los Angeles in the years following the collapse of organized commercial harvest (Resendiz pers. comm.). Anecdotal information from local fishermen suggests that by

the 1990 moratorium the green turtle population in Bahía de los Angeles was totally depleted (Savin de Smith, pers. comm.).

Today, East Pacific green sea turtles continue to be heavily impacted by human activities. High rates of mortality have been recorded from foraging areas along the Pacific coast lagoons of the Baja California peninsula and in the Gulf of California (Alvarado and Figueroa 1987; 1992, Nichols in prep., Seminoff et al. in prep. a), and this region may act as a "turtle sink." Green turtles migrating from southern nesting beaches are incidentally captured in the offshore drift-net and long-line fisheries and upon entering nearshore developmental and feeding areas are subject to incidental capture in local trawl and set-net fisheries (pers. obs.) and illegal poaching. Nichols (in prep.) estimates that between 5,000 and 7,000 sea turtles die annually in this region.

The killing of green turtles in feeding areas has resulted in a dramatic decline in nesting activity at the two largest rookeries (Alvarado and Figueroa 1987, 1989; Figueroa et al. 1992). In the 1950s an estimated 25,000 females nested annually at Colola and Maruata, Michoacán, México (Cliffon et al. 1982); however, this number has since dwindled to below 150 females (Alvarado and Delgado 2000). The Mexican Government has recently acknowledged the strong link between the crash in nesting females with mortality in feeding areas and efforts are underway to develop conservation strategies aimed to reduce these impacts (pers. obs.). Current research (this dissertation, Nichols in prep.) has begun to describe the ecology of *C. m. agassizii* in feeding areas and this information has been crucial in identifying priority areas and guiding appropriate protection efforts.

Taxonomic status of the East Pacific green turtle. – The East Pacific Green turtle (a.k.a. the black turtle) is in the family Cheloniidae and subfamily Cheloniinae (Deraniyagala 1953). Its species designation has been under tremendous scrutiny; some authors support full species status (e.g., Pritchard et al. 1983, Figueroa 1989) whereas others favor subspecies status (e.g., Bowen et al. 1992, Karl et al. 1992, Zug 1996). This turtle was originally described as a full species, *Chelonia agassizii*, by Bocourt (1868). Carr (1952) described it as a subspecies, *Chelonia mydas agassizii*. However, in a later treatment Carr (1961) appeared to waver toward support of full species status as he recognized the unique coloration and shape of this turtle; “I would say that a complete novice in turtle study would be able to separate 95 to 98 percent of a mixed lot of *Chelonia*.” Caldwell (1962b) described the Northeastern Pacific green turtle and provided the apparent subspecies synonym of *Chelonia mydas carrinegra* (the name is derived from Caldwell’s colleague, Archie Carr, and the turtles’ dark pigmentation). Figueroa (1989) examined skull characteristics of turtles from the Michoacán nesting rookery and those from the Caribbean nesting colony at Tortuguero, Costa Rica, and concluded that the *agassizii*-type was sufficiently dissimilar to the Caribbean green turtle stock to warrant its status as a full species. Pritchard (1998) also justified full species status, stating that “*agassizii*- and *mydas*-like forms are sympatric in several places in the Pacific, including the Galapagos Islands and New Guinea; the degree of differentiation in size, shape, and color is more extreme than that found in any other *Chelonia* population; the dark plastral pigment of *agassizii* is not environmentally derived; and there may be purely physical reasons why a 40-kg adult male *agassizii* may be unable to mate with a

200-kg female *mydas*, even if the two do come in contact.” Subsequent contributions on the subject include that of Kamezaki and Matsui (1995) who examined forty-five skulls from six nesting sites around the world including *agassizii* skulls from the Galapagos Islands and concluded that, though the *agassizii* form was unique, it did not warrant full species status. Similarly, genetic studies by Bowen et al. (1993) and Grady and Quattro (1999) found that East Pacific green turtles represented only a small subset of lineage diversity within the mtDNA gene tree for globally distributed *Chelonia*, and thus were deserving of no greater distinction than subspecies level. Studies by Karl et al. (1992) on nuclear DNA supported these findings.

Today, the debate over subspecies versus full species status continues. Pritchard (1999) maintains his classification as full species whereas Bowen and Karl (1999) and Karl and Bowen (1999) believe such recognition is a ‘geopolitical’ designation for a population that shows little genetic variation from other green turtle stocks. From an official management standpoint, the East Pacific green turtle is currently considered a subspecies under the Recovery Plan for the U.S. Pacific Populations of the East Pacific Green Turtle (United States Fish & Wildlife Service and National Marine Fisheries Service 1998).

In accordance with the U. S. Fish and Wildlife and National Marine Fisheries Service and current genetic evidence, I support the *agassizii* subspecies designation of the East Pacific green turtle. However, I argue that the East Pacific green turtle, regardless of taxonomic designation, is uniquely impacted by human activities and should thus be the focus of intensive conservation efforts.

Natural History of the East Pacific Green turtle. – Like most sea turtles, *C. m.*

agassizii is migratory and uses a range of widely separated nesting localities and foraging habitats during its life time. The primary nesting beaches are located in Michoacán, México (Figueroa et al. 1993, Pritchard and Clifton 1980), the Revillagigedo Islands, México (Brattstrom 1982, Awbrey et al. 1984), and the Galapagos Islands, Ecuador (Green 1984). Sporadic nesting has been reported from the coast of Middle America (Cornelius 1976; 1982). The most important feeding areas of East Pacific green turtles are found in the Gulf of California (Caldwell 1962, Clifton et al. 1982), the Pacific coast lagoons of the Baja California peninsula (Townsend 1916), Columbia (Sanchez and Quiroga unpubl. data), Peru (Paredes 1967), and the Galapagos Islands, Ecuador (Green and Ortiz-Crespo 1982). Green turtles have also been observed along the Pacific Coast of the United States from San Diego (Stinson 1984, Dutton and McDonald 1992) to Alaska (Loshbaugh 1993).

Green turtles once nested year round at several nesting localities (Clifton, pers. comm.), but today nest most commonly during the winter months of October to February (Alvarado and Figueroa 1987; 1992). Females deposit up to five clutches in a nesting season, depositing a mean of 66 eggs per nest (Figueroa et al. 1992). Nesting occurs every two to three seasons (Figueroa et al. 1992) and genetic evidence indicates that females return to the same beach from which they originally hatched (i.e. nest site fidelity; Dutton et al. 1996, Chassin Noria et al. in press). Mean clutch size varies among rookeries with reports ranging from 65 eggs/nest (Michoacán, México; Alvarado and Figueroa 1990) to 87 eggs/nest (Playa Naranjo, Costa Rica; Cornelius 1976). Hatchlings

emerge between 42 and 62 days after deposition (Zamora 1990). Upon entering the marine environment, hatchlings begin a pelagic phase that is followed by immigration into foraging and developmental habitats.

The nesting area – feeding area link has been established through flipper tag returns from turtles nesting in the Galapagos that forage along the Pacific Coast of Central America (Green 1984) and turtles nesting in Michoacán, México, that forage along the Pacific coast of Central America to the Gulf of California (Alvarado and Figueroa 1992). Recent genetic study has similarly established the link between nesting areas in Michoacán, with feeding areas along the Baja California peninsula (Nichols et al. in press) and movements between these areas have been tracked through satellite telemetry (Nichols et al. 2000).

Most studies of *C. m. agassizii* away from nesting beaches have occurred in the Baja California and Gulf of California region and focused on size distributions and diet selection. In addition, a number of behaviors have been observed that are unique among the global *Chelonia* complex. The distribution of size classes in this region has been described primarily through inspection of turtles landed during the days of legal fisheries. In the Gulf of California, Caldwell (1962, 1963), Márquez and Dol (1973) and Clifton et al. (1982) reported the presence of immature and adult green turtles of both sexes. The only reports on size distribution in Pacific waters come from Stinson (1984) and Dutton and McDonald (1992), who described the year-round residence of both immature and adult green turtles.

The diet of *C. m. agassizii* has been described as primarily herbivorous (Bjorndal 1997). Food selection is habitat specific and turtles may be primarily sea grass consumers (e.g., Felger and Moser 1973) or marine algae consumers (e.g., Marquez 1990) depending on the feeding area. In addition, East Pacific green turtles are known to consume larger portions of animal matter than *Chelonia* populations from other regions (Bjorndal 1997).

East Pacific green turtles inhabiting the temperate waters of the Eastern Pacific ocean face tremendous annual fluctuation in sea water temperature that elicit a series of unique behaviors not described for other green turtle populations. During winter months, waters of the northern and central Gulf of California and Pacific coast of the Baja California peninsula may drop to below 15 C. In response, green turtles become sluggish and may exhibit overwintering torpor (Felger et al. 1976), a behavior that has not been described in other green turtle populations. This behavior has had unfortunate consequence in that it facilitated large-scale harvests of torpid turtles during the 1960s and 1970s (Felger et al. 1976). During the warmest summer months, Gulf of California water temperatures may approach 30 C (Fig. I.1-6.). During these periods, green turtles facing critical thermal thresholds may exhibit unusual surfacing and floating behavior in an effort to reduce body temperatures (Heath and McGinnis 1980).

Historic records of green turtle populations in the Gulf of California indicate that the extensive marine algae pastures and sea grass beds in this region supported a population of considerably larger size than that of today (Townsend 1916, Caldwell 1962b). The decline in number of green turtles due to human harvest has been documented (Caldwell

1963, Clifton et al. 1982, Nichols in prep.). Despite these declines, the marine habitats of this sea remain intact and continue to provide abundant food resources for green turtles. This highlights the importance of the Gulf of California as a critical green turtle feeding region and establishes this area as a priority candidate for future management and conservation efforts.

Explanation of Dissertation Format. – The specific goals, methods, results, and discussions for each component of this research are provided in stand-alone chapters included as Appendices A, B, and C in this dissertation. The remaining portions of the dissertation include appendices that contain illustrations, photographs, and various data sets (e.g., sea surface temperature, flipper tagging register) that I hope will be useful for others studying sea turtles in the Gulf of California.

In each of the primary chapters my co-authors are Wallace J. Nichols (University of Arizona) and Antonio Resendiz S. Hidalgo (Centro Regional de Investigación Pesquera, México). Nichols and I have been researching Mexican sea turtles since 1993. Currently, he is completing his dissertation entitled “Biology and Conservation of the Sea Turtles of Baja California.” This work focuses on migration, genetics, and mortality of *C. m. agassizii* and does not overlap with my research on this endangered species. Resendiz has facilitated this research by providing key contacts, local guides, and housing during all phases of this investigation. Though both Nichols and Resendiz are co-authors on each chapter, this dissertation represents my original and independent research.

PRESENT STUDY

The methods, results, and conclusions of this study are presented in the papers appended to this dissertation. The following is a summary of the most important findings of this dissertation. The primary goals of this research were to determine the population structure, foraging ecology, and local movement patterns of the East Pacific green turtle in the Bahía de los Angeles foraging habitat of the western central Gulf of California and contribute our findings to efforts recently-undertaken to protect this species.

Study Area. – Fieldwork was conducted at the Bahía de los Angeles foraging area of the central Gulf of California, México (28°58' N, 113°33' W). This semi-enclosed NNE-oriented bay is approximately 12 km long with a maximum width of 5 km at its southern limit. A series of seventeen islands separate the bay from the deep waters of the adjacent Ballenas Channel. This region is influenced by the waters of the Ballenas Channel that are characterized by strong tidal mixing (Bray and Robles 1991) and high nutrient levels (Alvarez-Borrego et al. 1978). Marine algae are the prevailing marine vegetation in the study area (Pacheco-Ruíz and Zertuche-González 1996a; 1996b, Pacheco-Ruíz et al. 1999). Extensive marine algae pastures are present along the western and southern margins within the bay. The dominant macroalgae species in these regions are *Gracilariopsis lemaneiformis* (Pacheco-Ruiz et al. 1999) and *Sargassum* spp. (Pacheco-Ruíz et al. 1998). In addition, a diverse assemblage of marine invertebrates occurs throughout the bay (Brusca 1980).

Population structure. – Information derived from mark-recapture study and flipper tag returns show that Bahía de los Angeles foraging population appears to be comprised of

both resident turtles and transients. Among resident turtles, telemetry efforts have established that most turtles maintain distinct home ranges within this habitat (Seminoff in prep. c). Residents apparently maintain fidelity to specific regions within this foraging habitat and, if displaced, are able to return to these sites. We observed two cases of apparent homing by displaced green turtles. Such behavior has been demonstrated by green turtles at other feeding areas (Ireland 1979), but our data are the first to show this behavior in the Eastern Pacific Ocean.

Residents are composed of pre-reproductive size classes, which includes new immigrants to large immature-sized turtles. It is also likely that adults are resident to this feeding habitat between nesting cycles. However, it remains unclear how many of the adult-sized turtles captured during this study were resident and what proportion were transients from other feeding habitats en route to and from distant breeding grounds.

In the present study we have not attempted to sample the entire range of habitats within Bahía de los Angeles, but have focused on the shallow habitats. The limitations of entanglement netting did not allow capture attempts in deep water zones, thus our efforts may not accurately describe the population characteristics of *C. m. agassizii* in these areas. Further, the lack of definitive procedures such as radioimmunoassay (Owens et al. 1978), ultrasound imaging (Rostal et al. 1990), or laparoscopy (Wood et al. 1983) limited our ability to absolutely determine maturity status or sex. While use of the mean nesting size criterion only provides an approximation of the true size upon sexual maturity, it remains the preferred non-invasive maturity estimation technique (Limpus and Reed 1985, Limpus pers. comm.). Based on this criterion, the population of green turtles in the

shallow, near-shore areas of Bahía de los Angeles is structured as follows. It contains predominantly immature-sized turtles (1.3:1.0 immature:adult ratio) that recruit to this foraging ground at SCL = 45 cm or larger. The population of turtles with SCL \geq mean nesting size is strongly biased toward probable female turtles (2.7:1.0 unsexed:male sex ratio). Posthatchlings and small juvenile turtles are absent from this habitat.

The absence of the small juvenile green turtles may be the result of varying habitat requirements for different life history stages. Carr and Caldwell (1956) and Carr (1980) introduced the concept of developmental migration to account for differences in size classes of turtles for different feeding grounds. The waters around Baja California provide evidence for such a migration. While Bahía hosts predominantly larger immatures and adults, capture data from Pacific lagoons of Baja California show a prevalence of smaller juveniles (Seminoff et al. 2000, Nichols in prep). In addition to the differences in size structure, these two feeding habitats differ considerably in their physical make-up (described in Seminoff et al. 2000), and these differences likely play a role in recruitment patterns of green turtles.

The presence of a greater number of unsexed turtles observed during this study is consistent with Caldwell's (1962) study of the turtle fishery in this feeding area and may provide additional evidence of a developmental migration. If as indicated in maturity structure analyses, a developmental migration is present, then it is possible that as adult males exhibit a tendency for pelagic existence which limits entrance into nearshore habitats (Cliffon pers. comm., Ross 1984). If developmental migration is a common element in the life history of *C. m. agassizii*, it will require sampling from multiple

feeding grounds rather than a single habitat to describe the population structure of *C. m. agassizii* in the Gulf of California.

We measured a maximum growth rate of 2.6 cm yr^{-1} (70.0-79.9 cm SCL size class). While this figure is considerably higher than growth rates of *C. m. agassizii* in the Galapagos (0.15 to 0.45 cm yr^{-1} ; Green 1993), it falls within the range of values found for green turtles at other feeding areas outside the Eastern Pacific Ocean (e.g., Limpus and Walter 1980, Bjorndal and Bolten 1988). It is important to note that the growth witnessed in this study was for a limited size range (50 – 90 cm SCL) and does not represent the entire growth curve for *C. m. agassizii*. Thus it remains difficult to predict absolute age at sexual maturity, and we are instead limited to estimation of the time-to-sexual maturity after immigrating into the Bahía de los Angeles foraging habitat. We estimated time-to-sexual maturity for turtles based on a linear growth model, using the mean growth rate of all sizes pooled (1.7 cm yr^{-1}). The smallest size class represented by the capture data is the 45-50 cm SCL category. Assuming that the average *C. m. agassizii* foraging in this study area reaches sexual maturity at size close to the mean nesting size and that growth rates determined at Bahía de los Angeles remain constant until maturity, then turtles measuring 45 cm SCL would require roughly 16 years to reach sexual maturity after immigrating into the Bahía de los Angeles foraging area. Despite the speculative nature of this estimate, it is clear that turtles will require a large period of time at this foraging habitat to reach a size consistent with sexual maturity.

Stranding evidence from Bahía de los Angeles (this study) and other areas in Baja California (Nichols in prep.), and accounts of local human consumption suggest that

human-induced mortality remains at dangerously high levels. The 4.6% of known dead turtles in Bahía de los Angeles indicates a problem with bycatch in local set nets. In assessing the impact of this mortality, it is essential to note that strandings and flipper tag returns are only a minimum estimate of actual mortality. Considering the conservative nature of these data, these cases represent a serious blow to the local population. Despite the low frequency of observed sea turtle consumption events, it is likely that a very large number of green turtles are consumed locally each year.

Our estimate of mean survivorship ($\phi = 0.52$, $SE = 0.21$) indicates that nearly half of all turtles either leave or are extracted from this system annually. However, an accurate interpretation of this figure remains difficult due to our inability to determine how many animals are extracted from the system (i.e. human-induced mortality) versus the number of turtles that emigrate naturally. Similarly, our estimates of immigration can not depict how many turtles were present but not caught in previous years versus how many were new recruits to the feeding grounds. Regardless, our measures of emigration versus immigration indicate an alarming decline in the number of green turtles in Bahía de los Angeles.

Few studies have addressed survivorship in green turtles, but those that have provide figures that are generally much greater than that found in this study (e.g. $\phi = 0.67 - 0.95$ in Oman, Siddeek and Baldwin 1996). In the Oman case and in our study, survivorship is based on both the number of turtles that remain after some level of human extraction and those that survive natural mortality. Our assumption for the Bahía de los Angeles population is that the vast majority of deaths are in some way human-induced. Thus,

reducing human intervention, can conceivably increase survivorship. Without such efforts the current population will likely continue its declining trend. If we consider that, based on growth data, a newly settling turtle must remain in coastal foraging habitats for upwards of 20 years before reaching maturity, then it is imperative that human impacts in foraging areas must be substantially reduced to enable a recovery of *C. m. agassizii*.

An accurate assessment of sea turtle population structure and a thorough understanding of the negative impacts to these populations are vital to the implementation of appropriate conservation strategies. Though this study may be indicative of biological patterns at other feeding grounds in the Gulf, the conclusions presented here are specific only to Bahía de los Angeles. Assessment of population structure and the causes for particular distributional patterns for the entire eastern Pacific green turtle population will require additional studies in both nearshore and offshore feeding areas throughout the range of this endangered species.

Foraging Ecology. – East Pacific green turtles in Bahía de los Angeles forage primarily on marine algae. Their predominantly herbivorous diet is consistent with *Chelonia* throughout its range (Bjorndal 1980, Mortimer 1981, Garnett et al. 1985, Ross 1985, Bjorndal 1997). The red alga *Gracilariopsis lemaneiformis* (Rhodophyta) was the most commonly ingested food item among the turtles we examined. The prevalence of *G. lemaneiformis* among the diet samples reflects this species' great abundance in the study area. With an annual biomass of 10-20 metric tons per hectare, it is the most widespread marine alga in the study area (Pacheco-Rúiz et al. 1999). Dense stands or 'pastures' of this red alga occur over roughly 15 ha of sandy bottom habitat along the

shallow water margins of the bay (Pacheco-Rúiz et al. 1999). Green turtles commonly congregated over these pastures for foraging activities (Seminoff et al. in prep.). Turtles also foraged on less common algae from nearshore areas lacking *G. lemaneiformis*. The recovery from diet samples of green algae (Chlorophyta) species such as *Ulva lactuca*, *Chaetomorpha antennina*, and *Codium* spp. confirm that *C. m. agassizii* forage in a variety of marine habitats throughout the bay.

My data support prior observations that green turtles modify their diets to meet local conditions (Balazs 1980, Bjorndal 1980, Ross 1984, Balazs et al. 1987). The diet of green turtles in Bahía de los Angeles is significantly different than that of other central Gulf of California populations. The diversity of herbivorous foods consumed by green turtles in this marine algae-dominated region of the Gulf of California is greater than that of turtles feeding in a nearby seagrass ecosystem (Felger and Moser 1973, 1987; Clifton et al. 1982). While I have documented at least five major algal diet items in the turtles examined in Bahía de los Angeles, green turtles in the Infiernillo Channel of the east-central Gulf of California feed almost exclusively on eelgrass (*Zostera marina* L.) (Felger and Moser 1973, 1987).

Whereas feeding specificity on seagrasses may be a result of hind-gut endosymbiont specialization (Bjorndal 1985), it appears that the micro-flora in the hind guts of green turtles examined in this study are capable of processing a wide variety of both red and green algae species. To better facilitate nutrient assimilation, green turtles appear to take small bites of marine algae foods during consumption. In the diet samples examined, algae were commonly fragmented to very small size (ca. 1-cm length). The resulting

small food particle size is functionally beneficial to nutrient assimilation in species such as the green turtle that rely on hind-gut endosymbiont fermentation (Bjorndal et al. 1991). In freshwater herbivorous turtles benefiting from hind-gut fermentation, Bjorndal (1990) showed that smaller food-particle size resulted in greater amounts of exposed food surface area in the digestive tract, thus, more efficient digestion.

There remain at least two algae that appear indigestible to green turtles. The brown algae (Phaeophyta) *Sargassum* spp. and *Padina durvillaei* were commonly found intact in fecal samples. While these species are abundant in the study area, their trace occurrence in diet samples indicates possible avoidance by green turtles. The intact nature of these items after passing through the digestive tract indicates their structural composition is able to withstand digestion by the *C. m. agassizii* I examined. Thus, it appears that, to some extent the digestibility of local foods affects the diet selection of green turtles.

Green turtles in Bahía de los Angeles augment their diet with animal matter. The possibility that such foods make a major contribution of vitamins, trace minerals, or essential amino acids for herbivorous green turtles has been discussed (Bjorndal 1990, 1991; Hirth et al. 1993) and may explain why, even with abundant algae resources, green turtles feed on animal matter. I documented consumption of over 25 non-algal species. However, because (1) rigid invertebrate parts are not easily recovered in lavage techniques and (2) soft bodied invertebrates are completely digested and leave behind no identifiable remains in fecal samples, the species richness and abundance of non-algal species recovered in this study are likely underestimates. Invertebrate consumption by green turtles in Bahía de los Angeles is noteworthy regardless of this sampling bias.

Though foraging on invertebrates has been previously observed in green turtles (Carr 1952, Felger and Moser 1973, Balazs 1980, Mortimer 1981), few studies have revealed such great diversity and abundance.

Much of the invertebrate material found in diet samples is attributable to incidental consumption; however, there is evidence that at least one animal species was purposefully consumed. The fleshy sea pen (*Ptilosarcus undulatus*) was frequently recovered in diet samples. This solitary cnidarian anchors in sandy substrates at depths of 10 m to 50 m (Brusca 1980). Its patchy distribution within the study area does not overlap even the deepest occurring marine alga, thus minimizing the likelihood of incidental consumption. The high rate of occurrence of *P. undulatus* among diet samples despite its uncommon nature in Bahía de los Angeles suggests this item was actively sought by foraging green turtles. Unlike other invertebrates that were slow to digest by green turtles (e.g., sponges, sea slugs), all but the calcareous spines of these animals were digested prior to leaving the stomach region. This ease of digestion may have contributed to the selection of sea pens by green turtles.

In addition, green turtles ingested sand, pebbles, shell fragments, and anthropogenic debris. These items were present in small quantities in the diet contents and were likely taken as turtles foraged on benthic foods. Anthropogenic debris may have also been consumed by green turtles at the water's surface where it collects in driftlines or convergences.

In terms of overall life cycle, a general model of the foraging ecology of *C. m. agassizii* in Bahía de los Angeles has become evident. Both juveniles and adults of both

sexes exploit the abundant food resources of Bahía de los Angeles. Green turtles forage for the majority of their diet in near-shore waters of depths no greater than 10 m. They remain closely associated with algal pastures in these regions during diurnal and nocturnal periods. Gastric lavage sampling of day- and night-captured turtles indicate that they feed throughout the diel cycle. Movement is not restricted to these habitats and green turtles continue to feed after departing the near shore algal pastures. The prevalence of deep water benthic invertebrates such as tube worms (Sabellidae), sea pens, and yellow-polyp black coral (*Antilopathes galapagensis*) in diet samples confirms that the majority of animal matter consumption occurs in deeper, offshore habitats.

Nocturnal foraging at Bahía de los Angeles is consistent with reports from the Caribbean (Bjorndal 1980, Ogden et al. 1983), Hawaii (Balazs et al. 1987) and western Pacific (Hirth et al. 1992). We observed heavy boat traffic and fishing pressure on a daily basis over nearshore feeding pastures throughout the study area. The particular foraging behavior we observed may be in response to these human activities. Similarly, Balazs et al. (1987) saw regular night time foraging in Hawaiian *C. mydas* and suggested this was an avoidance response to human presence in the nearshore feeding localities.

The role of Bahía de los Angeles in respect to the entire Gulf of California green turtle population remains unclear. Green turtles in this algae-dominated area appear to exhibit different foraging trends than those reported from other areas in the Gulf (Cliffon et al. 1982, Felger and Moser 1973; 1987) and it is likely that these differences affect both growth rate and reproductive output at these distinct foraging localities (Carr

and Carr 1970). To elucidate these trends, additional diet studies in a variety of other foraging habitats within the Gulf are needed.

Home range. – Home ranges of green turtles in Bahía de los Angeles are significantly larger than areas of use for sea turtles in other regions. I measured a mean minimum convex polygon size of 1,801 ha. In comparison, Renaud et al. (1995) reported home ranges of 22 to 311 ha for juvenile green turtles in south Texas; Mendonca (1983) found home ranges of immature *C. mydas* from 180 ha to 1,662 ha in a Florida lagoon; and Whiting and Miller (1998) measured short-term foraging ranges from 84 to 860 ha for adults in Australia. The largest home ranges observed in this study were from turtles that exhibited movements between the two primary marine algae pastures and turtles that shuttled between insular and peninsular activity centers. I believe the great distance (8 km) between the two primary algae pastures and wide separation between insular and peninsular habitats (≥ 4.5 km) contribute to the enlarged home range areas I measured here. Distance between activity centers is considerably less at other green turtle foraging habitats. Ogden et al. (1983) described feeding and resting sites in Tague Bay, St. Croix, to be separated by 200 to 500 m, and Williams (1988) found that immature green turtles used feeding and resting sites that were separated by less than 500 m.

Home range size varied greatly and was not correlated with body size. Differences in home range sizes were particularly clear when comparing the small home ranges of turtles 225 and 311 (584 ha and 697 ha, respectively) to the large home ranges of turtles 314 and 413 (2,833 ha and 3,908 ha, respectively). Further, some of the largest turtles in this study had the smallest home ranges, whereas some of the smallest turtles moved

within the largest home range area. In contrast, Mendonca (1983) showed a positive correlation of turtle size with home range size in a Florida lagoon, and Arms (1996) reported that range of movement of green turtles within the lower Laguna Madre of South Texas Gulf of México was related to turtle size, with the largest turtles traveling the greatest distances. I believe the lack of correlation between home range size and body size is related to the particular oceanography of Bahía de los Angeles. Unlike the gradual continental shelf drop-off characteristic of green turtle foraging areas in the Caribbean (Bjorndal 1980, Ogden et al. 1983) and the Gulf of Mexico (Renaud et al. 1995, Arms 1996), the coasts near Bahía de los Angeles are marked by dramatic bathymetry with great water depths close to shore. The Ballenas Channel which marks the western boundary of the study area is the site of a deep water trench, and waters drop to over 3,000 m depth within 15 km of the study site (Bray and Robles 1991). The steep shores, lack of extensive shallow water habitats, and reduced photic zone minimize the area of macroalgae-dominated feeding habitat. Wide ranging movements are thus restricted and the scale of foraging movements among different sizes and life stages is homogenized.

Loss of transmitter signal was responsible for a lack of sufficient data to estimate home ranges of 10 tagged turtles. While tag malfunction, tag loss, and human-intervention (i.e., illegal poaching) may have played a role in the loss of transmitter signal, I believe that in most cases the loss of signal during tracking periods was due to departure of tagged turtles from the study area. Transmitter signals prematurely ceased in nearly 40% of tracked immatures and over two thirds of the tagged adults. The higher rate of signal loss among tagged adults may be indicative of a higher rate of departure

(i.e., transience) among these turtles. However, because one can not be sure of the particular causes of signal loss, it remains unclear how many of the turtles captured during this study were resident and what proportion were transients from other feeding habitats en route to and from distant breeding grounds.

Daily movements. – Green turtle vagility in Bahía de los Angeles is large compared to other green turtle populations (mean = 9.5 km/d). Mendonca (1983) found summer daily vagility distances for immature green turtles in Florida ranging from 1.22 to 4.08 km/d; Whiting and Miller (1998) documented a daily vagility range of 0.9 to 4.9 km/d for adult Australian green turtles; and Renaud et al. (1995) reported small movements with a maximum vagility of 1.2 km/d for juvenile green turtles in Texas waters. The large distances between foraging and resting habitats in Bahía de los Angeles may be responsible for the relatively large 24-h vagility observed in this study.

As revealed by the short-term tracking, daily vagility of green turtles is variable. The 24-h movements observed in this study range from 5,118 m to 15,340 m. Variation is especially evident when the shorter movements of turtles 311, 406, and 415 (mean = $5,818 \pm 374$ m) are compared to the long distance movements of turtles 310, 314, and 422 (mean = $13,388 \pm 1,335$ m). Such individual differences in movement patterns within a foraging ground population have also been noted for green turtles in Australia (Whiting and Miller 1998), Florida (Mendonca 1983), and Texas (Arms 1996).

Turtles tracked during this study followed a bimodal pattern in which they moved over nearshore marine algae pastures during evening and night hours and by midmorning moved to offshore and insular sites. Turtles visit the nearshore regions to forage on the

abundant marine algae (Seminoff et al. 1998, in prep. b) but activities associated with offshore habitats are less clear. On occasion turtles forage in offshore non-algae habitats (Seminoff et al 1998, in press, in prep. b); however, the movement patterns and submergence intervals observed during tracking efforts in these offshore and insular regions are more commonly associated with resting behavior (van Dam and Diez 1996, Hochscheid et al. 1999).

Though the timing of movements may differ in other populations, there is a consistency in terms of the overall bimodal nature of movement and foraging activity witnessed. Mendonca (1983) showed that green turtles exhibited an extremely predictable diel movement pattern with turtles feeding on grass flats in mid-morning and mid-afternoon and moving into deeper water during midday hours. Similarly, Bjorndal (1980) noticed regular feeding bouts in the early- to midmorning and mid- to late afternoon in Bahaman green turtles, and Ogden et al. (1983) showed that *C. mydas* in St. Croix actively fed during morning and afternoon hours and rested during mid-day periods. Further, Brill et al. (1995) reported that green turtles in Hawaii exhibited daily shuttling behavior between daylight and night time areas.

The repetitive daily movements of *C. m. agassizii* between widely separated activity centers suggest that these animals are capable of orientation during travel. Though orientation mechanisms of small scale movements are poorly understood, it is reasonable to assume that animals are capable of remembering the locations if resources occur in a patchy but predictable pattern (Ford 1983). Spatial recognition and homing has been reported in a number of studies. Cyclic movements between activity centers were shown

for adults in the Gulf of Mexico (Arms 1996) and immatures in Florida (Mendonca 1983). Balazs et al. (1987) found juvenile *C. mydas* exhibited strong fidelity to specific microsites among coral reef heads along the coast of Hawaii and Renaud et al. (1995) demonstrated that immature greens in south Texas waters maintained fidelity to specific jetty habitats. In mark-recapture studies, Burnett-Herkes (1974) and Ireland (1979) showed homing behavior in Caribbean foraging habitats. Magnetic reference has been attributed to migratory orientation in sea turtles (Lohmann and Lohmann 1996); however, the smaller scale of movements in feeding areas may require navigation by some other means.

Winter movement – My data on winter movement indicate that at least some *C. m. agassizii* stay in the Bahía de los Angeles vicinity during cold water periods. The sustained activity by turtles is indicative of elevated body temperatures. Active *C. mydas* are able to maintain regional endothermy (Standora et al. 1982) and elevated body temperature may play a role in maintenance of digestive performance during cold periods. Winter-active turtles in this study were found in food-rich habitats and their sustained activity suggests the possibility of foraging. Foraging at low water temperature has been reported by Read et al. (1996) who showed that active Australian *C. mydas* continued to forage in waters below 20 C. However, at some point along the temperature continuum, cold temperatures interrupt foraging by inhibiting activity and digestive performance (Spotila et al. 1997). This is supported by Felger et al. (1976) who showed that Gulf of California green turtles become sluggish and exhibit overwintering torpor

during cold winter periods. Our data indicate that this 'inactivity threshold' for green turtles in Bahía de los Angeles is below 15 C.

Conservation strategies. – Historic records of green turtle populations in Bahía de los Angeles indicate that the extensive marine algae pastures of this region supported a population of considerably larger size than that of today. The decline in number of green turtles due to human harvest in this region and the entire Gulf of California has been documented (Caldwell 1963, Clifton et al. 1982, Nichols in prep.). Despite these declines, the marine habitats of Bahía de los Angeles remain intact and provide abundant food resources for green turtles. This strengthens the importance of Bahía de los Angeles as green turtle feeding habitat and establishes this area as a candidate for future management and conservation efforts.

The year-round residence of both immature and adult green turtles in Bahía de los Angeles highlights the importance of this region as critical feeding habitat. The marine algae pastures of the eastern and southern edges of the study area are clearly epicenters of sea turtle activity, but my data indicate that turtles use a variety of insular and peninsular habitats throughout the bay. Green turtles are thus susceptible to impacts from a myriad of commercial fishing activities. Local fisheries which utilize set nets must be controlled to minimize incidental entanglement-induced mortality. Initial management efforts should focus on reducing human disturbance associated with nearshore algae pastures. However, I stress that because turtles use the entire bay, the long-term solution for stopping incidental mortality must be to limit or completely phase out the use of entanglement nets in the entire bay.

Recent Advances in Conservation Planning. – In May 2000 the first meeting of the Black (i.e., East Pacific Green Turtle) Sea Turtle Working Group convened in Mexico City, México. The goals of this one-day event were to (1) characterize the ecology of the East Pacific green turtle throughout its range, (2) identify causes of mortality for sea turtles in the Eastern Pacific, and (3) develop strategies to limit declines and ultimately increase populations. I presented natural history and mortality data generated from my dissertation research. Working group members were educated about the population structure, foraging ecology, and movements of *C. m. agassizii* in near-shore habitats. Mortality data collected during this research augmented existing knowledge and data presented by W. J. Nichols from the Pacific coast of the Baja California peninsula. This meeting resulted in the recognition by the Working Group of the unique ecology of the East Pacific green turtle in the Gulf of California and the high rate of mortality in feeding areas in this region. The final recommendation of the Group was that the Gulf of California must be considered as a critical area for sea turtle conservation efforts. All parties agreed that protection efforts must be must be holistic and include both top-down and bottom up approaches. Laws, regulations, and enforcement are essential elements. However, of perhaps greater importance is the enlistment of support from local community members for conservation efforts in communities adjacent to areas of high mortality. I believe this is a prototypical example of how information generated from dissertation research can be effectively integrated into conservation planning.

APPENDIX A:

CHELONIA CONSERVATION AND BIOLOGY

LRH: Seminoff et al.

RRH: Population structure of East Pacific green sea turtles

Population structure of the East Pacific green sea turtle (*Chelonia mydas agassizii*)
at a temperate feeding area in the Gulf of California, México.

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Key Words: East Pacific green turtle, *Chelonia mydas agassizii*, diet, herbivory, Gulf of
California, México.

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Population structure of the East Pacific green sea turtle (*Chelonia mydas agassizii*)
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Jeffrey A. Seminoff, Antonio Resendiz S. Hidalgo, and Wallace J. Nichols

Abstract. – We studied the East Pacific green turtle, *Chelonia mydas agassizii*, at the Bahía de los Angeles foraging grounds of the central Gulf of California, México. Between 1995 and 1999, use of entanglement nets resulted in 196 captures of 153 green turtles among 16 capture sites. Pooled straight carapace length (SCL; mean \pm SE) was 75.1 ± 0.79 cm. Though there was no significant variation in mean SCL among years, there was strong evidence of a difference in mean SCL among capture sites. Most of the population (58%) consisted of immature turtles but did not differ significantly from a 1:1 immature:adult ratio. Pooled adult sex ratio (Unsexed:Male) was heavily biased toward probable females (2.70:1.00) and differed substantially from a 1:1 ratio. Growth averaged 1.97 cm yr^{-1} and was consistent among all 10-cm size categories represented at this feeding area. Recaptures indicate that the mean warm-water population is 229 turtles with a mean survivorship of 0.52 and mean annual recruitment of 88 turtles. Epibionts were found on turtles during all sampling periods. The most common were the commensal turtle barnacle (*Chelonibia testudinaria*) and the burrowing barnacle (*Platylepas hexastylus*). Approximately 5% of the population showed signs of

anthropogenically derived injuries ranging from missing flippers to boat impact scars.

Human consumption of sea turtles persists at Bahía de los Angeles.

Key Words: East Pacific green sea turtle; *Chelonia mydas agassizii*; population structure; feeding grounds; adult sex ratio; growth; health status; epibionts; population size; survivorship; Bahía de los Angeles; Gulf of California; México.

Nesting biology of sea turtles has been extensively investigated but the biology of sea turtles at their feeding grounds has been neglected. The general poor understanding of sea turtle population structure and dynamics has been highlighted by numerous investigators (Crouse et al. 1987, Frazer 1992, Erhenfeld 1995). Sea turtles need to be studied in the feeding grounds where a wider cross-section of the population is available. Population structure in these areas is an important element of sea turtle demography and life history, and knowledge about particular foraging areas can help wildlife managers develop more appropriate conservation strategies for endangered populations.

The East Pacific green turtle (also known as the black turtle), *Chelonia mydas agassizii*, is an endangered population occurring throughout the Eastern Pacific Ocean (National Marine Fisheries Service and United States Fish and Wildlife Service 1998). Like most sea turtles, *C. m. agassizii* is migratory and uses a range of widely separated localities and habitats during its life time. The primary nesting beaches for this population are located in Michoacán, México (Figuroa et al. 1993), the Revillagigedo

Islands, México (Brattstrom 1982, Awbrey et al. 1984), and the Galapagos Islands, Ecuador (Green 1984). Information is available on much of its biology at these rookeries (Carr 1961, Figueroa et al. 1993, Chassin Noria et al. in press). However, data on *C. m. agassizii* after departing nesting beaches are scant, and little is known about its biology in distant feeding areas.

The Gulf of California has been considered an important region for feeding of *C. m. agassizii* (Felger et al. 1980, Clifton et al. 1995, Seminoff et al. 1998). Caldwell (1962, 1963) and Felger et al. (1976) reported the presence of immature and adult green turtles of both sexes in the central Gulf of California; however, since these reports *C. m. agassizii* numbers have decreased substantially (Márquez 1984, Clifton et al. 1995). Additional data are needed to describe the current population structure of *C. m. agassizii* in critical feeding and developmental habitats. Here we report on the size, juvenile/adult maturity ratio, adult sex ratio, health status, growth, population size, and survivorship of green turtles at a warm temperate foraging ground in the Gulf of California.

MATERIALS AND METHODS

Study Site. – Data were collected between May 1995 and October 1999 at the Bahía de los Angeles foraging area of the central Gulf of California, México (28°58' N, 113°33' W). This semi-enclosed NNE-oriented bay is approximately 12 km long with a maximum width of 5 km at its southern limit (Fig. A.1). A series of seventeen islands separate the bay from the deep waters of Canal de Ballenas. Marine substrates within the bay are mostly soft bottom, consisting of sand and silt (Grady 1964). Peninsular

shoreline composition is a mosaic of granitic sand, basaltic cobble, and basaltic boulders. Broad shallow sandy habitats extend up to 0.75 km offshore in subtidal regions. Insular benthic habitats are primarily basaltic in composition (Delgado-Argote and García-Abdeslem 1999).

Bahía de los Angeles has a mean precipitation of 4 cm yr⁻¹ with both summer and winter rains. Mean air temperatures vary between a maximum of 38°C in August to a minimum of 16°C in February (Crosswhite and Crosswhite 1982). Mean monthly sea surface temperatures (SSTs) follow approximately the fluctuations in ambient air temperature but are generally lower, ranging from 14 °C to 30°C (Robinson 1973). The open areas of Bahía de los Angeles have salinities close to that of full-strength seawater (35 ‰). Salinities in the northern and southern protected areas are slightly higher, reaching a maximum of 36.5 ‰. This part of the Gulf coast has two tidal cycles per day with a tidal range of ~3m at highest fall tides to ~0.5 m at neap tides. This region is influenced by the waters of the Ballenas Channel that are characterized by strong tidal mixing (Bray and Robles 1991) and high nutrient levels (Alvarez-Borrego and Lara-Lara 1991).

Macro algae comprise the prevailing marine vegetation in the study area. Distinct cold and warm water assemblages are present (Pacheco-Ruiz and Zertuche-González 1996a, 1996b, 1996c). The dominant macroalgae species are *Sargassum johnstonii* and *Gracilariopsis lemaneiformis*. *S. johnstonii* is found along both insular and peninsular habitats, anchoring well in both sandy and rocky benthic substrates. *G. lemaneiformis* occurs along peninsular coasts within 1 km of shore to mean tide depths of 7 m (Pacheco-

Ruíz et al. 1999). This red alga (Rhodophyta) is a cold water species but persists year-round along the sandy substrates of the El Bajo Shallows and southern bay capture sites (this study). It is the predominant food consumed by *C. m. agassizii* in this study area (Seminoff et al. 1998, 2000). Other common marine alga present in the study area include *Gracilaria robusta*, *Gracilaria tepocensis*, *Codium amplivesticutum*, *Codium simulans*, *Euchema uncinatum*, *Ulva lactuca*, *Gigartina pectinata*, and *Enteromorpha acanthophora* (Norris 1975, Zertuche-González and Pacheco-Ruíz 1997a, 1997b, Pacheco-Ruíz unpubl. data). All have been noted in dietary samples of *C. m. agassizii* (Seminoff et al. 1998).

Turtle capture and handling. – We captured turtles with specialized entanglement nets (100 m x 8 m, mesh size = 60 cm stretched; Ehrhart and Ogren 1999) along near-shore margins of Bahía de los Angeles. Distance from shore and water depth of netting sites ranged from 50 to 750 m, and 2 to 27 m, respectively. Nets were set during both day and night periods and monitored at 0.5 h to 12 h intervals. Entangled turtles were removed upon encounter and transferred to the Centro Regional de Investigación Pesquera Sea Turtle Research Station (CRIP-STRS) in Bahía de los Angeles. Upon capture, size measurements and other physical data were recorded, and diet samples were collected. Turtles were generally released at site of initial capture within 24 h; however, other aspects of this study required the holding of some individuals in captivity at the CRIP – STRS for up to 72 h (Resendiz et al. 2000). On several occasions inclement weather

prevented return to initial capture sites and turtles were thus released at the El Bajo site adjacent to CRIP-STRS.

Flipper tagging. – Prior to release, each turtle was tagged with two flipper tags. Initially, we applied plastic Roto-tags (Style YL-AA-2CMB; Modern Farm, Cody, Wyoming) in the proximal tagging location of each front flipper (Balazs 1999). The use of Roto-tags was discontinued in July of 1996 due to poor design and an apparent increased likelihood of entanglement in local fishermen's set nets (Nichols et al. 1998). For the remainder of the 1996 summer field season, turtles were marked by the notching of posterior marginal scutes (Ernst 1971). Commencing in January 1997, all turtles were tagged with Inconel tags (Style 681; National Band and Tag Company, Newport, KY) in each of the rear flipper's first large proximal scale (Balazs 1999).

Data collection. – Turtles were measured for straight carapace length (SCL), tail length (TLC), and mass. SCL (± 0.1 cm) was measured from the nuchal notch to the posterior edge of the rear marginals using a forester's caliper (Bolten 1999). This measurement has been shown to be the best single variable to determine individual size (Bjorndal and Bolten 1989). TLC (± 0.5 cm) was measured from the trailing edge of the carapace to the tip of the extended, straightened tail with a vinyl tape measure (Limpus and Reed 1985). A record of zero for this measurement indicated a distance short of the carapace margin. Turtles were weighed using a 150 kg spring balance (± 2 kg; Model 8930, Hanson Equip.,

Shubuta, Miss). Unless otherwise noted, only the set of measurements taken upon initial capture were used for analysis.

In our analysis of maturity structure, we used mean nesting size of females (MNS) to distinguish immatures and adults. Use of MNS provides the close approximation of the true maturity structure of a population in the absence of more accurate and invasive techniques such as radioimmunoassay (Owens et al. 1978) or laparoscopy (Wood et al. 1983). Based on the MNS of 77.3 cm SCL at the Michoacán, México, rookery (Figueroa et al. 1993) a turtle was assumed to be immature if SCL was <77.3 cm and mature if SCL was ≥ 77.3 cm.

We identified male turtles based on tail length (Ross 1984, Limpus and Reed 1985, Wibbels 1999). Any *C. m. agassizii* with an elongated tail (TLC ≥ 10) was identified as male, and any with TLC ≥ 20 cm were assumed to be mature (Meylan et al. 1994). Though most larger turtles with short tails are likely female, the possibility that some were late maturing males required that short-tailed *C. m. agassizii* were classified as unsexed (U). We similarly classified all immature-sized short tailed turtles as unsexed. However, because the accuracy of tail size-based sex assessment is greatest in the large size classes, assessment of sex ratios focused only on adult-sized turtles.

We assessed the general health of each turtle and noted missing flippers, large scars, and other external anomalies. The presence of epibionts was recorded and all barnacles on the carapace, plastron, head, and extremities were counted. When turtles were recaptured at interval greater than 30 d, we recounted barnacles and other epibionts.

Local mortality was quantified through stranding records, flipper tag returns, and documented events of human consumption. When possible, we determined the cause of death. Accounts of human consumption were compiled through interviews and periodic checks of carapace disposal sites.

Analysis of growth was determined through calculations of recapture intervals and comparisons of SCL upon initial capture and recapture. Only measurements taken at an interval of 50 days or greater were used in order to minimize the effect of measurement errors. Here we report the mean annual growth rate (van Dam 1999) as:

$$\text{mean annual growth rate} = (\text{measurement 2} - \text{measurement 1}) \div \text{interval in years}$$

Size specific growth rates were calculated for each size class in 10-cm increments for which turtles were recaptured. The size class of each turtle was taken as the average of its measurements from each capture.

We estimated population size, survivorship, immigration, and probability of capture of *C. m. agassizii* inhabiting the Bahía de los Angeles foraging area during warm-water periods from tagging-recapture data. Cormack-Jolly-Seber analyses (Lancia et al. 1994, Gerrodette and Taylor 1999) were restricted to turtles captured between May and October of each study year. Previously tagged turtles were considered recaptures only if tagged during a previous May – October season. Multiple recaptures within a single season were not included.

Statistical analyses. – We used a two-way ANOVA to assess variation in SCL among years and capture sites (Sokal and Rohlf 1995). Extra sum-of-squares F-tests were used

to compare full and reduced models and interactions between explanatory variables (Ramsey and Schafer 1997). Pearson Chi-square analyses determined the homogeneity of maturity structure and sex ratio among years and capture sites. Chi-square analyses were also used to test for a departure from a 1:1, U:M sex ratio, and a 1:1, Immature:Adult maturity ratio. In assessment of epibiont presence, we used a 2-sided t-test to determine if SCL was different between afflicted and non-afflicted turtles. A Fisher's Exact test was performed to determine correlation in the occurrence of barnacle species. ANOVA was calculated for assessment of growth rates in different size categories. Cormack-Jolly-Seber calculations were used to determine population size, survivorship, and emigration (Lancia et al. 1994, Gerrodette and Taylor 1999). Statistical calculations were performed with JMP software (SAS Institute 1996).

RESULTS

Turtle capture. – We attempted to capture *C. m. agassizii* at a total of 22 different near-shore sites in Bahía de los Angeles (Fig. A.1). This effort was made during nine calendar months with the greatest cumulative effort in July (Fig. A.2). Netting efforts occurred during all periods of a 24-h cycle. A total of 8,892 net-set hours yielded 196 captures of 153 individual turtles. Captures were made at 14 sites, with most turtles landed in July ($n = 46$; Fig. 3). A calculation of catch per unit effort (C/E) was made for each successful capture site (Table 1). One unit effort was equivalent to one 12-h in-water set for a single 100-m long net. Overall C/E for first-time captures was $0.20 \text{ turtles capture unit}^{-1}$, thus equaling one turtle for every 60-h of netting. The greatest capture efforts occurred in El

Bajo Shallows and El Cardon with 3,144 and 1,392 net-set hours, respectively. These sites accounted for 63% of all captures, yielding 70 captures from El Bajo Shallows and 28 captures from El Cardon. Of the sites producing a substantial number of captures, the highest C/E value was from El Bajo Shallows (C/E = 0.35). The capture site 'Other' yielded 12 turtles, most ($n = 9$) of which were brought in by fishermen and no specific capture site was provided. The remainder were strandings encountered in the study area. Because these turtles could have drifted passively for extended periods, no specific capture site was recorded; only the site of encounter.

Capture time-of-day was recorded for 114 turtles (74.3%). Fifty seven turtles were captured during daylight periods and fifty seven turtles were entangled during periods of darkness. There was no difference in mean SCL of turtles captured during day versus night ($t = 0.791$, $P = 0.437$, 112 *d.f.*). Frequency of day versus night captures was also similar with respect to sex ($X^2 = 2.93$, $P = 0.0876$, 1 *d.f.*), maturity ($X^2 = 2.59$, $P = 0.11$, 1 *d.f.*), and capture site ($X^2 = 12.12$, $P = 0.267$, 21 *d.f.*).

Recaptures.- A total of 33 turtles (21.7%) were recaptured on 43 occasions during this study; 25 turtles were recaptured one time, six turtles recaptured two times, and two recaptured on three occasions. The mean initial SCL for all recaptured turtles was 79.7 cm (SE = 1.95, range = 65.9 to 94.7 cm, $n = 33$). The mean recapture interval was 231 d (SE = 46.44, range = 3 to 1,160 d, $n = 43$). Most turtles were recaptured in the same vicinity as initial capture. Movement was evident on several occasions when turtles were recaptured at locations distant from initial capture. Two turtles, # 219 and # 323, were

captured at both insular and peninsular sites, Isla Pata-El Barco and El Bajo-Isla Ventana, respectively. On two occasions, turtles initially captured in the south bay were recaptured at El Bajo Shallows, nearly 9 km to the north, and once a turtle was recaptured at Los Barriles after initial capture at La Silica, a total distance of 7 km.

Evidence of possible homing behavior was seen on two occasions. In 1996 turtle # 120 was captured at El Quemado, but due to poor weather, was released at El Bajo, a distance of 26 km to the north. This turtle was recaptured in 1998 at El Quemado (447 d interval) at the precise site of initial capture. Similarly, turtle #012, initially captured in 1995 at El Cardon, was released at La Silica, 9 km to the north, and recaptured in 1997 near El Cardon.

On two occasions during the course of this five-year study we established a migratory link between the Bahía de los Angeles feeding area and Michoacán nesting rookery. One turtle was found dead in a net set by local fishermen near Bahía Las Animas (November, 1997) that was originally tagged at the nesting rookery in Colola, Michoacán, México (Orange plastic tag #A0945; Alvarado and Figueroa 1992), and turtle (# 139; SCL = 91.9 cm) tagged at the Bahía de los Angeles feeding area during this study was subsequently seen nesting at the Colola, Michoacán, rookery (Nichols et al. 2000).

Size and Mass. – Turtles of many different sizes were captured during all years of this study (Fig. A.4). Pooled SCL was 75.1 cm (SE = 0.79, range 46.0 to 100.0 cm). The smallest turtle captured during this study was landed from the islands in 1998 and the largest turtle was landed in 1996 from El Bajo Shallows. There was no evidence of

variation in mean SCL between years (2-way ANOVA $F_{4,148} = 2.13, P = 0.101$); however, there was sufficient evidence of a difference in SCL among capture sites (2-way ANOVA $F_{10,141} = 6.44, P < 0.0001$). There is strong evidence of an interactive effect of capture year versus capture site on SCL (Extra SS $F = 110.38, P < 0.0001$). Among years, the 1995 capture group shows the smallest mean SCL (69.2 cm, SE = 2.35, $n = 16$) and 1996 group had the greatest mean SCL (78.8 cm, SE = 1.23, $n = 39$ [Table A.2]). Among capture sites, the *Other* capture site yielded the smallest mean SCL (60.9 cm, SE = 2.52, $n = 12$) and *Campo Muñoz* yielded the largest mean (SCL = 85.1 cm, SE = 8.75, $n = 1$ [Table A.3]).

Body mass was measured for 142 turtles. Mean weight for all size and sex classes was 62.8 kg (SE = 1.79, range = 14.5 to 130.0 kg). Analysis of SCL to mass among all turtles results in the regression equation $Kg = 2.1SCL - 98.2$ (Fig. 5). The mean mass of turtles with SCL <77.3 cm was 47.4 kg (SE = 1.67, range = 14.5 to 71.8 kg, $n = 74$) and that of turtles with SCL ≥ 77.3 was 67 kg (SE = 79.3, range = 56.4 to 130.0 kg, $n = 68$). Despite a slight overlap there was strong evidence that the weights between these groups differed ($t=13.03, P < 0.0001, 140 d.f.$). Within the ≥ 77.3 cm SCL class, there was no difference in the weight of males versus unsexed turtles ($t = 0.56, P = 0.575, 66 d.f.$).

Maturity ratio and adult sex ratio. – Based on size criteria, Bahía de los Angeles hosts both immature- and adult-sized turtles. There were slightly more apparent immatures (79) than adults (74), yet the estimated Immature:Adult ratio did not differ significantly from a 1:1 ratio ($X^2 = 0.16, P > 0.05, 1 d.f.$). Estimated maturity ratios were not

homogeneous among years ($X^2 = 12.6$, $P = 0.013$, 4 *d. f.*) or capture sites ($X^2 = 23.4$, $P = 0.024$, 12 *d. f.*). A summary of size and sex assessment by year is presented in Table A.2, and a summary for size and sex ratio by capture site is found in Table A.3.

Twenty seven turtles exhibited tail differentiation consistent with male sex (Fig. A.6). Based on TLC, 11 males were considered prereproductive ($10 \text{ cm} < \text{TLC} < 20 \text{ cm}$) and 16 were assumed mature. Mean SCL of turtles with $\text{TLC} < 20 \text{ cm}$ was 76.1 cm (SE = 2.12, range 66.6 to 92.5 cm) and mean SCL of turtles with $\text{TLC} \geq 20 \text{ cm}$ was 83.9 cm (SE = 0.89, range = 77.3 to 89.2 cm). Male maturity status estimates based on tail length were not consistent with the carapace length-derived estimates of maturity status. Of the eleven *C. m. agassizii* that exhibited tail differentiation consistent with prereproductive male status, only seven fell in the immature SCL range ($\text{SCL} < 77.3 \text{ cm}$). Four males with $\text{TLC} < 20 \text{ cm}$ and all 16 males with $\text{TLC} \geq 20 \text{ cm}$ were in the adult SCL range ($\text{SCL} \geq 77.3 \text{ cm}$).

Observed sex ratios were homogeneous among years ($X^2 = 3.35$, $P = 0.50$, 1 *d. f.*) and capture sites ($X^2 = 9.13$, $P = 0.42$, 1 *d. f.*). Pooled sex ratio (U:M) of the 70 turtles with $\text{SCL} \geq 77.3 \text{ cm}$ was 2.70:1.00 (Table A.3), differing significantly from a 1:1 ratio ($X^2 = 13.92$, $P < 0.0005$, 1 *d. f.*).

Health. – A total of eight (5.2%) *C. m. agassizii* showed evidence of anthropogenic injuries and/or health problems. Four turtles (2.6%) possessed injuries consistent with boat or propeller collisions. Three (1.9%) turtles had a missing flipper and one turtle

turtles was 2.70:1.00 (Table A.3), differing significantly from a 1:1 ratio ($X^2 = 13.92$, $P < 0.0005$, 1 *d. f.*).

Health. – A total of eight (5.2%) *C. m. agassizii* showed evidence of anthropogenic injuries and/or health problems. Four turtles (2.6%) possessed injuries consistent with boat or propeller collisions. One turtle (0.65%) was recaptured in a highly emaciated state and three (1.9%) turtles had a missing flipper. Though missing flippers are commonly attributed to attempted predation by sharks, flipper loss in at least one of these turtles was attributed to human impact. In this case heavy gauged mono-filament fishing line was found tightly wrapped around the exposed front left humerus. It appears that this turtle was tied by the flipper for maintaining in sea water until human consumption. The mono-filament line likely severed the front flipper as the turtle struggled to escape.

Epibionts. – The presence of epiflora and epifauna was assessed for 136 *C. m. agassizii*. A majority of these turtles carried epibionts on their carapaces and, to a lesser extent, on the flippers, head, and plastron. The turtle barnacle (*Chelonibia testudinaria*) was the most common species, found on 62.5% of captures. The mean number of *C. testudinaria* on these turtles was 20.3 (SE = 8.24, range = 1-516). There was no difference in the SCL of afflicted versus non-afflicted turtles ($t = 0.54$, $P = 0.46$, 134 *d. f.*). The burrowing barnacle (*Platylepas hexastylus*) was seen at a lower incidence, present on 27.9% of turtles. The mean number of *T. cheloniae* per infested turtle was 4.94 barnacles (SE = 0.87, range = 1–20). There was no difference in the SCL of turtles bearing *T. cheloniae*

(*Ozobranchus* sp.), and bryozoans. Conspicuous algae growing on the carapace included *Enteromorpha*, *Ulva*, and corraline algae.

Green turtles bore *C. testudinaria* and other epibionts during warm and cold water seasons. Intra-seasonal analysis of barnacle infestations of recaptured turtles showed no apparent pattern in barnacle recruitment. Some individuals gained barnacles during a given season while others lost barnacles. Turtles captured in successive years showed different barnacle patterns on successive captures, indicating that *C. testudinaria* are able to settle on turtles within the Bahía de los Angeles habitat.

Mortality. – Evidence of mortality was gathered from individual strandings, flipper tag returns, and documented cases of human consumption. A total of four non-tagged turtles and one tagged turtle were found stranded (four beached and one floating in the central bay). Though most likely drowned in fishing nets, no immediate cause of death was apparent. In addition, incidental bycatch in gill-nets was implicated through information gained from tag recoveries. Fishermen returned flipper tags from a total of six turtles (four bearing plastic tags; two bearing metal tags); all but one were confirmed to have drowned in gill nets. Three turtles were recovered in Bahía San Rafael, a fishing village 80 km to the south; one turtle was killed near Bahía Guadalupe, 40 km to the north; one turtle killed at Las Animas, 17 km to the south; and one turtle in Bahía de los Angeles. One additional set of tags was returned anonymously, thus providing no details as to cause of death. These tag returns represent a known mortality of 4.6 % of all tagged turtles.

Evidence of human consumption was documented on multiple occasions within the nearby town of Bahía de los Angeles. Though freshly butchered carcasses were recovered from the town dump on several occasions and fishermen openly discussed the consumption of turtles, we only witnessed acts of sea turtle consumption on two occasions.

Growth. – During this study, there were 28 growth increments measured over intervals greater than 50 days. Two turtles were captured in more than two seasons; however, all turtles were assessed for growth based on two captures only. Mean recapture interval was 379 d (SE = 66.4, range = 50 to 1,160 d). Absolute SCL increases ranged from 0 cm to 14.1 cm (in 1,524 d for a turtle initially classified as an immature with SCL of 76.5 cm and an undifferentiated tail, but upon recapture classified as adult male with TLC of 23.5 cm). Mean SCL at first capture was 76.3 cm (SE = 2.49, range = 58.6 to 93.8 cm) and the mean SCL at recapture was 78.9 cm (SE = 2.67, range = 60.5 to 94.7 cm). Maximum growth rate was observed for the 70.0-79.9 cm SCL size class and equaled 2.6 cm/yr (SE=0.92, range = 0 to 6.9 cm/yr, $n = 10$). Minimum growth rate was observed in the 90-99.9 cm SCL size class, equaling 0.7 cm/yr (SE = 0.3, range = 0 to 1.1 cm/yr, $n = 3$). There were no significant differences among the five size classes assessed for growth (ANOVA $F_{4,11} = 0.45$, $P = 0.77$).

Population size, survivorship, recruitment, and standing crop. – Green turtles were observed at low population densities in the Bahía de los Angeles study area. The results

of the Cormack-Jolly-Seber analysis of the annual capture-recapture data are summarized in Table A.5. Averaged over 3 separate estimates, there was a mean warm-water population of 229 *C. m. agassizii* in Bahía de los Angeles (mean SE = 36). A 95% confidence interval about the mean for this value suggests that the true population size is between 75 and 382 turtles. The mean survivorship of these turtles was 0.52 (mean SE = 0.21) and the mean annual recruitment was 88 turtles (mean SE = 13) or approximately 38 % of the estimated population. A 95 % confidence interval suggests the true annual immigration into Bahía de los Angeles is between 0 and 257 turtles year⁻¹.

The estimated population of 229 turtles at Bahía de los Angeles was equivalent to a density of 5.08 turtles km⁻². By multiplying the average mass of turtles over the course of this study, we estimated that the standing crop of this turtle in Bahía de los Angeles is roughly 14,381.2 kg in 4,500 hectares, or 3.2 kg ha⁻¹.

DISCUSSION

Chelonia mydas agassizii was once very common in Bahía de los Angeles (Caldwell 1962; 1963) and by the early 1900s, a large scale sea turtle fishery in Baja California had started (Alger 1913, Averett 1920, Craig 1926). The abundant populations apparently supported this fishery for decades as Carr (1961) noted the tremendous harvest in the Gulf of California. Speaking of the Bahía de los Angeles harvest, Caldwell (1963) wrote, "I saw over 500 landed in a 3-week summer period in 1962 at Los Angeles Bay alone, and a comparable number, considering fishing effort, per week in winter". In total, 186.47 tons of sea turtles were landed that year from Bahía de los Angeles (Márquez

1984). Extraction was so heavy that during their investigations of *C. m. agassizii* in this region, Caldwell and Caldwell (1962) coined this species the 'black steer' of the Gulf of California. By the early 1980s, this population had crashed (Márquez 1984, Clifton et al. 1995). In 1982 only eleven tons of sea turtle were fished from Bahía de los Angeles, a figure representing a 96% drop in catch rate (Márquez 1984, Olguin-Mena 1990). As a result, the sea turtle fishing cooperative of Bahía de los Angeles disbanded in 1982 (Resendiz unpubl. data). Although not quantified, legal fishing continued at low levels near Bahía de los Angeles in the years following the collapse of organized commercial harvest. Anecdotal information from local fishermen suggests that by the 1990 Mexican ban on sea turtle fishing (Anonymous 1990), the population in Bahía de los Angeles was totally depleted. Anecdotal bycatch records and retrospection by local fishermen indicate that at the beginning of the 1990's there were 'no more turtles' (Savín de Smith pers. comm.). This study and anecdotal accounts reveal that the local green turtle population has increased at least slightly since the introduction of protective legislation by the Mexican government.

Bahía de los Angeles is approximately 2000 km north of the nearest primary nesting areas in Colola and Maruata, Michoacán, México. Nichols et al. (in press) has shown that nearly 90% of turtles in Bahía de los Angeles share genetic affinities with the Michoacán rookeries. Additionally, direct evidence linking these areas has been provided by a number of flipper tags applied at the nesting beaches that have been recovered in Bahía de los Angeles and nearby areas prior to this study (Alvarado and Figueroa 1992). The feeding ground to nesting beach migratory link has also been established by the siting of a

turtle tagged during this study in Colola, Michoacán (Nichols et al. 2000). Thus, based on genetics, tag recoveries, and turtle sightings, it is evident that the Michoacán rookeries supply the great majority of turtles in this feeding habitat and therefore most of the adult turtles in Bahía de los Angeles can be expected to carry out long-distance migrations to and from the Michoacán coast.

Information derived from mark-recapture study and flipper tag returns show that Bahía de los Angeles foraging population appears to be comprised of both resident turtles and transients. Among resident turtles, telemetry efforts have established that most turtles maintain distinct home ranges within this habitat (Seminoff in prep. c). Residents apparently maintain fidelity to specific regions within this foraging habitat and, if displaced, are able to return to these sites. We observed two cases of apparent homing by displaced green turtles. Such behavior has been demonstrated by green turtles at other feeding areas (Ireland 1979), but our data are the first to show this behavior in the Eastern Pacific Ocean.

Residents are composed of pre-reproductive size classes, which includes new immigrants to large immature-sized turtles. It is also likely that adults are resident to this feeding habitat between nesting cycles. However, it remains unclear how many of the adult-sized turtles captured during this study were resident and what proportion were transients from other feeding habitats en route to and from distant breeding grounds.

In the present study we have not attempted to sample the entire range of habitats within Bahía de los Angeles, but have focused on the shallow habitats. The limitations of entanglement netting did not allow capture attempts in deep water zones, thus our efforts

may not accurately describe the population characteristics of *C. m. agassizii* in these areas. Further, the lack of definitive procedures such as radioimmunoassay (Owens et al. 1978), ultrasound imaging (Rostal et al. 1990), or laparoscopy (Wood et al. 1983) limited our ability to absolutely determine maturity status or sex. While use of the mean nesting size criterion only provides an approximation of the true size upon sexual maturity, it remains the preferred non-invasive maturity estimation technique (Limpus and Reed 1985, Limpus pers. comm.). Based on this criterion, the population of green turtles in the shallow, near-shore areas of Bahía de los Angeles is structured as follows. It contains predominantly immature-sized turtles (1.3:1.0 immature:adult ratio) that recruit to this foraging ground at SCL = 45 cm or larger. The population of turtles with SCL > MNS is strongly biased toward unsexed (i.e. probable female) turtles (2.7:1.0 unsexed:male sex ratio). Posthatchlings and small juvenile turtles are absent from this habitat.

The absence of the smaller juvenile size classes may be the result of varying habitat requirements for different life history stages. Carr and Caldwell (1956) and Carr (1980) introduced the concept of developmental migration to account for differences in size classes of turtles for different feeding grounds. The waters around Baja California provide evidence for such a migration. While Bahía hosts predominantly larger immatures and adults, capture data from Pacific lagoons of Baja California show a prevalence of smaller juveniles (Seminoff et al. 2000, Nichols in prep). In addition to the differences in size structure, these two feeding habitats differ considerably in their physical make-up (described in Seminoff et al. 2000), and these differences likely play a role in recruitment patterns of green turtles.

The presence of a greater number of unsexed turtles observed during this study is consistent with Caldwell's (1962) study of the turtle fishery in this feeding area and may provide additional evidence of a developmental migration. If as indicated in maturity structure analyses, a developmental migration is present, then it is possible that as adult males exhibit a tendency for pelagic existence which limits entrance into nearshore habitats (Clifton pers. comm., Ross 1984). If developmental migration is a common element in the life history of *C. m. agassizii*, it will require sampling from multiple feeding grounds rather than a single habitat to describe the population structure of *C. m. agassizii* in the Gulf of California.

We measured a maximum growth rate of 2.6 cm yr^{-1} (70.0-79.9 cm SCL size class). While this figure is considerably higher than growth rates of *C. m. agassizii* in the Galapagos (0.15 to 0.45 cm yr^{-1} ; Green 1993), it falls within the range of values found for green turtles at other feeding areas outside the Eastern Pacific Ocean (e.g., Limpus and Walter 1980, Bjorndal and Bolten 1988). It is important to note that the growth witnessed in this study was for a limited size range (50 – 90 cm SCL) and does not represent the entire growth curve for *C. m. agassizii*. Thus it remains difficult to predict absolute age at sexual maturity, and we are instead limited to estimation of the time-to-sexual maturity after immigrating into the Bahía de los Angeles foraging habitat. We estimated time-to-sexual maturity for turtles based on a linear growth model, using the mean growth rate of all sizes pooled (1.7 cm yr^{-1}). The smallest size class represented by the capture data is the 45-50 cm SCL category. Assuming that the average *C. m. agassizii* foraging in this study area reaches sexual maturity at size close to the mean nesting size

and that growth rates determined at Bahía de los Angeles remain constant until maturity, then turtles measuring 45 cm SCL would require roughly 16 years to reach sexual maturity after immigrating into the Bahía de los Angeles foraging area. Despite the speculative nature of this estimate, it is clear that turtles will require a large period of time at this foraging habitat to reach a size consistent with sexual maturity.

Stranding evidence from Bahía de los Angeles (this study) and other areas in Baja California (Nichols in prep.), and accounts of local human consumption suggest that human-induced mortality remains at dangerously high levels. The 4.6% of known dead turtles in Bahía de los Angeles indicates a problem with bycatch in local set nets. In assessing the impact of this mortality, it is essential to note that strandings and flipper tag returns are only a minimum estimate of actual mortality. Considering the conservative nature of these data, these cases represent a serious blow to the local population. Despite the low frequency of observed sea turtle consumption events, it is likely that a very large number of green turtles are consumed locally each year.

Our estimate of mean survivorship ($\phi = 0.52$, $SE = 0.21$) indicates that nearly half of all turtles either leave or are extracted from this system annually. However, an accurate interpretation of this figure remains difficult due to our inability to determine how many animals are extracted from the system (i.e. human-induced mortality) versus the number of turtles that emigrate naturally. Similarly, our estimates of immigration can not depict how many turtles were present but not caught in previous years versus how many were new recruits to the feeding grounds. Regardless, our measures of emigration versus

immigration indicate an alarming decline in the number of green turtles in Bahía de los Angeles.

Few studies have addressed survivorship in green turtles, but those that have provide figures that are generally much greater than that found in this study (e.g. $\phi = 0.67 - 0.95$ in Oman, Siddeek and Baldwin 1996). In the Oman case and in our study, survivorship is based on both the number of turtles that remain after some level of human extraction and those that survive natural mortality. Our assumption for the Bahía de los Angeles population is that the vast majority of deaths are in some way human-induced. Thus, reducing human intervention, can conceivably increase survivorship. Without such efforts the current population will likely continue its declining trend. If we consider that, based on growth data, a newly settling turtle must remain in coastal foraging habitats for upwards of 20 years before reaching maturity, then it is imperative that human impacts in foraging areas must be substantially reduced to enable a recovery of *C. m. agassizii*.

An accurate assessment of sea turtle population structure and a thorough understanding of the negative impacts to these populations are vital to the implementation of appropriate conservation strategies. Though this study may be indicative of biological patterns at other feeding grounds in the Gulf, the conclusions presented here are specific only to Bahía de los Angeles. Assessment of population structure and the causes for particular distributional patterns for the entire eastern Pacific green turtle population will require additional studies in both nearshore and offshore feeding areas throughout the range of this endangered species.

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Table A.1. Summary of catch per unit effort for entanglement netting activities in Bahía de los Angeles, 1995 - 1999.

Initial captures, *recaptures*; 1 unit effort = 12 h in water duration for 2 – 6 m x 100 m nets; C / E based on initial captures only.

Map	Site	1995			1996			1997			1998			1999			Total		
		C	E	C/E	C	E	C/E	C	E	C/E	C	E	C/E	C	E	C/E	C	E	C/E
1	PTG							1	17	0.06							1	17	0.06
2	LBS								4					1	2		1	2	
3	PDG					3		1	7	0.14		2			6		1	18	0.06
4	EBR							7, 2	21	0.33	5, 2	25	0.25		22		12, 4	68	0.23
5	BBY											2			1			3	
6	IHS							2	19	0.11					6		2	25	0.08
7	WBN					3			4									7	
8	LSA				4, 3	10	0.40	6	43	0.14		4		4, 1	39	0.13	14, 4	96	0.14
9	EBS				15, 3	16	0.93	4	45	0.08	29, 7	81	0.35	21, 13	120	0.28	69, 23	262	0.35
10	LHS											7						7	

11	CGK					3						5			8				
12	CMZ				1, 1	5	0.20	2	12		3			1, 3	20	0.05			
13	ECN	13	36	0.36	12, 2	48	0.25	1	8	0.12	1	2	23	0.09	28, 2	116	0.24		
14	EST				2	6	0.33				1	2	0.50		3	8	0.38		
15	PDB								2							2			
16	PLB	3	12	0.25	2, 1	12	0.17	1	10		1	2	1	11	0.09	6, 3	50	0.12	
17	PTH								2								2		
18	PDJ										4						4		
19	EQM				1	4					1, 1	4	0.50		2, 1	8	0.25		
20	IVT					4			3		1	5		2	1		14		
21	IPN							1	4	0.25					1	4	0.25		
22	IRS								2								2		
	OTH							3, 1	2		3		4		12, 1				
	TOT	16	48	0.33	37, 10	114	0.32	28, 6	205	0.14	39,	142	0.27	32, 15	237	0.13	152, 43	743	0.20

Table A.2. Size and sex by capture year for *C. m. agassizii* captured in Bahía de los Angeles, Gulf of California, México.

Year	Total 1 st captures	Mean SCL (cm)	SE	<77.3 cm SCL		≥77.3 cm SCL		≥77.3 cm SCL Sex Ratio (U:M)
				Unsexed	Male	Unsexed	Male	
1995	16	69.2	2.35	10		6		1.00:0.00
1996	38	78.8	1.54	12	4	15	7	2.14:1.00
1997	28	74.0	1.77	17	2	6	3	2.00:1.00
1998	39	76.6	1.50	16		15	8	1.87:1.00
1999	32	72.7	1.66	17	1	12	2	6.00:1.00
TOTAL	153	75.1	0.79	72	7	54	20	2.70:1.00

Table A.3. Size and sex by capture site for *C. m. agassizii* captured in Bahía de los Angeles, Gulf of California, México.

Capture Site	Total 1 st Captures	Mean SCL (cm)	SE	<77.3 cm SCL		≥77.3 cm SCL		≥77.3 cm SCL Sex Ratio (U:M)
				Unsexed	Male	Unsexed	Male	
PTG	1	73.7	8.75			1		1.00:0.00
PDG	1	77.3	8.75	1				
EBR	12	78.1	2.52	6		4	2	2.00:1.00
HIS	2	64.1	6.18	2				
LSA	14	78.6	2.34	7		4	3	1.33:1.00
EBS	70	77.3	1.05	27	2	29	12	2.42:1.00
CMZ	1	85.1	8.75			1		1.00:0.00
ECN	28	72.4	1.65	15	2	10	1	10.00:1.00
EST	3	76.8	5.04	2		1		1.00:0.00
PLB	6	79.1	3.57	2		4		1.00:0.00
EQM	2	69.4	6.18	1	1			
IPN	1	77.3	8.75				1	0.00:1.00
Other	12	60.9	2.52	9	2		1	0.00:1.00
Total	153	75.1	0.79	72	7	54	20	2.70:1.00

Table A.4. Growth rates of green turtles grouped in 10-cm increments of straight carapace length. The size of each turtle is taken as the average of its measurements at each capture.

Straight				
Carapace	Growth rate (cm yr ⁻¹)			
Length (cm)	<i>X</i>	SE	Range	<i>N</i>
50-59.9	2.0	-	-	1
60-69.9	1.2	0.41	0.6-2.0	3
70-79.9	2.6	0.91	0.0-6.9	10
80-89.9	2.3	0.4	0.2-3.7	11
90-99.9	0.7	-	0.0-1.1	1

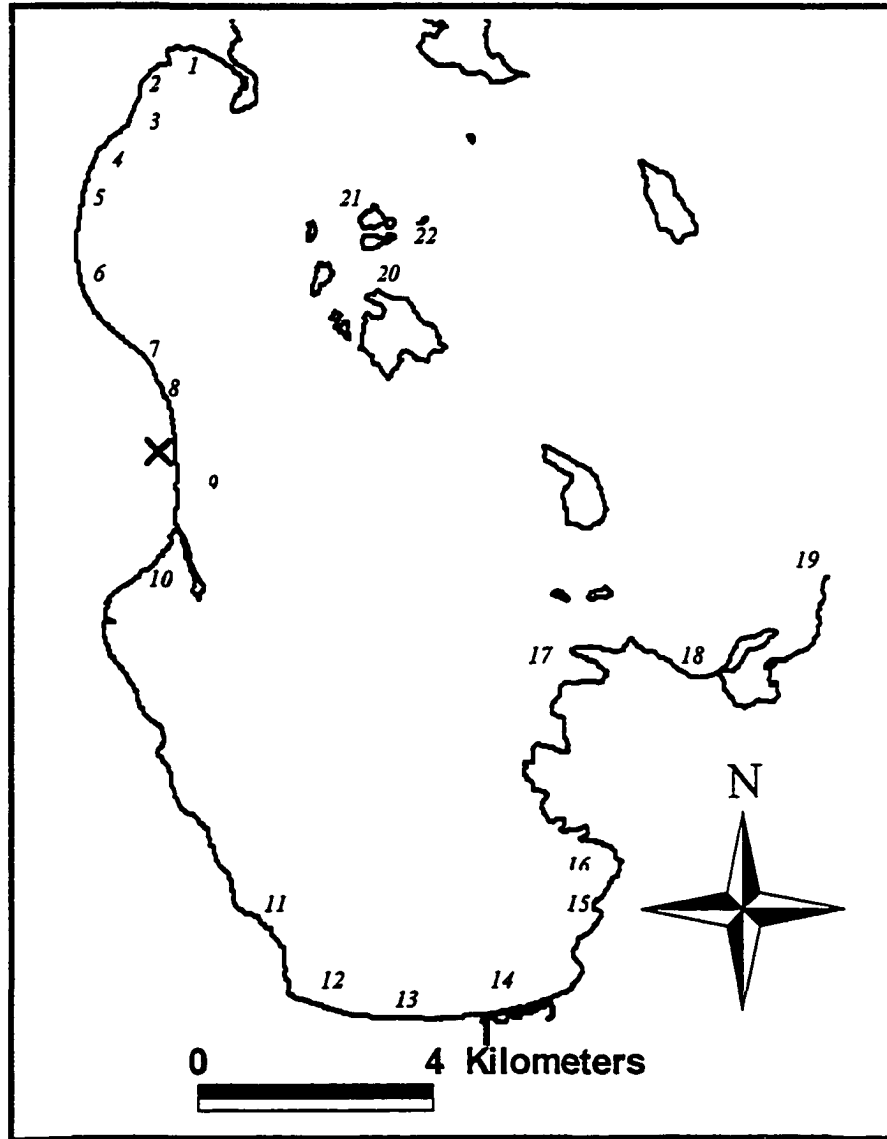


Fig. A.1. Map of Bahía del los Angeles study area. X indicates location of CRIP-STRS.

Capture sites are numbered (abbreviation in parenthesis): 1, La Gringa (PTG); 2, Los Barriles (LBS); 3, Pedregal de la Gringa (PDG); 4, El Barco (EBR); 5, Blue Bouy

(BBY); 6, Ice House (HIS); 7, Whale Bone (WBN); 8, La Silica (LSA); 9, El Bajo Shallows (EBS); 10, Lighthouse (LHS); 11, Camp Gekko (CGK); 12, Camp Muñoz (CMZ); 13, El Cardon (ECN); 14, Estero (EST); 15, Pedregal de Blanca (PDB); 16, Playa Blanca (PLB); 17, Punta Herradura (PTH); 18, Puerto Don Juan (PDJ); 19, El Quemado (EQM); 20, Isla Ventana (IVT); 21, N. Isla Pata (IPN); 22, S. Isla Rasita (IRS).

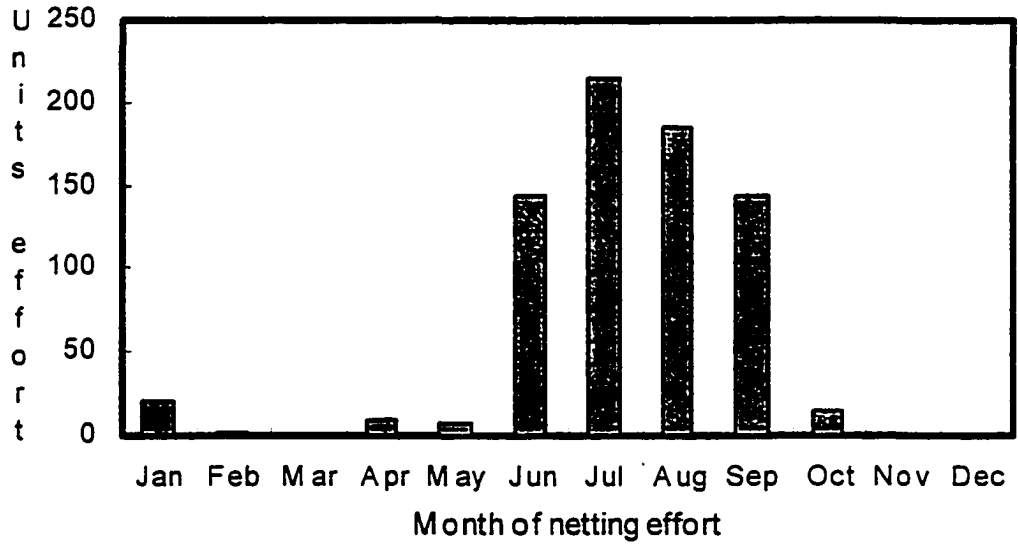


Fig. A.2. Monthly capture effort for entanglement netting activities in Bahía de los Angeles, 1995 – 1999.

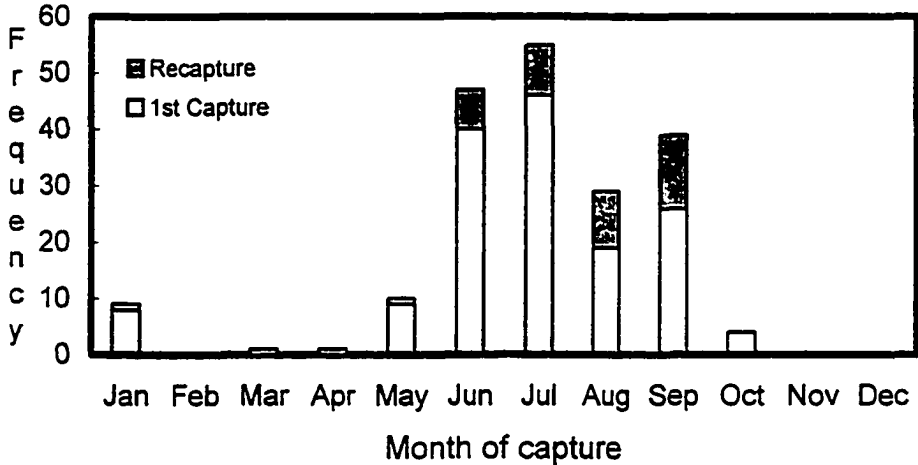


Fig. A.3. Monthly captures of *C. m. agassizii* in Bahía de los Angeles, 1995-1999.

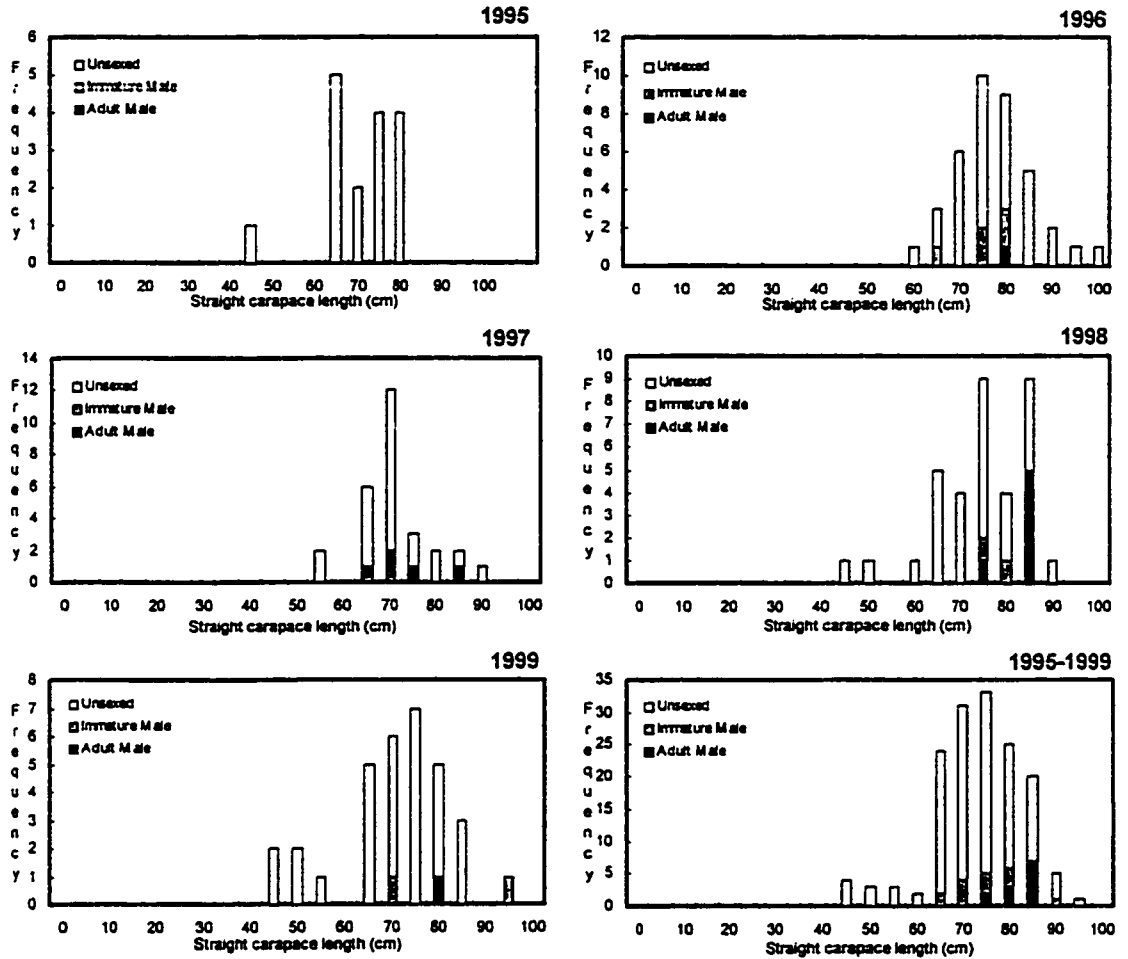


Fig. A.4. Size class distribution of *Chelonia mydas agassizii* captured at Bahía de los Angeles. 1995 (n = 16); 1996 (n = 38); 1997 (n = 28); 1998 (n = 39); 1999 (n = 32); 1995-1999 (n = 153). Includes only first-time captures.

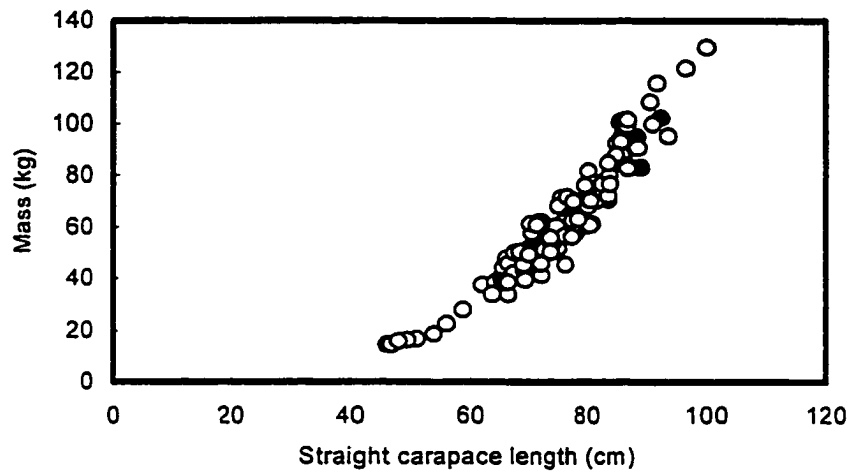


Fig. A.5. The morphometric relationship between carapace length and mass of *Chelonia mydas agassizii* from Bahía de los Angeles. The sexes have been plotted separately. ○, unsexed; ●, males.

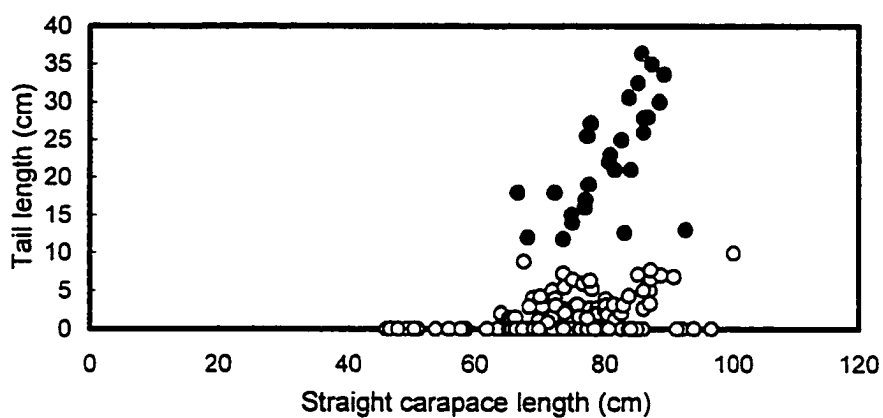


Fig. A.6. The morphometric relationship between straight carapace length and tail length in *Chelonia mydas agassizii* from the Bahía de los Angeles foraging area. The sexes have been plotted separately. ○, unsexed; ●, males.

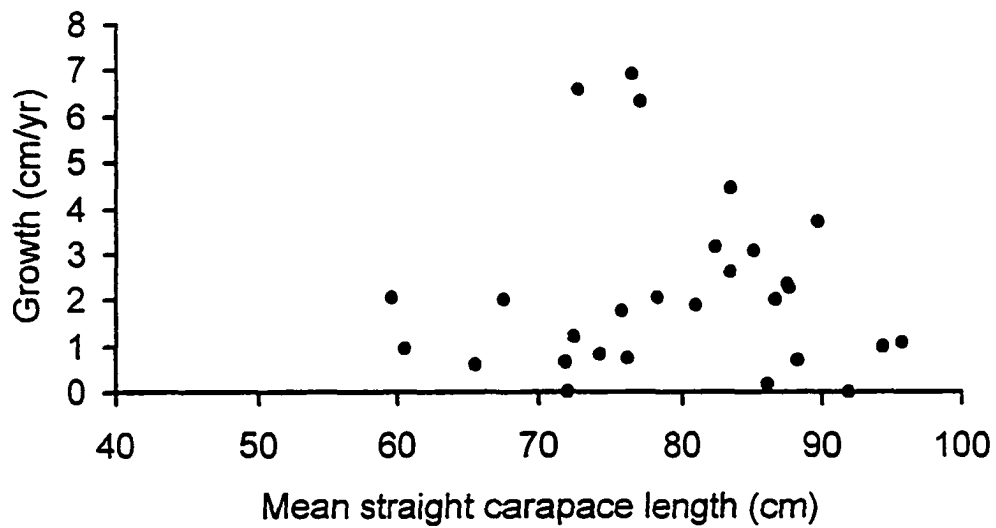


Fig. A.7. Growth rate (cm yr^{-1}) plotted against straight carapace length (cm) for 28 long term recaptures of *Chelonia mydas agassizii* landed in Bahía de los Angeles, Baja California, México.

APPENDIX B:

JOURNAL OF HERPETOLOGY

LRH: Seminoff et al.

RRH: Feeding ecology of East Pacific green turtles

Feeding Ecology of the East Pacific Green Turtle (Chelonia mydas agassizii)
in the central Gulf of California, México.

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Key Words: East Pacific green turtle, Chelonia mydas agassizii, diet, herbivory, Gulf of California, México.

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Feeding Ecology of the East Pacific Green Turtle (Chelonia mydas agassizii) in the
Central Gulf of California, México.

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ABSTRACT. - We studied diet in the East Pacific green turtle (Chelonia mydas agassizii) at the Bahía de los Angeles foraging area of the Gulf of California, México, between 1995 and 1999. Gastric lavage samples were collected from 101 green turtles and fecal samples were collected from a subset of 45 turtles. Digestive tract contents were analyzed from seven stranded carcasses. The mean straight-line carapace length of all but stranded turtles was 75.8 cm. The mean straight-line carapace length of the stranded turtles was 71.8 cm. Red algae (Rhodophyta) of the Gracilariaceae were the most prevalent diet constituents among all sample types. The primary alga recovered in diet samples was Gracilariopsis lemaneiformis. Other major diet items included the green algae Codium sp. and Ulva lactuca. Animal matter was found in all sample types. Tube worms (Sabellidae), sponges (Porifera), sea hares (Aplysia vaccaria), and sea pens (Ptilosarcus undulatus) were the most commonly ingested invertebrates. Heavy consumption of Gracilariaceae paralleled its high abundance in the study area; however, common species such as Sargassum sp. and Padina durvillaei were conspicuously absent from diet samples. The correlation

of invertebrate consumption to resource availability in the study area was less established.

Key Words.—East Pacific green turtle, Chelonia mydas agassizii, diet, herbivory, Gulf of California, México.

The East Pacific green sea turtle (a.k.a. black sea turtle), Chelonia mydas agassizii, occurs throughout the East Tropical Pacific Ocean and adjacent waters (Felger et al., 1976; Clifton et al., 1982). Upon dispersing from rookeries in Michoacán, México, green turtles move into coastal neritic habitats for foraging and development (Alvarado and Figueroa, 1989). Occasional glimpses into the diet of East Pacific green turtles have been obtained (Table 1), yet detailed studies of foraging ecology at feeding grounds are lacking. The Gulf of California has been considered an important region for foraging (Clifton et al., 1982). Our greatest understanding of green turtle foraging ecology in these waters comes from the Infiernillo Channel region where green turtles primarily consume seagrass (Felger and Moser, 1973). However, this region is unique as the only Gulf locality with abundant seagrass stands. The diet and foraging tactics from areas which lack seagrasses remain unclear.

Carr and Carr (1970) and Bjorndal (1995) have suggested that variation in diet of C. m. agassizii at different foraging grounds may affect the rate of net nutritional gain and in turn, reproductive output and demography. Thus, diet study should be an

important component for the development of conservation strategies for the vulnerable East Pacific green turtle population. Here we report on the feeding ecology of C. m. agassizii in Bahía de los Angeles, a temperate feeding area dominated by marine algae in the central Gulf of California, México.

MATERIALS AND METHODS

Study Area. - The Bahía de los Angeles foraging area of the central Gulf of California (28°58' N, 113°33' W) is a semi-enclosed NNE-oriented bay measuring approximately 12 km long with a maximum width of 5 km at its southern limit (Fig. 1). A series of seventeen islands separates the bay from offshore waters. Marine substrates within the bay are mostly soft bottom, consisting of sand and silt. Peninsular shorelines are a mosaic of sand, cobble, and boulders of granitic and basaltic composition. Insular benthic habitats are primarily basaltic in composition. Bahía de los Angeles has a mean precipitation of 4 cm yr⁻¹ with sporadic summer and winter rains. Mean air temperatures vary between a maximum of 38 C in August to a minimum of 16 C in February (Crosswhite and Crosswhite, 1982). Mean monthly sea surface temperatures (SSTs) follow approximately the fluctuations in ambient air temperature but are generally lower, ranging from 14 C to 30 C (Robinson, 1973). The open areas of Bahía de los Angeles have salinities close to that of full strength sea-water (35 ‰). Salinities in the northern and southern protected areas are slightly higher, reaching a maximum of 36.5 ‰. There are two tidal cycles per day with a 3m maximum tidal range. This region is influenced by the waters of the Ballenas

Channel that are characterized by strong tidal mixing and high nutrient levels ((Bray and Robles).

Marine algae are the prevailing marine vegetation in the study area (Norris, 1975). Extensive marine algae pastures are present along the western and southern margins within the bay. The dominant macroalgae species in these regions are Gracilariopsis lemaneiformis (Pacheco-Ruiz et al., 1999) and Sargassum spp. (Pacheco-Ruiz et al., 1998). A diverse assemblage of marine invertebrates occurs throughout the bay (Brusca, 1980).

Turtle Capture and Measurement. - Between May 1995 and October 1999, specialized entanglement nets (100 m x 8 m, mesh size = 50 cm stretched) were used to capture green turtles along near-shore margins of Bahía de los Angeles. Distance from shore and water depth of netting sites ranged from 50 m to 750 m, and 2 m to 27 m, respectively. Nets were set during both day and night periods and monitored at 0.5-h to 12-h intervals. Entangled turtles were removed upon encounter and transferred to the Centro Regional de Investigación Pesquera - Sea Turtle Research Station (CRIP-STRS) in Bahía de los Angeles and held captive for up to 48 h.

Diet of C. m. agassizii was characterized through gastric lavage and fecal sampling from live turtles and analysis of digestive tracts collected from stranded carcasses. Gastric lavage, the esophageal flushing of recently ingested food items, followed protocol by Forbes and Limpus (1993) and was performed immediately after capture. Residual food material in the mouth region was collected manually. To collect feces, we isolated turtles in a 1500-L seawater tank at CRIP-STRS. All feces

were gathered and rinsed through a 0.5-mm fine mesh sieve with clean sea water. Ingested food samples were analyzed from the stomach only.

All dietary samples were fixed in a 4% formalin solution in clean seawater. We determined the composition of samples by sorting dietary components according to species (i.e., one algal species equals one diet component). Items were analyzed with a binocular dissecting scope and identified from Norris (1975), Brusca (1980), and Zertuche-González et al. (1995). Morphologically indistinguishable fragments of related genera were grouped together by the next highest taxonomic level. Entire sample volume and relative volume of each diet component were calculated through water displacement in a graduated cylinder to the nearest 10 ml.

We calculated frequency of occurrence (% F) for all diet items in each sample type by the following equation:

$$\% F = \frac{\text{Number of samples containing diet item}}{\text{Total number of samples}} \times 100$$

We determined mean % sample volume (% vol) of each prey group as follows:

$$\% \text{ vol} = \frac{\text{Total volume of diet item in all samples}}{\text{Total volume of all samples}} \times 100$$

Any item with a relative volume $\geq 5\%$ in at least one sample was considered a major diet constituent (Garnett et al., 1985).

Benthic transects were performed throughout the study area during the 1999 study season. SCUBA was used to carry out 100 m transects in five localities within the Bahía de los Angeles study: El Bajo Shallows, La Gringa, El Cardon, Central Bay, and Islands. Depth of transects ranged from 3 m to 25 m. For each 100-m transect,

we identified the major plant taxa, total % coverage of each species, mean water depth, and substrate type. Water temperatures were logged continuously in three regions of the bay using remote data sensors (HOBO Temp; Onset Computers, Pocasset, MA).

Prior to release we measured straight carapace length (SCL; ± 0.1 cm) from the nuchal notch to the posterior-most portion of the rear marginals using a forester's caliper (Forestry Suppliers, Jackson, MS). We estimated maturity status for all captures based on the subjective criterion of mean size of nesting females (MNS) at the Michoacán, México, rookery (77.3 cm SCL; Figueroa et al., 1993). Based on this criterion, a turtle was assumed to be immature if SCL < 77.3 cm and mature if SCL \geq 77.3 cm. Each turtle was tagged with Inconel tags (Style 681, National Band and Tag Company, Newport, KY), in the first large proximal scale of each rear flipper.

We used ANOVA to measure consistency of mean SCL among years. Non-parametric Wilcoxon tests were used to determine differences between the adult and immature groups in the amount of *G. lemaneiformis* and animal matter consumed. Statistical calculations were performed according to Sokol and Rohlf (1995).

RESULTS

We collected gastric lavage samples from 101 live-captured *C. m. agassizii*. Fecal samples were recovered from a subset of 40 of these turtles. We analyzed stomach samples from seven stranded carcasses. Most feeding data were collected June – September of each study season. Mean monthly sea surface temperature (SST)

during this interval ranged from 20 C to 29.5 C. The mean SCL of turtles yielding lavage and fecal samples was 75.8 cm (SE = 7.6 cm; range = 50.4 cm to 96.6 cm; Fig. 2) and did not differ significantly among years ($F_{3,97} = 2.26$, $P = 0.086$). This group was comprised of 52 immature-sized turtles and 49 adult-sized. Mean SCL of stranded turtles was 71.8 cm (SE = 7.5 cm, range = 46.0 cm to 92.5 cm, $n = 5$). The stranded group was comprised of four immatures and one adult male turtle. In addition, two stomach samples were recovered by local fishermen from stranded turtles. No measurements were available. Mean sample volume of lavage and fecal samples were 159.3 ml (SE = 30.81, range = 5 to 2000 ml) and 562.1 ml (SE = 115.5, range = 50 to 3,000 ml), respectively. Lavage samples were successfully recovered from turtles captured during both day and night periods. Mean sample volume of stomach contents from stranded animals was 1,385 ml (SE = 329, range = 200-2,700 ml).

Marine Algae. – Our greatest understanding of marine algae consumption was derived from lavage samples (Table 1) and to a lesser extent, stomach samples (Table 2). Recovered algae were generally macerated to a high degree and morphologically similar species were commonly indistinguishable. We thus made four ‘higher taxon’ groupings; Codium amplivesticulatum and C. simulans (Codium spp.), Gigartina johnstonii and G. pectinata (Gigartina spp.), Sargassum johnstonii and S. sinicola camouii (Sargassum spp.), and Gracilariopsis lemaneiformis and Gracilaria robusta (Gracilariaceae).

The most important foods of C. m. agassizii in Bahía de los Angeles were red algae of the family Gracilariaceae. Algae in this family combined for 91.4% of the mean volume of gastric lavage samples: Gracilariopsis lemaneiformis was the most commonly ingested, followed by Gracilaria robusta, and Gracilaria spinigera (Table 2). There was no evidence of a difference in the amount of Gracilariaceae foods in gastric lavage samples from immature- versus adult-sized turtles (Wilcoxon $Z = -0.38$, $P=0.70$). Additional algae species were present in lavage samples, albeit to a much lesser extent. These included Codium spp. (8 samples with $\geq 5\%$ vol), Ulva lactuca (3 samples with $\geq 5\%$ vol), and Chaetomorpha antennia (3 samples with $\geq 5\%$ vol). In stomachs examined, G. lemaneiformis and G. spinigera were the most prevalent species, accounting for a mean of 59% of the sample contents (Table 3). Other algae species were present in trace levels only. Among fecal samples, intact undigested fragments of Sargassum spp. and Padina durvillaei were recovered.

Animal Matter. – Animal matter was recovered in all sample types. We measured % F and % vol of animal matter in lavage and stomach samples. However, among fecal samples the mechanical breakdown of foods and volumetric changes associated with gut passage rendered volumetric analyses inappropriate. We therefore based our quantification of fecal egesta on % F only.

The greatest relative volume of animal matter per sample was found in the stomachs examined during this study (Table 3). Mean relative volume of animal matter among stomach samples was 20.6% (SE = 13.3, range = 0% to 77%). The greatest volume of non-algal ingesta was found in turtle #409, in which gastropod egg

cases composed 65% of the stomach contents, and in turtle #407, in which a total of 23 sea hares (*Aplysia vaccaria*) composed 77% of the stomach volume. Additional animal species were recovered from stomachs in trace amounts only.

We recovered the highest number of animal species (22 spp.) from fecal samples (Table 4). Animal material in these samples was identified from rigid parts passing undigested (e.g. gastropod shells, sponge spicules, vestigial shells of sea slugs and squid, and sea pen spines). The most common animals were sabellid worms (found in 45.2% F), sponges (42.8% F), sea pens (16.6% F), and small gastropods (41% F).

Gastric lavage samples revealed a total of 10 animal species (Table 4). Sabellid tube worms (41.5% F) and sea pens (3.9% F) were the most frequently occurring items among lavage samples. The difference in the amount of animal matter in samples from immature-sized and adult-sized turtles was not significant (Wilcoxon $Z=0.94$, $P=0.34$).

Ingested Substrate and Plastics. – Substrate particles were comprised of sand, pebbles, and shell fragments. These items were found in 52.4% and 52.3% of lavage and fecal samples, respectively. Anthropogenic debris was recovered in 1.9% of lavage samples and 19.0% of fecal samples. Recovered items included plastic bags, nylon chord, mesh bags, and tarp fragments. Plastic debris was found in two of the digestive tracts analyzed from stranded turtles; however, there was no evidence to suggest this as a cause death.

Vegetation Surveys. – We performed a total of 72 transects among five localities at the Bahía de los Angeles foraging habitat (Table 5). Rhodophyta was the most

common algal division, occurring in all sub-regions of the study area. G. lemaneiformis and G. robusta were the most commonly encountered red algae. The El Bajo Shallows feeding pasture was site of the greatest abundance of this group (80% cover). Phaeophyta was the second most common group. The two primary species encountered were Sargassum sp. and Padina durvillaei. The greatest density of these species was found at the Island sub-region where they occurred in mixed stands. Maximum algal coverage in this sub-region was 55%.

DISCUSSION

East Pacific green turtles in Bahía de los Angeles forage primarily on marine algae. Their predominantly herbivorous diet is consistent with Chelonia throughout its range (Bjorndal, 1980; Mortimer, 1981; Ross, 1985). The red alga Gracilariopsis lemaneiformis (Rhodophyta) was the most commonly ingested food item among the turtles we examined. The prevalence of G. lemaneiformis among the diet samples reflected its great abundance in the study area. With an annual biomass of 10-20 metric tons per hectare, it is the most abundant marine alga in the study area (Pacheco-Ruiz et al., 1999). Dense stands or 'pastures' of this red alga occur over roughly 15 ha of sandy bottom habitat along the shallow water margins of the bay (Pacheco-Ruiz et al., 1999). Green turtles commonly congregated over these pastures for foraging activities (Seminoff et al. In prep). Turtles also foraged on less common algae from nearshore areas lacking G. lemaneiformis. Our recovery from diet samples of green algae (Chlorophyta) species such as Ulva lactuca, Chaetomorpha

antennina, and Codium spp. confirm that C. m. agassizii forage in a variety of marine habitats throughout the bay.

Our data support prior observations that green turtles modify their diets to meet local conditions (Balazs, 1980; Bjorndal, 1980; Ross, 1985; Balazs et al., 1987). The diet of green turtles in Bahía de los Angeles is significantly different than the other central Gulf of California populations. The diversity of herbivorous foods consumed by green turtles in this marine algae-dominated region of the Gulf of California is greater than that of turtles feeding in a nearby seagrass ecosystem (Felger and Moser, 1973; 1987, Clifton et al., 1982). While we have documented at least five major algal diet items in the turtles we examined, green turtles in the Infiernillo Channel of the central Gulf of California feed almost exclusively on eelgrass (Zostera marina) L. (Felger and Moser, 1973; 1987).

Whereas feeding specificity on seagrasses may be a result of hind-gut endosymbiont specialization (Bjorndal, 1985), it appears that the micro-flora in the hind guts of green turtles examined in this study are capable of processing a wide variety of both red and green algae species. To better facilitate nutrient assimilation, green turtles appear to take small bites of marine algae foods during consumption. In the diet samples we examined, algae were commonly fragmented to very small size (ca. 1-cm length). The resulting small food particle size is functionally beneficial to nutrient assimilation in species such as the green turtle that rely on hind-gut endosymbiont fermentation (Bjorndal et al., 1991). In freshwater herbivorous turtles benefiting from hind-gut fermentation, Bjorndal et al. (1990) showed that smaller

food particle size resulted in greater amounts of exposed food surface area in the digestive tract and, thus, more efficient digestion.

There remain at least two algae that appear indigestible to green turtles. Fragments of the brown algae (Phaeophyta) Sargassum spp. and Padina durvillaei were commonly found intact in fecal samples. While these species are abundant in the study area, their trace occurrence in diet samples indicate possible avoidance by green turtles. The intact nature of these items after passing the digestive tract indicates their structural composition is able to withstand digestion by the C. m. agassizii we examined. Thus, it appears that to some extent, the digestibility of local foods affects the diet selection of green turtles.

Green turtles in Bahía de los Angeles augment their diet with animal matter. The possibility that such foods make a major contribution of vitamins, trace minerals, or essential amino acids for herbivorous green turtles has been discussed (Bjorndal, 1990; Bjorndal, 1991; Hirth et al., 1993) and may explain why, even with abundant algae resources, green turtles feed on animal matter. We documented consumption of over 25 non-algal species. However, because (1) rigid invertebrate parts are not easily recovered in lavage techniques and (2) soft bodied invertebrates are completely digested and leave behind no identifiable remains in fecal samples, the species richness and abundance of non-algal species recovered in this study are likely underestimates. Invertebrate consumption by green turtles in Bahía de los Angeles is noteworthy regardless of this sampling bias. Though foraging on invertebrates has

been previously observed in green turtles (Carr, 1952; Balazs, 1980; Mortimer, 1981), few studies have revealed such great diversity and abundance.

Much of the invertebrate material found in diet samples may be attributable to incidental consumption; however, there is evidence that at least one animal species was purposefully consumed. The fleshy sea pen (Ptilosarcus undulatus) was frequently recovered in diet samples. This solitary cnidarian anchors in sandy substrates at depths of 10 m to 50 m (Brusca 1980). Its patchy distribution within the study area does not overlap even the deepest occurring marine alga, thus minimizing the likelihood of incidental consumption. The high rate of occurrence of P. undulatus among diet samples despite its uncommon nature in Bahía de los Angeles suggests this item was actively sought by foraging green turtles. Unlike other invertebrates that were slow to digest by green turtles (e.g., sponges, sea slugs), all but the calcareous spines of these animals was digested prior to leaving the stomach region. This ease of digestion may have contributed to the selection of sea pens by green turtles.

In addition, green turtles ingested sand, pebbles, shell fragments, and anthropogenic debris. These items were present in small quantities in the diet contents and were likely taken as turtles foraged on benthic foods. Anthropogenic debris may have also been consumed by green turtles at the water's surface where it collects in driftlines or convergences.

In terms of overall life cycle, a general model of the foraging ecology of C. m. agassizii in Bahía de los Angeles has become evident. A wide size range of turtles of

both sexes exploit the abundant food resources of Bahía de los Angeles. Green turtles forage for the majority of their food in near-shore waters of depths no greater than 10 m. They remain closely associated with algal pastures in these regions during diurnal and nocturnal periods. Gastric lavage sampling of day- and night-captured turtles indicate that they feed throughout the diel cycle. Movement is not restricted to these habitats and green turtles continue to feed after departing the near shore algal pastures. The prevalence of deep water benthic invertebrates such as tube worms (Sabellidae), sea pens, and yellow-polyp black corral (*Antilopathes galapagensis*) in diet samples confirms that the majority of animal matter consumption occurs in deeper, offshore habitats.

Nocturnal foraging at Bahía de los Angeles is consistent with reports from the Caribbean (Bjorndal, 1980; Ogden et al., 1983), Hawaii (Balazs et al., 1987) and western Pacific (Hirth et al., 1992). We observed heavy boat traffic and fishing pressure on a daily basis over nearshore feeding pastures throughout the study area. This behavior may be an avoidance response to these human activities. Similarly, Balazs et al. (1987) saw regular night time foraging in Hawaiian *C. mydas* and suggested this was in response to human presence in the nearshore feeding localities.

The role of Bahía de los Angeles in respect to the entire Gulf of California green turtle population remains unclear. Green turtles in this algae-dominated area appear to exhibit different foraging trends than those reported from other areas in the Gulf (Cliffon et al., 1982; Felger and Moser, 1973; 1987) and it is likely that these differences affect both growth rate and reproductive output at these distinct foraging

localities (Carr and Carr, 1970). To elucidate these trends, additional diet studies in a variety of other foraging habitats within the Gulf are needed.

Historic records of green turtle populations in Bahía de los Angeles indicate that the extensive marine algae pastures of this region supported a population of considerably larger size than that of today. The decline in number of green turtles due to human harvest in this region and the entire Gulf of California has been documented (Caldwell, 1963; Clifton et al., 1982). Despite these declines, the marine habitats of Bahía de los Angeles remain intact and provide abundant food resources for green turtles. This highlights the importance of Bahía de los Angeles as a critical green turtle feeding habitat and establishes this area as a candidate for future management and conservation efforts.

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TABLE B.1. Checklist of published and unpublished accounts of diet of the East Pacific green turtle from 1931 to present. Accounts are listed from south to north within the Eastern Pacific Ocean.

Authors (year)	Study area	No.	Recovered foods
			turtles
Brito-Montero (unpubl)	Chile	-	<u>Durvillaea antarctica</u> , <u>Glossophora kunthii</u> , <u>Gymnogongrus furcellatus</u> , <u>Plocamium violaceum</u> , <u>Ulva lactuca</u> , <u>Lessonia</u> sp., <u>Porphyra columbia</u> , Porifera, Annelida, Medusae, plastic
Paredes (1969)	Pisco, Perú	20	Algae, Medusae, fish, Mollusca
Hays Brown and Brown (1982)	Pisco, Perú	39	Rhodophyta (<u>Gigartina</u> sp., <u>Rhodomenia</u> sp.) <u>Distichlis</u> sp., Mollusca (<u>Mytilus</u> sp., <u>Nassarius</u> sp., <u>Semele</u> sp.), Polychaeta, Medusae, Amphipoda, fish and fish eggs, Crustacea
Fritts (1981)	Manta, Ecuador	1	<u>Sargassum</u> sp., fish eggs,
Slevin (1931)	Galapagos Islands, Ecuador	11	<u>Rhizophora</u> sp.
Pritchard (1971)	Galapagos Islands,	-	Chlorophyta (<u>Caulerpa</u> sp.), <u>Rhizophora</u> sp.

Ecuador		
Green and Ortiz-Crespo (1982)	Galapagos Islands, Ecuador	- 15+ spp. marine algae
Green (unpubl.)	Galapagos Islands, Ecuador	- Chlorophyta (<u>Ulva</u> sp., <u>Caulerpa</u> sp.), <u>Rhizopora</u> sp.
Carr (1952)	Bay of Fonseca, Honduras	10 <u>Zostera marina</u> , kelp, Porifera
Casas-Andreu and Gómez-Aguirre (1980)	Colima and Jalisco, México	7 Chlorophyta, Rhodophyta, invertebrates, Chordates
Felger and Moser (1973)	Gulf of California, México	- <u>Zostera marina</u> , Chlorophyta, invertebrates
Clifton, Cornejo, and Felger (1982)	Gulf of California, México	- <u>Zostera marina</u> , <u>Ruppia maritima</u> , Fucales, Gelidiales, Ulvales, invertebrates
Márquez (1990)	Gulf of California, México	19 <u>Gracilaria</u> sp., <u>Rhodomencia</u> sp., <u>Gelidium</u> sp., <u>Grateloupia</u> sp., <u>Gigartina</u> sp., <u>Griffitsia</u> sp., <u>Sargassum</u> sp., <u>Padina</u> sp., <u>Ulva</u> sp., <u>Cladophora</u> sp., Mollusca, Crustacea, Bryozoa Porifera, Medusae, Echinodermata

TABLE B.2. Average % sample volume and frequency of occurrence of major plant taxa among gastric lavage samples collected from C. m. agassizii near Bahía de los Angeles, México. (T = occurs in trace levels)

Species	Average % sample volume	No. of samples sp. present	% samples sp. present
<u>Codium</u> spp. ^A	2	13	12.8
<u>Chaetomorpha antennina</u> (Bory) Kütz	1.6	10	9.9
<u>Ulva lactuca</u> L.	2.1	7	6.9
<u>Enteromorpha acanthophora</u> Kütz	T	1	0.9
Total Chlorophyta	5.6	27	26.7
<u>Sargassum</u> spp. ^B	T	12	11.9
<u>Ishige sinicola</u> Setchell et. Gardner	T	2	1.9
<u>Dictyota flabellata</u> Setchell et. Gardner	T	1	0.9
<u>Padina durvillaei</u> Bory	T	1	0.9
<u>Sporochnus bolleanus</u> Montagne	T	1	0.9
Total Phaeophyta	T	14	13.8
Gracilariaceae ^C	87.3	94	93.1
<u>Gracilaria spinigera</u> Dawson	4.1	24	23.7

<u>Lithophyllum</u> spp.	1.1	13	12.8
<u>Gelidium johnstonii</u> Setchell et. Gardner	T	4	3.9
<u>Gigartina</u> spp. ^D	T	2	1.9
<u>Euchema uncinatum</u> Setchell et. Gardner	T	1	0.9
<u>Halymenia refugiensis</u> Dawson	T	1	0.9
<u>Laurencia johnstonii</u> Setchell et. Gardner	T	1	0.9
Total Rhodophyta	93	97	96

^A Codium amplivesticulatum Setchell et. Gardner and Codium simulans Setchell et. Gardner

^B Sargassum johnstonii Setchell et. Gardner and Sargassum sinicola camouii Setchell et. Gardner

^C Gracilariopsis lemaneiformis (Bory) Dawson, Acleto et. Foldvik and Gracilaria robusta Dawson

^D Gigartina johnstonii Dawson and Gigartina pectinata Dawson

<u>Haliclona</u> sp.	-	T	T	-	-	-	-	T
Gastropod egg cases	65	-	-	-	-	-	-	9 (9)
Substrate	-	-	T	-	T	T	T	T

TABLE B.4. Frequency of occurrence of non-algal ingesta in gastric lavage, fecal, and stomach samples collected from *C. m. agassizii* near Bahía de los Angeles, México.

Species	Common name	Lavage (n = 101)		Fecal (n = 42)		Stomach (n=7)	
		No.	%	No.	%	No.	%
Annelida							
<i>Sabellidae</i>	Feather dusters	42	41.5	19	45.2	-	-
Asciacea							
<i>Ascidia interrupta</i>	Solitary tunicate	1	0.9	1	2.4	-	-
Bryozoa							
<i>Hyppothoa</i> sp.	Bryozoan	-	-	2	4.6	-	-
Cnidaria							
<i>Antipathes galapagensis</i>	black corral	3	2.9	3	7.1	-	-
<i>Lytocarpus nuttingi</i>	stinging hydroid	-	-	1	2.4	-	-
<i>Muricea</i> sp.	gorgonian	2	1.9	1	2.4	-	-
<i>Ptilosarcus undulatus</i>	fleshy sea pen	4	3.9	7	16.6	4	57
Crustacea							
un-ID Natantia	true shrimp	3	2.9	-	-	-	-

Echinodermata

<u>Clypeaster testudinarus</u>	sand dollar	-	-	1	2.4	-	-
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Mollusca

un-ID gastropod eggs		-	-	1	2.4	1	14
<u>Aplysia vaccaria</u>	sea hare	-	-	8	19	2	29
<u>Dentalium neohexagonum</u>	tusk shell	1	0.9	-	-	-	-
<u>Dosidicus gigas</u>	Humbolt squid	3	2.9	5	11.9	-	-
<u>Columbela fuscata</u>	columbela shells	-	-	1	2.4	-	-
<u>Mytella guyanensis</u>	mussel	-	-	1	2.4	-	-
<u>Olivella dama</u>	pygmy olive shell	-	-	3	7.1	-	-
<u>Trypsica trypsica</u>	worm shell	-	-	1	-	-	-
Turridae	turrid shells	-	-	1	-	-	-

Porifera

un-ID poriferan		-	-	4	9.5	-	-
<u>Acarus erithacus</u>	red velvet sponge	1	0.9	8	19	-	-
<u>Halisarca</u> sp.	slime sponge	-	-	7	16.7	-	-
<u>Haliclona</u> sp.	encrusting sponge	-	-	-	-	2	29
<u>Hymeniacidon rugosus</u>	encrusting sponge	1	0.9	4	9.5	-	-
<u>Hymeniacidon sinapium</u>	encrusting sponge	-	-	10	23.8	-	-
Labrisomidae vertebra	Labrisomid blenny	-	-	1	2.4	-	-
Substrate		53	52.4	22	52.3	-	-
Plastics		2	1.9	8	19	-	-

TABLE B.5. Mean % coverage and frequency of occurrence (in parentheses) of major plant taxa in the benthic transects. * = transects performed by W. Rice (in prep.)

	El Bajo	La Gringa*	El Cardon*	Off Shore*	Islands*
	N = 15	N = 12	N = 13	N = 15	N = 18
Mean water depth (m)	7.34	14.5	12.4	15.5	15
Mean % total coverage	58.6	27.9	12.1	25.1	25
Species Composition					
<u>Gracilariaceae</u> ^A	80 (91.6)	22.7 (33.3)	37.1 (46)	47.8 (53.3)	1.6 (5.5)
<u>Gigartina</u> spp. ^B	17.9 (33.3)	1.3 (8.3)	-	-	0.1 (5.5)
<u>Euchema uncinatum</u> Setch <i>et.</i> Gardn	-	0.2 (8.3)	9.3 (25)	4.4 (6.6)	-
Total Rhodophyta	97.9 (100)	24 (41.6)	46.4 (46)	52.2 (53.3)	1.7 (11.1)
<u>Codium</u> spp. ^C	-	2.8 (41.6)	-	3.7 (26.6)	-
<u>Ulva lactuca</u> L.	-	-	12 (15.4)	-	-
<u>Chaetomorpha antennina</u> (Bory) Kütz	0.5 (8.3)	-	0.8 (23)	-	-
Total Chlorophyta	0.5 (8.3)	2.8 (41.6)	2.8 (30.7)	3.7 (26.6)	-
<u>Sargassum</u> spp. ^D	-	-	-	-	21 (50)
<u>Padina durvillaei</u> Bory	0.4 (8)	-	-	-	34 (72)
Total Phaeophyta	0.4 (8)	-	-	-	55 (78)

^A Gracilariopsis lemaneiformis (Bory) Dawson, Acleto *et.* Foldvik; Gracilaria robusta Dawson; and Gracilaria spinigera Dawson.

- ^B Gigartina johnstonii Dawson and Gigartina pectinata Dawson
- ^C Codium amplivesticulatum Setchell et. Gardner and Codium simulans Setchell et. Gardner
- ^D Sargassum johnstonii Setchell et. Gardner and Sargassum sinicola camouii Setchell et. Gardner



FIG. B.1. Map of Bahía de los Angeles study area, Gulf of California, México. Square indicates location of CRIP-STRS.

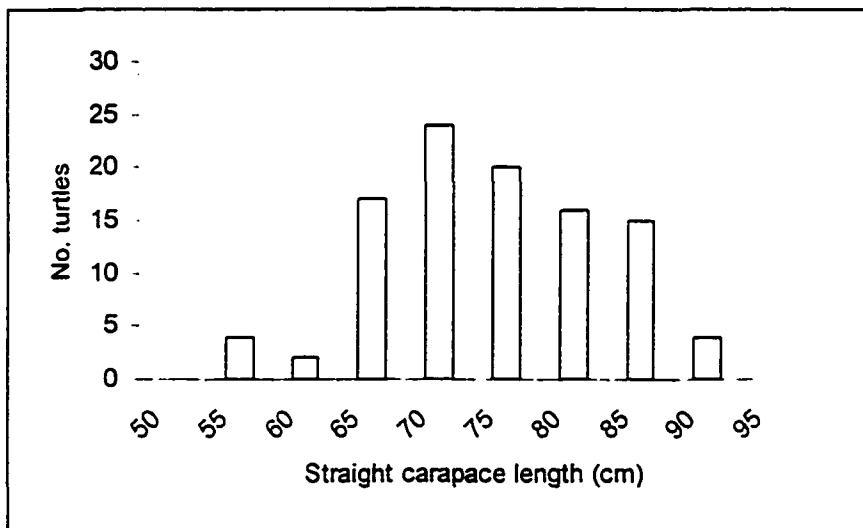


FIG. B.2. Size distribution of *C. m. agassizii* from which diet samples were recovered

APPENDIX C:

COPEIA

Home range and movement of the East Pacific Green Turtle (*Chelonia mydas agassizii*)
at a warm temperate feeding area in the Gulf of California, México.

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Key words: East Pacific green turtle, *Chelonia mydas agassizii*, homerange, movement,
24-h vagility, VHF telemetry, acoustic telemetry, Gulf of California, México.

Suggested Running Head: Movement and homerange of *C. m. agassizii*

Manuscript Category: Major Article

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Home range and movement of the East Pacific green sea turtle (*Chelonia mydas agassizii*)
at a warm temperate feeding area in the Gulf of California, México.

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We studied home range size and movement patterns of the east Pacific green turtle (*Chelonia mydas agassizii*) at the Bahía de los Angeles feeding area of the Gulf of California, México. Between 1996 and 1999, radio and acoustic telemetry data were collected on 23 *C. m. agassizii*. Home range was calculated for 12 turtles. Daily vagility was monitored through continuous 24-h tracking sessions of eight *C. m. agassizii*. Mean minimum convex polygon (MCP) home range area was 1,801 ha. Kernel density estimates (95%) of home range area had a mean of 1,545 ha. Home range length averaged 7,548 m. Home range sizes did not vary significantly among years and were not correlated with turtle SCL or number of relocations. Mean 24-h vagility was 9,535 m. There was no relationship between turtle size and 24-h vagility. Mean area of 24-h polygons was 368 ha and did not significantly differ among maturity class. The mean area of 24-h use polygons was 23% of mean MCP area. There was a strong relationship between area of 24-h use polygons and MCP areas. Diurnal and nocturnal movements were evident. Turtles exhibited a bimodal pattern in which they foraged in nearshore marine algae pastures during evening and night hours and moved to offshore and/or insular resting sites by midmorning.

Key words.- East pacific Green turtle, *Chelonia mydas agassizii*, home range, movement, VHF telemetry, acoustic telemetry, Gulf of California, México.

Information on the movements of sea turtles is based largely on adult females in the inter-nesting environment and post nesting migrations. Comparatively less is known of sea turtle movements in foraging habitats. While sea turtles assembled in these regions are often vulnerable to exploitation, understanding spatial use patterns and habitat needs has been recognized as an essential element for the successful recovery of sea turtle stocks (Thompson et al., 1990).

The East Pacific green sea turtle (a.k.a. black sea turtle), *Chelonia mydas agassizii*, occurs throughout the eastern Pacific ocean (Cliffon et al., 1982; Green, 1984; Alvarado and Figueroa, 1992). The U. S. Department of the Interior, under the authority of the Endangered Species Act, currently lists the Mexican Pacific population as endangered (National Marine Fisheries Service and US Fish and Wildlife Service, 1998). The Mexican nesting population continues in a state of decline (Figueroa et. al. 1993, Alvarado pers. comm.) and recent evidence from feeding areas indicates an alarming rate of human-induced mortality (Nichols, in prep.; Seminoff, in prep. a). Despite the highly vulnerable status of *C. m. agassizii*, few data are available on its movements. Migratory links between nesting areas in Michoacán, México, and feeding grounds in the Gulf of California, México, have been established through tag returns (Alvarado and Figueroa,

1992; Seminoff, in prep. a), mtDNA analysis and satellite telemetry (Nichols in prep.). Figueroa et al. (1993) studied local movements of *C. m. agassizii* in the inter-nesting habitat and Byles et al. (1995) studied post nesting movements; however, data away from nesting areas are lacking and there are no published accounts of movements in nearshore foraging habitats of Pacific México. Here we report on the home range size and local movements of the East Pacific green turtle in Bahía de los Angeles, a warm-temperate foraging habitat of the central Gulf of California, México.

Methods

Study site. – Fieldwork was conducted at the Bahía de los Angeles foraging area of the central Gulf of California, México (28°58' N, 113°33' W). This semi-enclosed NNE-oriented bay is approximately 12 km long with a maximum width of 5 km at its southern limit (Fig. C.1). A series of seventeen islands separate the bay from the deep waters of the adjacent Ballenas Channel. Bahía de los Angeles has a mean precipitation of 4 cm yr⁻¹ with sporadic summer and winter rains. Mean air temperatures vary between a maximum of 38 C in August to a minimum of 16 C in February (Crosswhite and Crosswhite, 1982). Mean monthly sea surface temperatures (SSTs) follow approximately the fluctuations in ambient air temperature but are generally lower, ranging from 14 C to 30 C (Robinson, 1973). The waters of Bahía de los Angeles have salinities close to that of full strength sea-water (35 parts per thousand). There are two tidal cycles per day with a 3-m maximum tidal range. This region is influenced by the waters of the Ballenas

Channel that are characterized by strong tidal mixing (Bray and Robles, 1991) and high nutrient levels (Alvarez-Borrego et al., 1978).

The study area is comprised of largely different insular and peninsular habitats separated by deep mid-bay waters. Marine substrates are primarily soft bottom, consisting of sand and silt (Grady, 1964). Peninsular coastlines are a mosaic of granitic sand and basaltic cobble. Shallow (< 10 m water depth) habitats extend up to 0.75 km offshore from the eastern edge of the study area and host extensive marine algae pastures. The dominant macroalgae species is *Gracilariopsis lemaneiformis* (Pacheco-Ruiz et al., 1999). Insular habitats are characterized by sloping boulder fields that rise off the soft-bottomed sea floor from depths of 20-50 m (Delgado-Argote and García-Abdeslem, 1999). Marine invertebrates such as gorgonians and soft corals are abundant (Brusca, 1980). Mid-bay waters are deep (to 50 m) with sandy benthic habitats dominated by yellow-polyp black coral (*Antilopathes galapagensis*), fleshy sea pens (*Ptilosarcus undulatus*), and sabellid worms (Sabellidae). Habitat characteristics of Bahía de los Angeles are further described in Seminoff (in prep. b).

Data collection and analysis.- From June 1996 to September 1999, 23 green turtles (17 immatures, three adult females, and three adult males) were fitted with very high frequency (VHF) radio transmitters and acoustical 'sonic' transmitters and followed for periods ranging from one day (d) to 14 months. We used large-mesh entanglement nets (100 m x 8 m, mesh size = 60 cm stretched; Ehrhart and Ogden, 1999) to capture turtles along nearshore margins of the feeding area. Nets were set during both day and night periods and monitored at 0.5-h to 12-h intervals. Entangled turtles were removed upon

encounter and transferred to the Centro Regional de Investigación Pesquera Sea Turtle Research Station (CRIP-STRS) in Bahía de los Angeles where they were kept for 24 – 48 hours. All turtles were measured then marked with Inconel tags (Style 681, National Band and Tag Company, Newport, KY), in the first large proximal scale of each rear flipper (Balazs, 1999). We estimated maturity status for all captures based on straight carapace length (SCL; measured from the nuchal notch to the posterior-most portion of the rear marginals). We used the subjective criterion of mean size of nesting females to distinguish maturity status (Limpus pers. comm.). Based on mean nesting size at the Michoacán rookery (Figueroa et al., 1993), we classified all turtles with $SCL < 77.3$ cm as immatures and all with $SCL \geq 77.3$ cm SCL as adults. Among adults, we determined sex based on tail length (TL, Ross, 1984; Limpus and Reed, 1985). Any *C. m. agassizii* with $TL \geq 20$ was classified as male (Meylan et al., 1994). VHF transmitters (15-MOD 400, seven-MOD 600, and one-MOD 050; Telonics, Inc., Mesa, Arizona) were attached to the crown of the carapace using fiberglass resin and cloth ($n=12$; Balazs, 1995), acrylic epoxy ($n=8$; Mitchell, In press), or a backpack harness ($n=2$; Eckert and Eckert, 1986). We attached acoustic transmitters (five-V16, 10-V32P; Vemco Ltd., Nova Scotia, Canada; and three-CHP87, five-DT96, Sonitronics; Tucson, Arizona) to the carapace posterior with epoxy and electrician ‘tie-wraps’ fit through holes drilled in the marginal scutes (Mendonca, 1983; Epperly et al., 1996). Weight of transmitter packages ranged from 50 – 250 g (0.5 – 3.8% of turtle body weight). A 12-ft inflatable boat (Achilles w/ 25-hp motor) was used to collect all locational data. We relocated turtles using a Telonics TR-4 radio receiver with a hand-held floppy H-antenna and VemcoVR-60 sonic

receiver with V-10 directional hydrophone. VHF transmissions were audible at distances of up to 14 km in open areas. Maximum transmission distance of acoustic transmitters was ~2 km. We attempted to relocate each turtle at least once per day during each tracking season. Careful attention was given to minimize disturbance to turtles. All locational fixes were recorded with a Global Positioning System (± 50 m; GPS 12, Garmin, Ltd., Hampshire, UK). We described water depth and general habitat type at all relocation points within the study area. Water depth was measured (± 0.5 m) with an electronic depth sounder (Speedtech Instruments, Great Falls, VA). General habitat type was characterized as peninsular, insular, or mid-bay. Relocations were considered peninsular when within 1 km of the peninsular coastline and insular when within .25 km of island habitats. All other relocations were described as occurring in mid-bay habitat.

Home range sizes were calculated for each turtle relocated at least 15 times over a minimum interval of 30 d. To minimize autocorrelation (i.e. dependency among observations), a maximum of one relocation event per 4 h was included in home range calculations (Swihart and Slade, 1985). We estimated home range size using the 100% minimum convex polygon (MCP; Mohr, 1947), Kernel density estimator (KDE; Worton, 1989), and home range length methods (RL; Kenward, 1987). KDE calculations used least squares cross validation with an H value of 506.92. Outer edge of KDE estimates were based on 95 % probability contours. KDE activity centers were defined as the area within the 50% probability contour (Worton, 1989). To determine daily vagility (i.e., distance traveled), movements of seven turtles (five immatures, one adult male, one adult female) were continuously monitored for 24-h periods. Vagility was calculated by

adding linear distances between each successive turtle observation. We determined the total area of 24-h movements based on the same methods used for MCP calculation (Mohr, 1947). All home range sizes and movement distances were calculated with the computer program 'Ranges V' (Institute of Terrestrial Ecology, 1992) and plotted with "Arcview 3.2" (Environmental Systems Research Institute, 1999). We used analysis of variance (ANOVA) for comparisons between home range sizes, daily movements, maturity class, and number of activity centers. Regression analyses were used to determine correlation between home range size and daily vagility in respect to number of relocations, tracking interval, SCL, and total area. We used Wald's Chi-squared test to determine the relationship between number of maturity class and number of activity centers (Sokal and Rohlf, 1995). Mean values are followed by standard error (\pm SE). Computations were made in JMP (SAS Institute, 1996).

Results

In total, we logged 283 turtle days (days in which at least one turtle relocation position was recorded) resulting in 1,101 relocations. Of all relocations, 723 (65.7 %) were visually confirmed, and 378 (34.3%) were established through acoustic signals. We were able to relocate all but three *C. m. agassizii* at intervals > 1 d after release. Most data were collected June – September of each study season. Winter data were collected during January 1998 and January 1999. Sea surface temperatures during summer tracking periods ranged from 25.0 C to 29.1 C. Sea surface temperatures during January 1998 and January 1999 ranged from 13.5 to 17.0 C and 15.0 to 19.0 C, respectively. The

mean SCL of immatures was 69.2 ± 1.2 cm (range = 50.9 to 76.2 cm, $n = 17$); of adult males, 83.6 ± 3.1 cm (range = 77.5 to 87.3 cm, $n = 3$) and of adult females, 78.8 ± 2.7 cm (range = 77.4 to 82.5 cm, $n = 4$). One immature turtle (316) was missing its entire left fore flipper. One turtle (407) was found dead on a beach in the southern portion of the study area three days after release. Scarring patterns on the head and upper shoulders of this turtle were consistent with net entanglement.

Home Range. – Home range size was calculated for 12 (52%) of the 23 tagged turtles (Table C.1; Figs. C.2, C.3, C.4). Overall, 10 (59%) immatures and 2 (33%) adults yielded sufficient data for home range estimation. The mean number of relocation events per turtle was 30.1 ± 4.48 (range = 16 – 58 relocation events) and mean tracking interval was 61.2 ± 5.6 d (range = 34 - 96 d). Six turtles were also recaptured in entanglement nets during periods outside the tracking interval. Home range size estimates were highly variable. Mean MCP and Kernel homerange areas were $1,801 \pm 309.75$ ha (range: 584 - 3,908 ha) and $1,545 \pm 351.97$ ha (range = 284 – 3,688 ha), respectively. Mean home range length was $7,548.8 \pm 820.6$ m (range = 4,792 – 13,336 m). There was no relationship between home range size and; 1.) number of days tracked ($p_{\text{MCP}} = 0.9$; $p_{\text{KDE}} = 0.96$; $p_{\text{RL}} = 0.88$), 2.) number of relocations ($p_{\text{MCP}} = 0.65$; $p_{\text{KDE}} = 0.53$; $p_{\text{RL}} = 0.72$), 3.) maturity/sex class ($p_{\text{MCP}} = 0.58$; $p_{\text{KDE}} = 0.65$; $p_{\text{RL}} = 0.77$), or 4.) SCL ($p_{\text{MCP}} = 0.73$; $p_{\text{KDE}} = 0.96$; $p_{\text{RL}} = 0.88$).

In general, MCP estimates were slightly higher than KDE home range estimates for individual turtles; however the difference was not significant ($p = 0.29$). Of the 12 turtles for which home range was calculated, KDE was higher than MCP in only two instances

(turtles 127 and 316). The differences in MCP versus KDE estimates are particularly evident when relocation data sets have one or more outlying relocations. Whereas MCP home range estimates are based on the outermost relocation events and thus include areas that separate outlying fixes from core areas, KDE techniques weigh outlying fixes accordingly and do not include vast areas of apparent non-use (e.g., turtle 310; Fig. C.5). This trend commonly results in MCPs of greater area than KDE estimates. As distance between outliers and core areas increase, MCP home range estimates become progressively larger than estimates derived with KDE. When relocation events are more evenly distributed within a region and outliers are absent, KDE and MCP estimates become increasingly similar (e.g., turtle 406; Fig. C.6).

The largest home ranges recorded during this study were made by sub-adults 316 (Fig. C.3) and 413 (Fig. C.4). Their respective MCP home range areas measured 3,908 ha and 2,775 ha. Both green turtles were initially captured in the southern-most region of the study area and later relocated at the northern end of the study area. Accordingly, these turtles showed the longest home range lengths: 11,911 ha for turtle 316 and 13,336 ha for turtle 413. The smallest home ranges were exhibited by turtles 225 (Fig. C.2), 311 (Fig. C.3), 406, and 419 (Fig. C.4). All remained in the vicinity of peninsular algae pastures throughout tracking intervals. Mean MCP home range area was 673 ± 40 ha and mean range length was $4,923 \pm 411$ m.

Activity centers were distributed along shallow peninsular margins and boulder slope habitats in insular regions. Four immature turtles maintained a single activity center (225, 311, 316, 419), five maintained two activity centers (127, 314, 323, 415, 422) and one

moved between three activity centers (413). The adult male and female moved between two and three activity centers, respectively. Number of activity centers showed no relationship to SCL ($p=0.41$), maturity/sex class ($X^2 = 0.22, p = 0.84$), or home range area ($p_{MCP} = 0.17, p_{KDE} = 0.24$).

Overall mean distance between individual turtles' activity centers was $4,546 \pm 857$ m (range = 1,815 – 11,048 m). Two turtles (310, 415) had activity centers at island and mainland sites; mean distance was $3,792 \pm 327$ m (range = 4,299 – 3,645 m). Five turtles (311, 314, 406, 413, and 422) moved between two or more peninsular activity centers; mean distance was $5,433 \pm 1,371$ m (range = 1,815 – 11,048 m). One turtle (323) moved between two insular activity centers separated by a distance of 2,403 m.

Home range shapes varied considerably among individuals; however, there was a high rate of overlap along the eastern edge of the study area. This was particularly evident during the 1998 (Fig. C.3) and 1999 (Fig. C.4) summer tracking seasons. During both years, areas of greatest overlap were directly over marine algae pastures.

Vagility. – Data on 24-h movements were collected during the 1998 (Fig. C.7) and 1999 (Fig. C.8) summer tracking periods. Turtles moved during both day and night periods. All seven turtles showed affinities with peninsular algae pasture habitats. Three types of 24-h movement patterns were displayed: 1.) movement restricted to shallow peninsular regions (311), 2.) movement between peninsular algae pastures and mid-bay waters (314, 406, 419, and 422), and 3.) shuttling behavior between peninsular algae pastures and insular boulder habitats (turtles 310 and 415). Regardless of overall movement pattern, most turtles associated with nearshore algae pastures during evening

and nocturnal periods, and during diurnal periods moved offshore. The two turtles that shuttled to insular habitats followed a similar trajectory from the El Bajo algae pastures to the north end of Isla Jorobado. Turtles spent a large portions of time within activity centers during 24-h tracking episodes. This is particularly evident with turtle 415 as it moved between its activity centers over peninsular marine algae pastures and insular boulder habitats (Fig. C.9). Only one turtle (311) did not move into mid-bay waters, remaining in peninsular shallows with strong affinity to the El Bajo Shallows marine algae pastures.

Our data indicate that shuttling movements between insular and peninsular habitats do not necessarily follow the same pattern on sequential days. Turtle 415 was followed for an additional 12-h period subsequent to the initial 24-h tracking interval (Fig. C.9). From 1139h on 5 August 1999 to 1144h on 6 August 1999 turtle 415 remained in waters <10 m deep along the eastern edge of the study area. Starting at mid-morning of the second consecutive tracking day this turtle moved offshore to Isla Jorobado, a west-bound movement lasting nearly 2 h. Upon arrival at the insular site at 13:34, movements of 311 were confined to an isolated boulder field along the north edge of the island. It remained at this locality until 17:35, at which time tracking efforts ceased.

Among the seven turtles for which we collected 24-h vagility data, the mean distance traveled per 24-h was $9,536 \pm 3,223$ m (range = 5,118 - 15,340 m; Table 2). Total distance traveled was not correlated with size ($p = 0.32$), maturity class ($p = 0.22$), or sex ($p = 0.22$). Mean area of 24-h polygons was 368 ± 343 ha (Figs. C.10, C.11) and did not significantly differ among maturity class ($p = 0.50$). The mean area of 24-h use polygons

was 23% (range 15% - 34%) of the mean area of MCPs. There was a strong relationship between area of 24-h use polygons versus MCP areas ($p=0.0005$; Fig. C.12).

Winter movement – We relocated four turtles during winter periods (Table C.3). In January 1998 two turtles (230, 305) were captured with entanglement nets and released with telemetry packages. Both left the study area shortly after release. Turtle 230 was released on 10 January 1998 and remained in the study area for two days before moving south out of the bay. The final relocation of this turtle was in Bahía Quemado, 15 km to the south. Turtle 305 was released on 18 January 1998 and left the study area within 6 h of release. In January 1999 movement data were collected on two turtles (311, 323) initially captured and tracked during the summer of 1998. Both were active and found in the same vicinity as their respective summer activity centers (Fig. C.13). Winter movement polygon areas averaged 7.75 % (range 1.5% to 15%, $n = 2$) of the area of summer MCPs.

Marine environment affinities. – Movements of green turtles among the various water depths was highly variable, and different patterns were apparent among immatures, the adult male, and adult female (Fig. C.14). Among immatures, the greatest number of relocations (32%) were in the 11-20 m water depth and the fewest relocations (8.8%) were in waters greater than 40 m. The single adult male had the greatest number of relocations (28%) in 11-20 m depth class and was found with regularity in deeper waters with 24% of relocations in the 41m + water depth class. The adult female turtle was most commonly relocated in the 21-30 m water depth class (44% of relocations) and was not relocated in waters greater than 40 m deep.

All maturity classes were relocated most commonly in peninsular habitats (Fig. C.15). While most turtles were relocated on at least one occasion within this subregion, only four turtles (310, 314, 323, 415) were relocated in association with insular habitats. The greatest number of relocations in insular habitats were of turtle 323, an immature tracked during the summer of 1998 and winter of 1999. Despite initial capture over algae pastures of the eastern bay, this animal showed strong affinity to insular habitats with 57% of relocations in this region. The most equal distribution of relocations among the three habitat types for a single turtle was found in the adult male (310). As supported by 24-h tracking, this male routinely moved between widely separated regions within the study area.

Discussion

Home range. – Home ranges of green turtles in Bahía de los Angeles are significantly larger than areas of use for sea turtles in other regions. We measured a mean minimum convex polygon size of 1,801 ha. In comparison, Renaud et al. (1995) reported home ranges of 22 to 311 ha for juvenile green turtles in south Texas; Mendonca (1983) found home ranges of immature *C. mydas* from 180 ha to 1,662 ha in a Florida lagoon; and Whiting and Miller (1998) measured short-term foraging ranges from 84 to 860 ha for adults in Australia. The largest home ranges observed in this study were from turtles that exhibited movements between the two primary marine algae pastures and turtles that shuttled between insular and peninsular activity centers. We believe the great distance (8 km) between the two primary algae pastures and wide separation between insular and

peninsular habitats (≥ 4.5 km) contribute to the enlarged home range areas measured here. In support, core habitat spacing at other green turtle foraging habitats is considerably less. Ogden et al. (1983) described feeding and resting sites in Tague Bay, St. Croix to be separated by 0.2 to 0.5 km and Williams (1988) found that immature green turtles used feeding and resting sites that were separated by less than 500 m.

Home range size varied greatly and was not correlated with body size. Differences in home range sizes were particularly clear when comparing the small home ranges of turtles 225 and 311 (584 ha and 697 ha, respectively) to the large home ranges of turtles 314 and 413 (2,833 ha and 3,908 ha, respectively). Further, some of the largest turtles in this study had the smallest home ranges whereas some of the smallest turtles moved within the largest home range area. In contrast, Mendonca (1983) showed a positive correlation of turtle size with home range size in a Florida lagoon and Arms (1996) reported that range of movement of green turtles within the lower Laguna Madre of South Texas Gulf of México was related to turtle size with the largest turtles traveling the greatest distances. We believe the lack of correlation between home range size and body size is related to the particular oceanography of Bahía de los Angeles. Unlike the gradual continental shelf drop-off characteristic of green turtle foraging areas in the Caribbean (Bjorndal, 1980; Ogden et al., 1983) and the Gulf of Mexico (Renaud et al., 1995; Arms, 1996), the coasts near Bahía de los Angeles are marked by dramatic bathymetry with great water depths close to shore. The Ballenas Channel which marks the western boundary of the study area is the site of a deep water trench, and waters drop to over 3,000 m depth within 15 km of the study site (Bray and Robles, 1991). The steep shores,

lack of extensive shallow water habitats, and reduced photic zone minimizes the area of macroalgae-dominated feeding habitat. Wide ranging movements are thus restricted and the scale of foraging movements among different sizes and life stages is homogenized.

Loss of transmitter signal was responsible for a lack of sufficient data to estimate home ranges of 10 tagged turtles. While tag malfunction, tag loss, and human-intervention (i.e., illegal poaching) may have played a role in the loss of transmitter signal, we believe that in most cases the loss of signal during tracking periods was due to departure of tagged turtles from the study area. Transmitter signals prematurely ceased in nearly 40% of tracked immatures and over two thirds of the tagged adults. The higher rate of signal loss among tagged adults may be indicative of a higher rate of departure (i.e., transience) among these turtles. However, because we can not be sure of the particular causes of signal loss, it remains unclear how many of the turtles captured during this study were resident and what proportion were transients from other feeding habitats en route to and from distant breeding grounds.

Comparison of home range estimation techniques. – We define home range as the area that is traversed by an animal during its normal daily activities excluding long distance migrations or erratic movements (Bailey, 1984). Though this and other definitions of home range discussed in the literature are similar, there are a wide variety of techniques used to measure home range size. We used the minimum convex polygon (Mohr, 1947), Kernel density estimator (Worton, 1989), and range length techniques (Kenward, 1987). Our goal was to determine the most appropriate home range estimation procedure for green turtles examined in this study.

Each technique had clear advantages and disadvantages and provided slightly different results. Their simultaneous use generated a well rounded interpretation of green turtle movement and maximized our ability to compare our findings with other studies. Range length analysis gave a linear distance from point *a* to point *b* but did not provide a value for home range area. These data are generally useful for comparison with mark-recapture and maximum-distance-moved data such as that reported by Burnett-Herkes (1974), Ireland (1979), and Whiting and Miller (1998). The minimum convex polygon analysis is the most commonly used technique (e.g., Mendonca, 1983; Renaud et al., 1995; Whiting and Miller, 1998) and serves as a benchmark for comparison between different populations. However, its lack of resolution and inability to discern uneven spatial use patterns hindered its ability to highlight activity centers. The Kernel technique is a non-parametric procedure that calculates a utilization distribution and produces probability contours to determine activity centers. Though this is not as intuitively straight forward as the minimum convex polygon method, the ability to determine specific core areas was noteworthy. This is the first study to report Kernel estimates for sea turtles, thus limiting comparisons with other studies.

Regardless of the technique used, we believe that ranges for turtles as outlined by the these methods should be considered as estimators and indicators of movement scales rather than as estimators of the areas actually used by an animal. By incorporating areas of non-use that separated patches of highly-used habitat, minimum convex polygons overestimated the area used by turtles. Conversely, there is evidence to suggest that Kernel techniques were prone to underestimating the total area used. Though Kernel

estimates provided a finer scale resolution of the spatial use by green turtles in Bahía de los Angeles, we believe this technique weighed core areas too heavily by excluding movement corridors. Nevertheless, we preferred minimum convex polygon and Kernel estimations due to the fact that they provide a two-dimensional value of area use versus the one dimensional distances provided by range length estimation.

Daily movements. – Green turtle vagility in Bahía de los Angeles is large compared to other green turtle populations (mean = 9.5 km/d). Mendonca (1983) found summer daily vagility distances for immature green turtles in Florida ranging from 1.22 to 4.08 km/d; Whiting and Miller (1998) documented a daily vagility range of 0.9 to 4.9 km/d for adult Australian green turtles; and Renaud et al. (1995) reported small movements with a maximum vagility of 1.2 km/d for juvenile green turtles in Texas waters. The large distances between foraging and resting habitats in Bahía de los Angeles may be responsible for the relatively large 24-h vagility observed in this study.

As revealed by the short term tracking, daily vagility of green turtles is variable. The 24-h movements observed in this study range from 5,118 m to 15,340 m. Variation is especially evident when the shorter movements of turtles 311, 406, and 415 (mean = 5818 ± 374 m) are compared to the long distance movements of turtles 310, 314, and 422 (Mean = $13,388 \pm 1335$ m). Such individual differences in movement patterns within a foraging ground population have also been noted for green turtles in Australia (Whiting and Miller, 1998), Florida (Mendonca, 1983), and Texas (Arms, 1996).

Turtles tracked during this study followed a bimodal pattern in which they moved over nearshore marine algae pastures during evening and night hours and by midmorning

moved to offshore and insular sites. Turtles visit the nearshore regions to forage on the abundant marine algae (Seminoff et al., 1998; in prep. b) but we are less aware of the activities associated with offshore habitats. On occasion turtles forage in offshore non-algae habitats (Seminoff et al., 1998; in press; in prep. b); however the movement patterns and submergence intervals observed during tracking efforts in these offshore and insular regions are more commonly associated with resting behavior (van Dam and Diez, 1996; Hochscheid et al., 1999).

Though the timing of movements may differ in other populations, there is a consistency in terms of the overall bimodal nature of movement and foraging activity witnessed. Mendonca (1983) showed that green turtles exhibited an extremely predictable diel movement pattern with turtles feeding on grass flats in mid-morning and mid-afternoon and moving into deeper water during midday hours. Similarly, Bjorndal (1980) noticed regular feeding bouts in the early- to midmorning and mid- to late afternoon in Bahaman green turtles, and Ogden et al. (1983) showed that *C. mydas* in St. Croix actively fed during morning and afternoon hours and rested during mid-day periods. Further, Brill et al. (1995) reported that green turtles in Hawaii exhibited daily shuttling behavior between daylight and night time areas.

We observed heavy boat traffic and fishing pressure on a daily basis over nearshore feeding pastures throughout the study area. The nocturnal foraging and bimodal nature of movements within Bahía de los Angeles may be an avoidance response these human activities. Similarly, Hawaiian green turtles exhibit bimodal movements with nocturnal

foraging in nearshore areas to avoid daytime human presence in the nearshore feeding localities (Balazs et al., 1987).

The repetitive daily movements of *C. m. agassizii* between widely separated activity centers suggest that these animals are capable of orientation during travel. Though orientation mechanisms of small scale movements are poorly understood, it is reasonable to assume that animals are capable of remembering the locations if resources occur in a patchy but predictable pattern (Ford, 1983). Spatial recognition and homing has been reported in a number of studies. Cyclic movements between activity centers were shown for adults in the Gulf of Mexico (Arms, 1996) and immatures in Florida (Mendonca, 1983). Balazs et al. (1987) found juvenile *C. mydas* exhibited strong fidelity to specific microsites among coral reef heads along the coast of Hawaii and Renaud et al. (1995) demonstrated that immature greens in south Texas waters maintained fidelity to specific jetty habitats. In mark-recapture studies, Burnett-Herkes (1974) and Ireland (1979) showed homing behavior in Caribbean foraging habitats. Magnetic reference has been attributed to migratory orientation in sea turtles (Lohmann and Lohmann, 1996); however, the smaller scale of movements in feeding areas may require navigation by some other means.

Winter movement – Our data on winter movement indicate that at least some *C. m. agassizii* stay in the Bahía de los Angeles vicinity during cold water periods. The sustained activity by turtles is indicative of elevated body temperatures. Active *C. mydas* are able to maintain regional endothermy (Standora et al., 1982) and elevated body temperature may play a role in maintenance of digestive performance during cold

periods. Winter-active turtles in this study were found in food-rich habitats and their sustained activity suggests the possibility of foraging. Foraging at low water temperature has been reported by Read et al. (1996) who showed that active Australian *C. mydas* continued to forage in waters below 20C. However, at some point along the temperature continuum, cold temperatures interrupt foraging by inhibiting activity and digestive performance (Spotila et al., 1997). This is supported by Felger et al. (1976) who showed that Gulf of California green turtles become sluggish and exhibit overwintering torpor during cold winter periods. Our data indicate that this 'inactivity threshold' for green turtles in Bahía de los Angeles is below 15 C.

Conservation Implications. – The year-round residence of both immature and adult green turtles in Bahía de los Angeles highlights the importance of this region as critical feeding habitat. The marine algae pastures of the eastern and southern edges of the study area are clearly epicenters of sea turtle activity, but our data indicate that turtles use a variety of insular and peninsular habitats throughout the bay. Green turtles are thus susceptible to impacts from a myriad of commercial fishing activities. Local fisheries which utilize set nets must be controlled to minimize incidental entanglement-induced mortality. Initial management efforts should focus on reducing human disturbance associated with nearshore algae pastures. However, we stress that because turtles use the entire bay, the long-term solution for stopping incidental mortality must be to limit or phase out the use of entanglement nets in the entire bay. In such efforts, it is essential that local inhabitants are provided with appropriate alternatives that encourage sustainable marine resource use and economic progress.

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TABLE C.1. Length of period monitored, relocation interval in days, number of relocations (N), number of captures outside of tracking interval (TI), minimum convex polygons (MCP), Kernel estimates, and maximum length of home range sizes of *Chelonia mydas agassizii*.

Turtle #	SCL (cm)	Tracking Interval	Total Days	N	Captures outside TI	MCP (ha)	Kernel (ha)	Length (m)
Immatures								
127	73.9	06/25/97 - 08/08/97	45	58	3	2,066	2,203	6,606
224	73.8	09/22/97 - 09/24/97	3	3	1	-	-	-
225	70.4	08/28/97 - 10/06/97	40	32	-	648	339	3,819
228	68.2	10/07/97 - 01/15/98	100	5	1	-	-	-
230	71.8	01/09/98 - 01/20/98	12		-	-	-	-
311	65.2	06/24/98 - 10/01/98	96	46	2	697	284	4,792
314	71.4	07/02/98 - 08/19/98	77	45	2	2,833	2,610	9,597
316	69.0	07/13/98 - 08/29/98	48	43	-	2,775	3,231	11,911
323	65.3	07/19/98 - 07/13/98	72	61	-	2,289	2,243	7,666
330	65.2	08/12/98 - 08/13/98	2	5	-	-	-	-
409	75.1	08/01/99 - 08/01/99	1	2	-	-	-	-
412	66.3	07/16/99 - 07/18/99	3	10	-	-	-	-
413	72.3	07/17/99 - 09/17/99	63	16	-	3,908	3,688	13,336
415	50.9	07/20/99 - 09/22/99	65	30	-	1,284	1,234	6,332

419	71.3	08/01/99 - 09/03/99	34	34	-	584	422	5,670
422	67.5	08/05/99 - 09/17/99	44	20	-	1,378	469	7,981
427	72.4	09/05/99 - 09/05/99	1	3	-	-	-	-

Adult Males

219	77.6	18/08/97 - 21/09/98	34	5	1	-	-	-
305	86.0	01/28/98 - 01/28/98	1	14	-	-	-	-
310	77.5	06/25/98 - 08/29/98	65	54	-	2,395	1,416	7,462

Adult Females

405	77.7	06/24/99 - 06/27/99	4	5	-	-	-	-
406	82.5	06/22/99 - 09/15/99	86	18	1	775	411	5,414
411	77.4	07/13/99 - 07/17/99	5	6	-	-	-	-

TABLE C.2. Relocation interval, SCL, number of relocations (N), distance traveled, 24-h polygon area (24-h P), and percent of MCP home range area.

Turtle	SCL		N	24-h	24-h P	% Total
	(cm)	Relocation Interval		distance (m)	(ha)	MCP
310	77.5	08/29/98 - 08/30/98	26	15,340	759	32
311	65.2	08/28/98 - 08/29/98	27	5,118	127	18
314	71.4	08/15/98 - 08/16/98	18	13,989	966	34
406	82.5	08/16/99 - 08/17/99	62	6,395	146	19
415	50.9	08/05/99 - 08/06/99	28	5,941	205	16
419	71.3	08/30/99 - 08/31/99	62	9,769	165	28
422	67.5	09/03/99 - 09/04/99	49	10,835	212	15

TABLE C.3. Length of period monitored, the number of relocations (N), mean water temperature (T_w), distance traveled, vagility, Winter use polygon area (WP), and behavior of *C. m. agassizii* tracked during winter periods.

Turtle	Location interval	N	Mean	Distance	Vagility	WP	Behavior
			Water Temp. (C)	(m)	(m/d)	(ha)	
230	01/09/98 - 01/20/98	13	19.0	21,543	1,958.40	-	depart study site
305	01/28/98 - 01/28/98	14	19.0	7,135	42,981.9	-	depart study site
311	01/07/99 - 01/13/99	7	14.5	3,761	618.6	100.85	active
323	01/07/99 - 01/13/99	9	14.5	3,345	546.1	35.80	active



Fig. C.1. Map of Bahía de los Angeles study area.

Grey lines indicate 10-m water bathymetric contours. Triangle indicates location of CRIP-STRS.

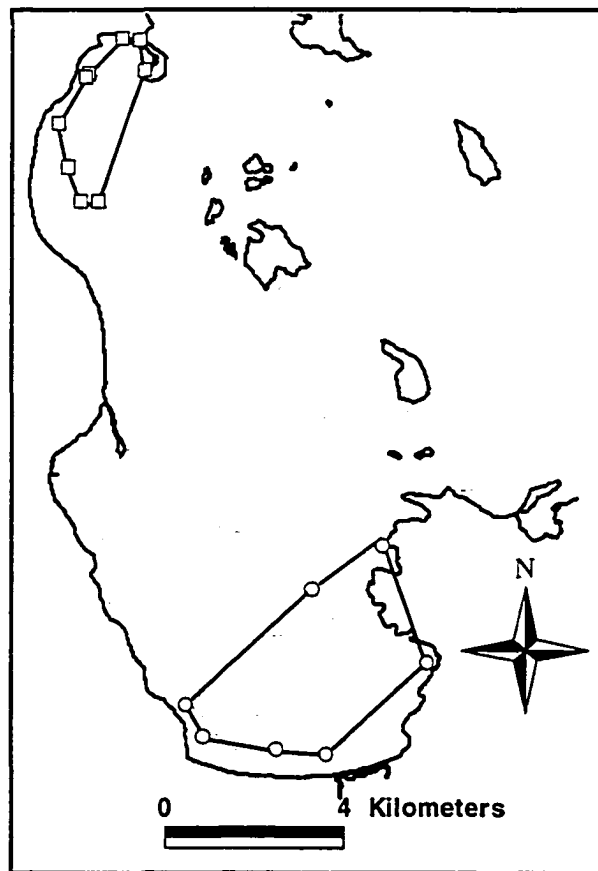


Fig. C.2. 1997 Summer MCP polygons;

127 (circles), 225 (squares).

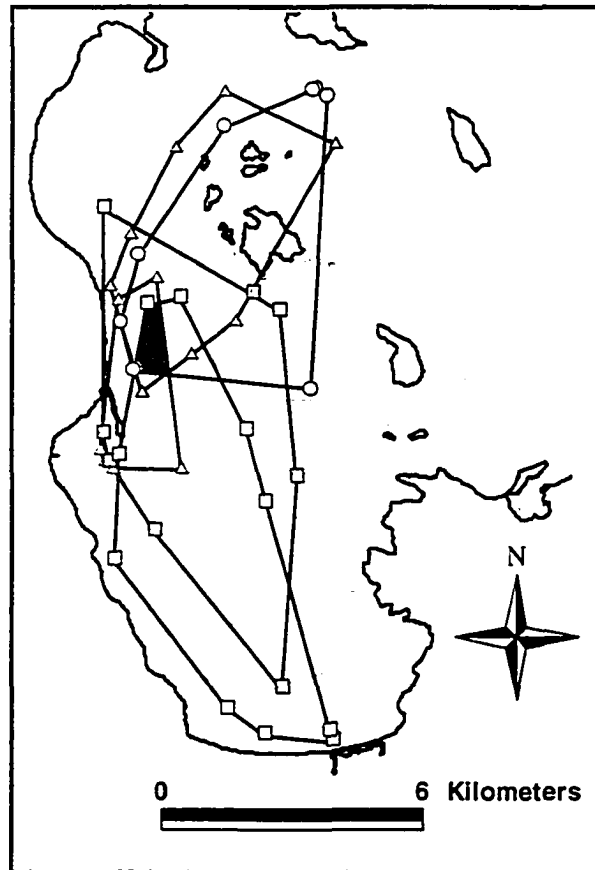


Fig. C.3. 1998 Summer MCP polygons; 310 (shaded triangles), 311 (triangles), 314 (shaded squares), 316 (squares), and 323 (circles).

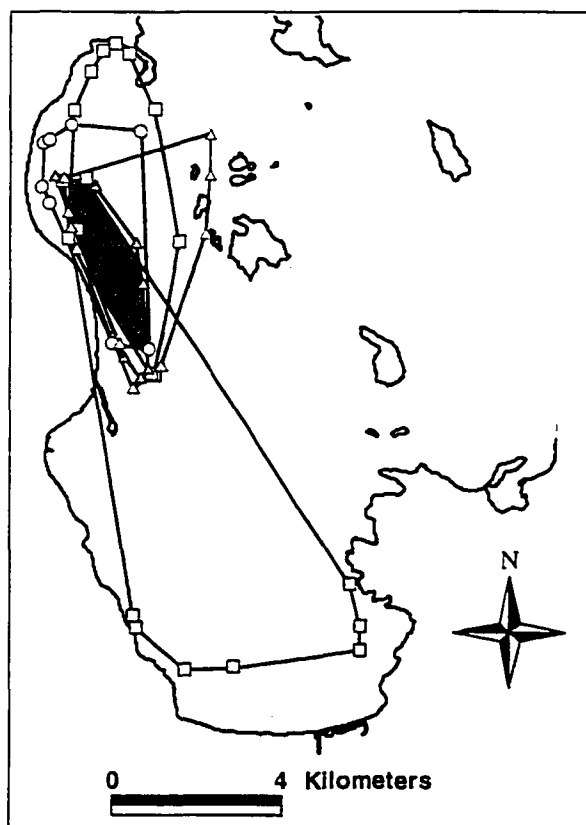


Fig. C.4. Summer 1999 MCP polygons;
406 (shaded triangles), 413 (shaded squares),
415 (triangles), 419 (circles), and 422 (squares).

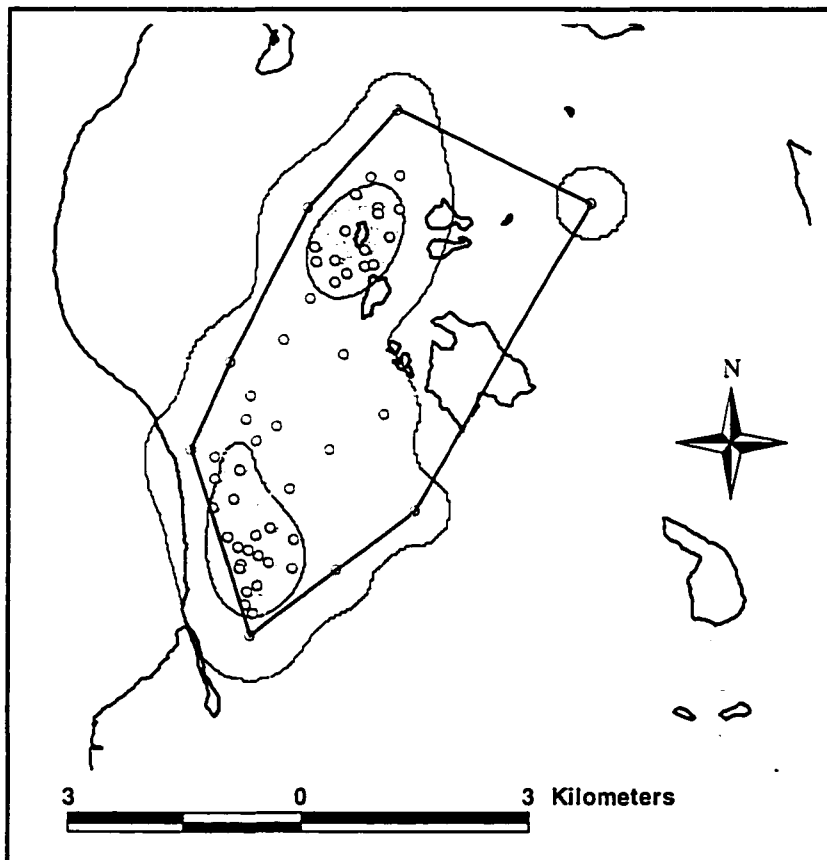


Fig. C.5. Overlay of minimum convex polygon outline on Kernel home range estimate for turtle 310. Circles indicate relocations, light shading corresponds with 95 % probability contours and dark shading indicates activity centers based on 50% probability contours. Dark line marks minimum convex polygon outline.

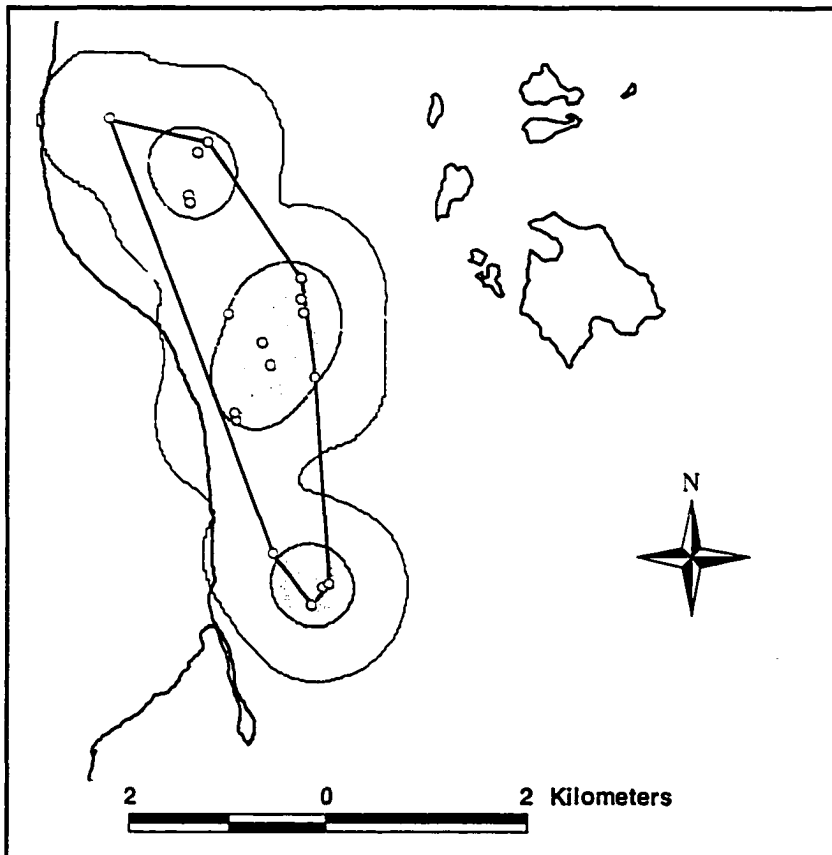


Fig. C.6. Overlay of minimum convex polygon outline on Kernel home range estimate for turtle 406. Circles indicate relocations, light shading corresponds with 95 % probability contours and dark shading indicates activity centers based on 50% probability contours. Dark line marks minimum convex polygon outline.

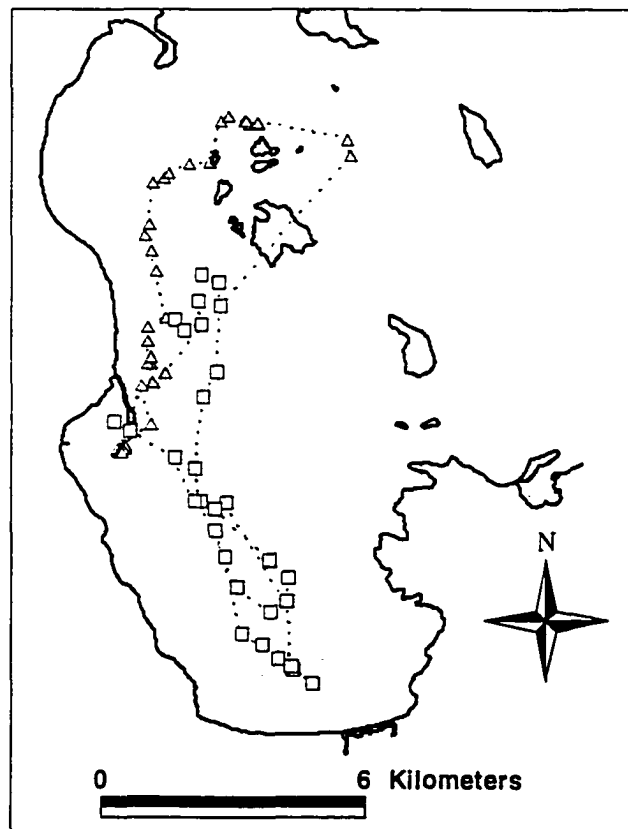


Fig. C.7. 24-h movement paths for turtle 310 (shaded triangles), 311 (triangles), and 314 (squares).

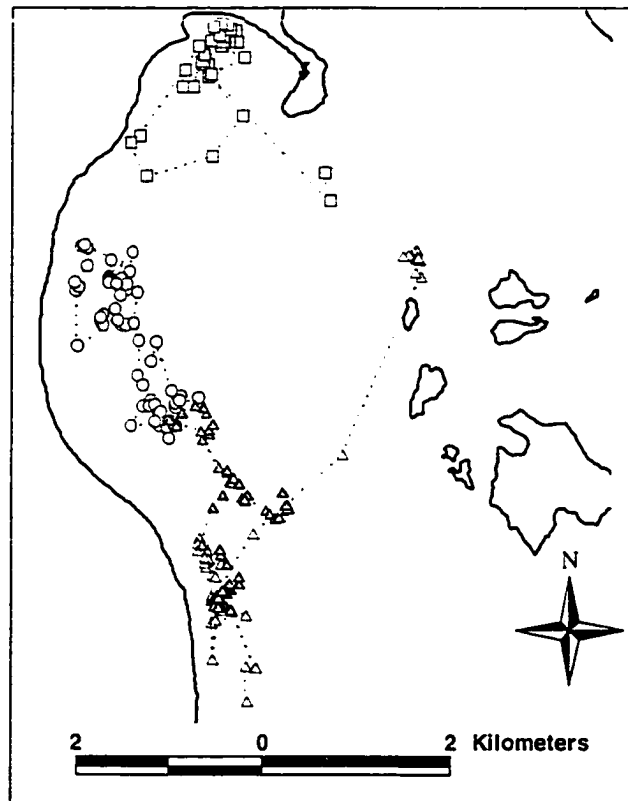


Fig. C.8. 24-h movement paths for turtles 406 (shaded triangles), 415 (triangles), 419 (circles), and 422 (squares).

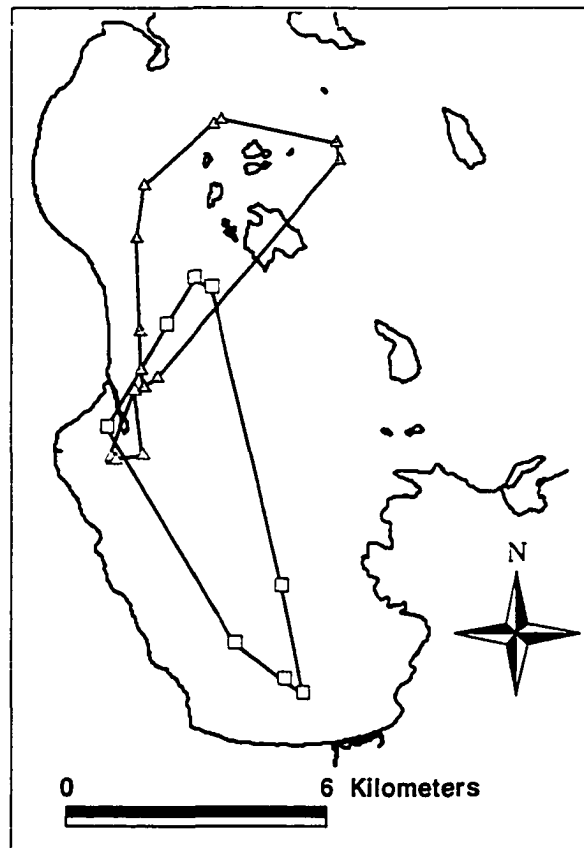


Fig. C.9. 24-h movement polygons for turtles tracked during summer 1998; 310 (shaded triangles), 311(triangles), and 314 (squares).

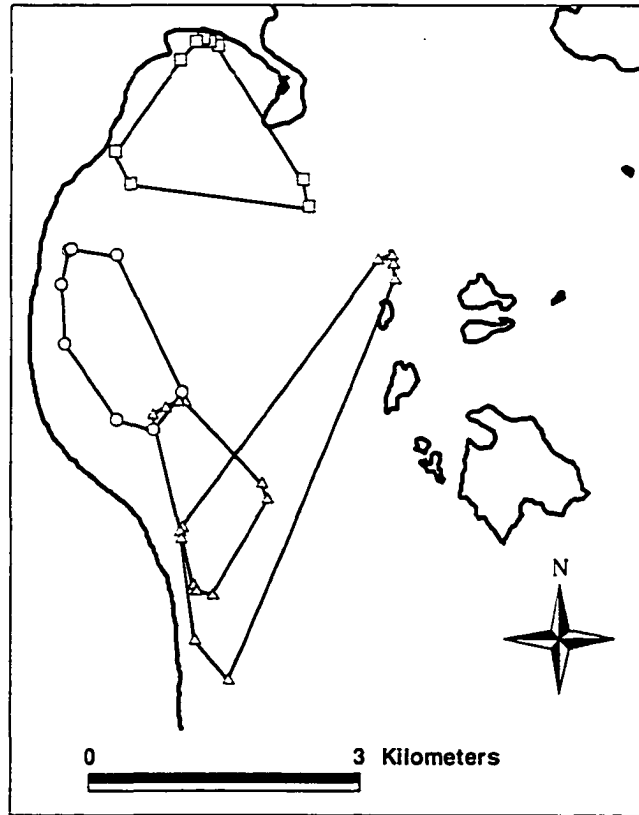


Fig. C.10. 24-h movement polygons for turtles tracked during summer 1999; 406 (shaded triangles), 415 (triangles), 419 (circles), and 422 (squares).

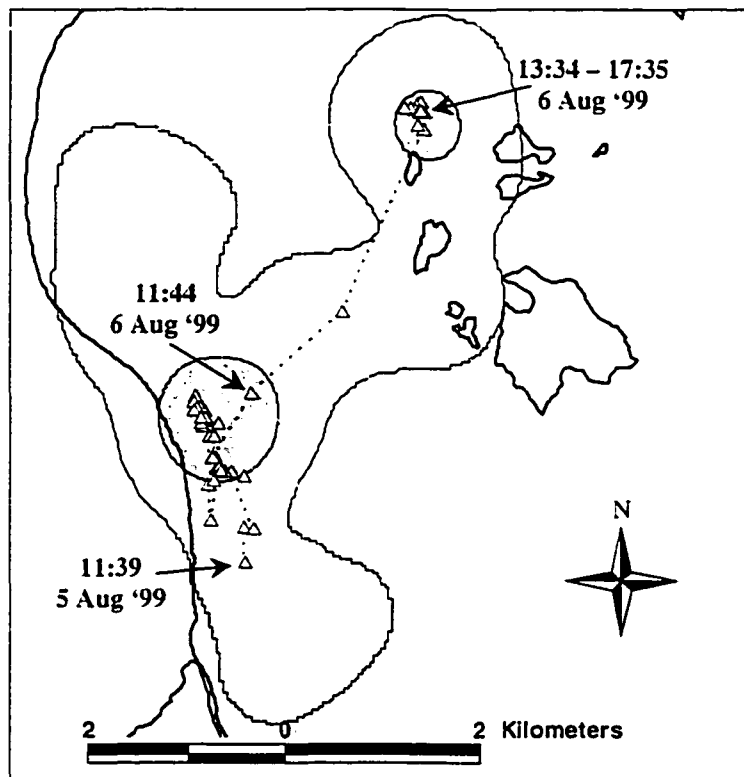


Fig. C.11. 24-h track of turtle 415 over Kernel home range estimate. Triangles indicate relocation events during 24-h track; dashed lines indicate 24-h movement path; light gray shading indicates 95% usage area; dark shading indicates 50% activity centers.

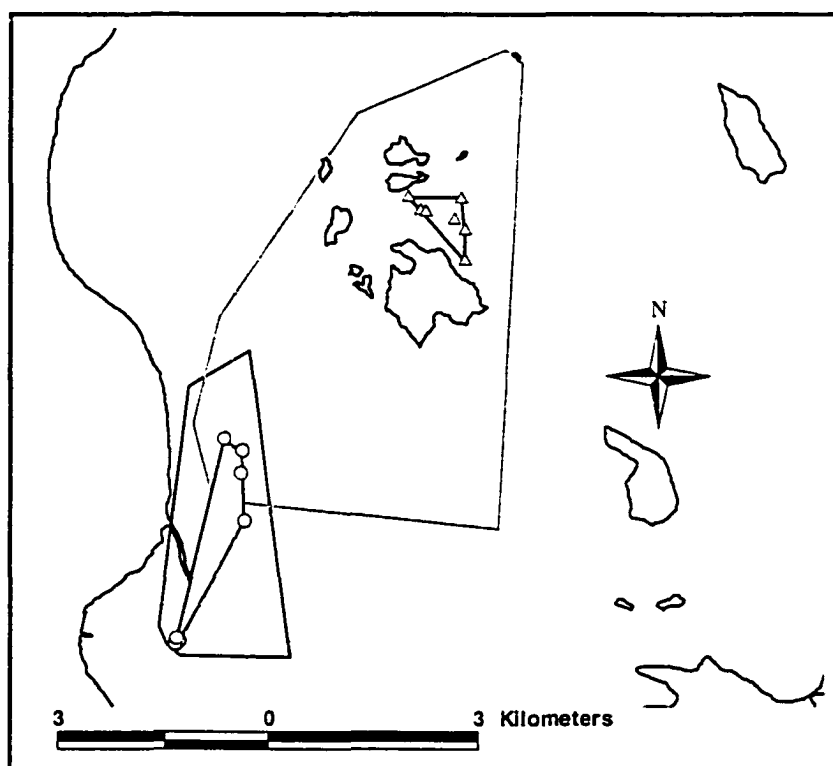


Fig. C.12. Winter relocation polygons for turtles 311 (circles) and 323 (triangles). For comparison, summer MCP outlines are shown for 311 (dark line) and 323 (gray line)

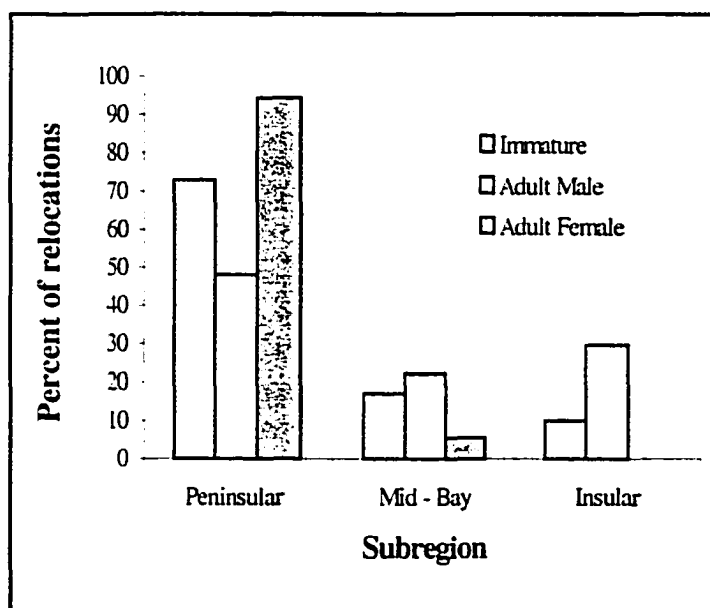


Fig. C.13. Regression of 24-h use polygon area versus minimum convex polygon area.

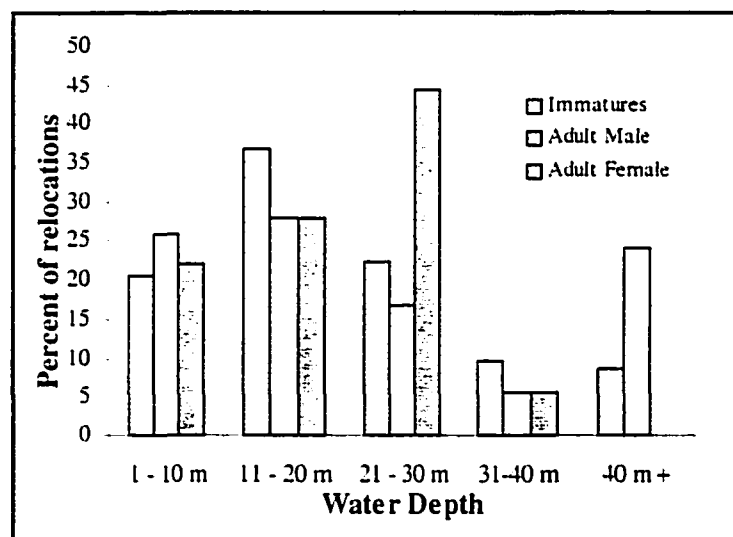


Fig. C.14. Distribution of relocation events among water depth classes for green turtles in Bahía de los Angeles.

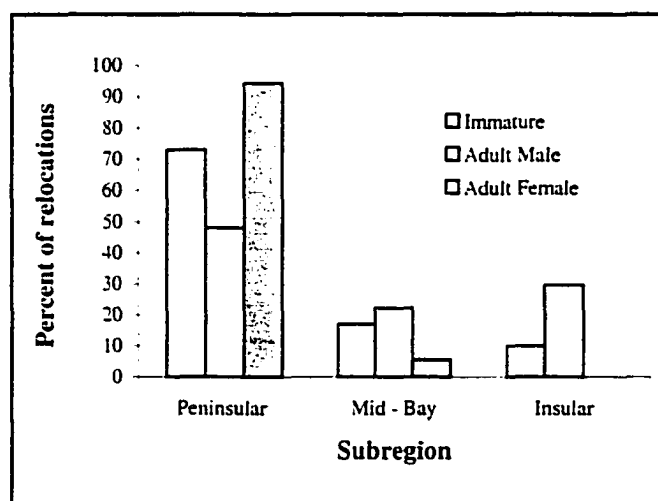


Fig. C.15. Distribution of relocation events among habitats for green turtles in Bahía de los Angeles.

APPENDIX D. ILLUSTRATIONS OF THE EAST PACIFIC GREEN TURTLE,
CHELONIA MYDAS AGASSIZII

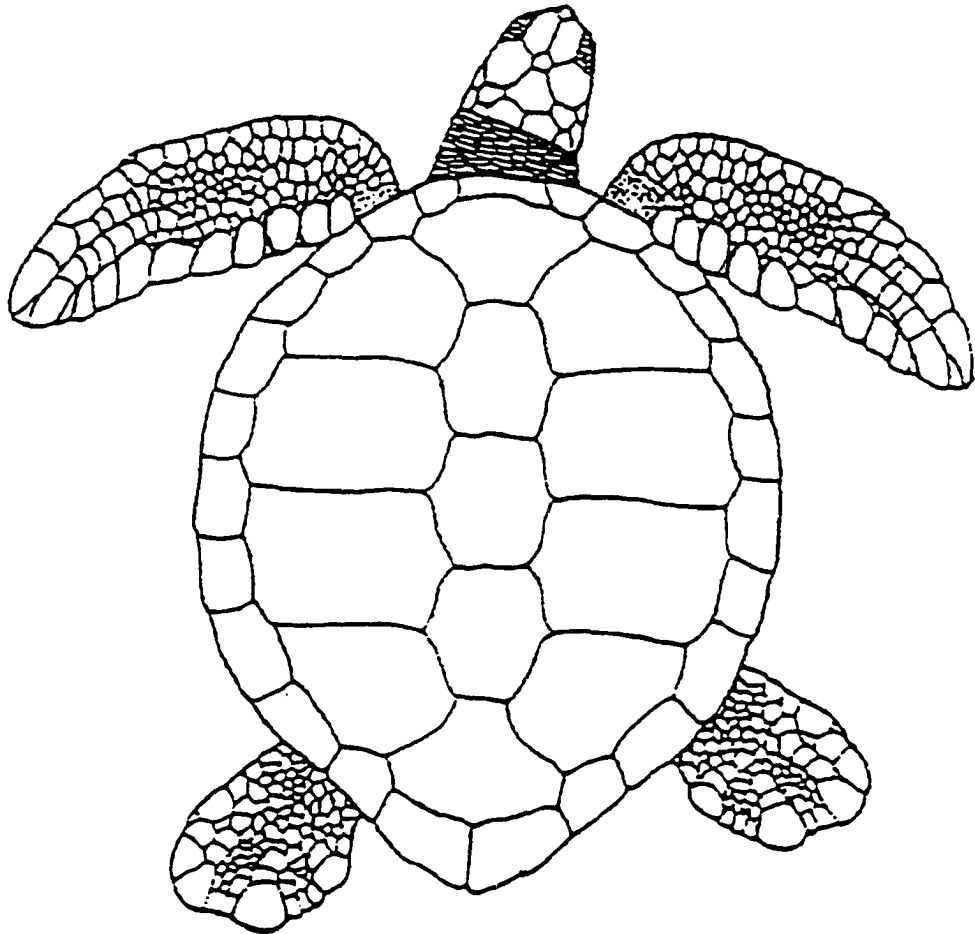


Figure D.1. Illustration of dorsal view of East Pacific Green Turtle, *Chelonia mydas agassizii* (courtesy of T. McFarland).

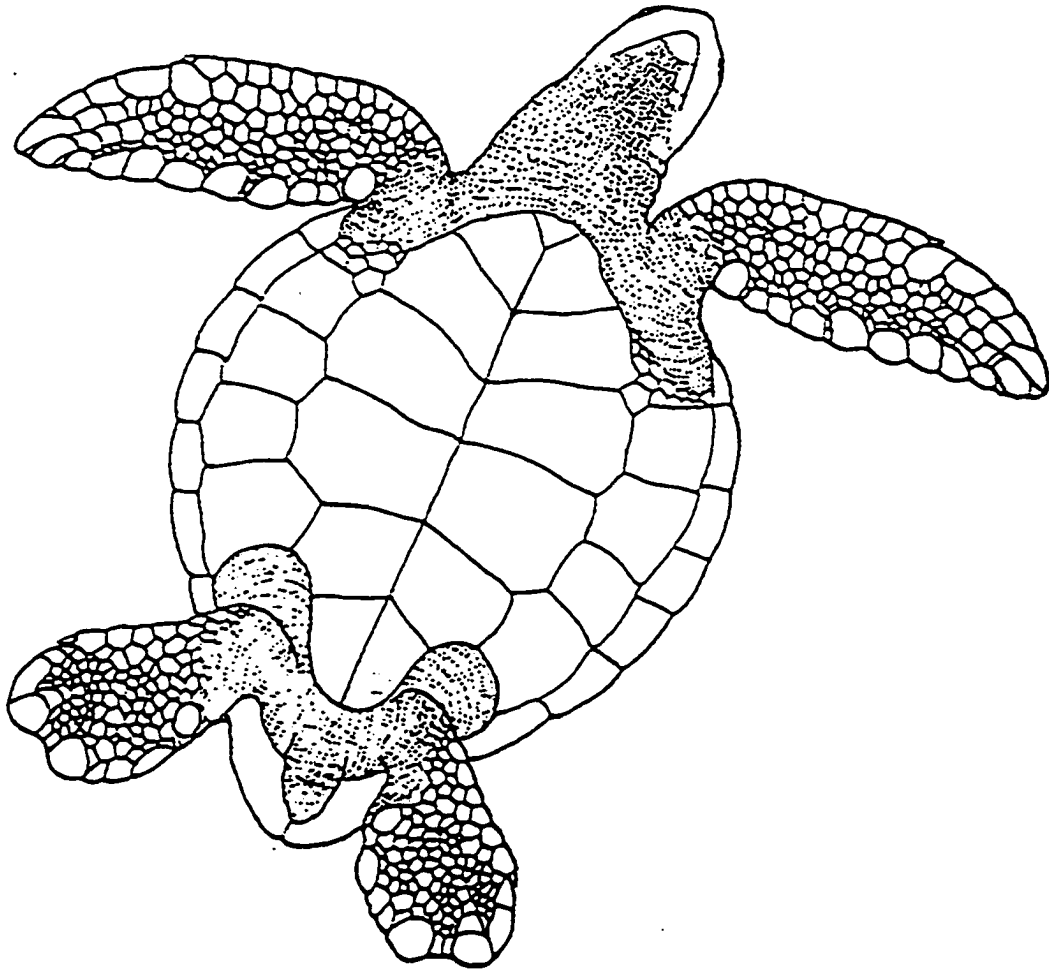
APPENDIX D. - *Continued*

Figure D.2. Illustration of ventral view of East Pacific Green Turtle, *Chelonia mydas agassizii* (courtesy of T. McFarland).

APPENDIX E. PHOTOGRAPHS OF EAST PACIFIC GREEN TURTLES, *CHELONIA MYDAS AGASSIZII*, FROM BAHIA DE LOS ANGELES.

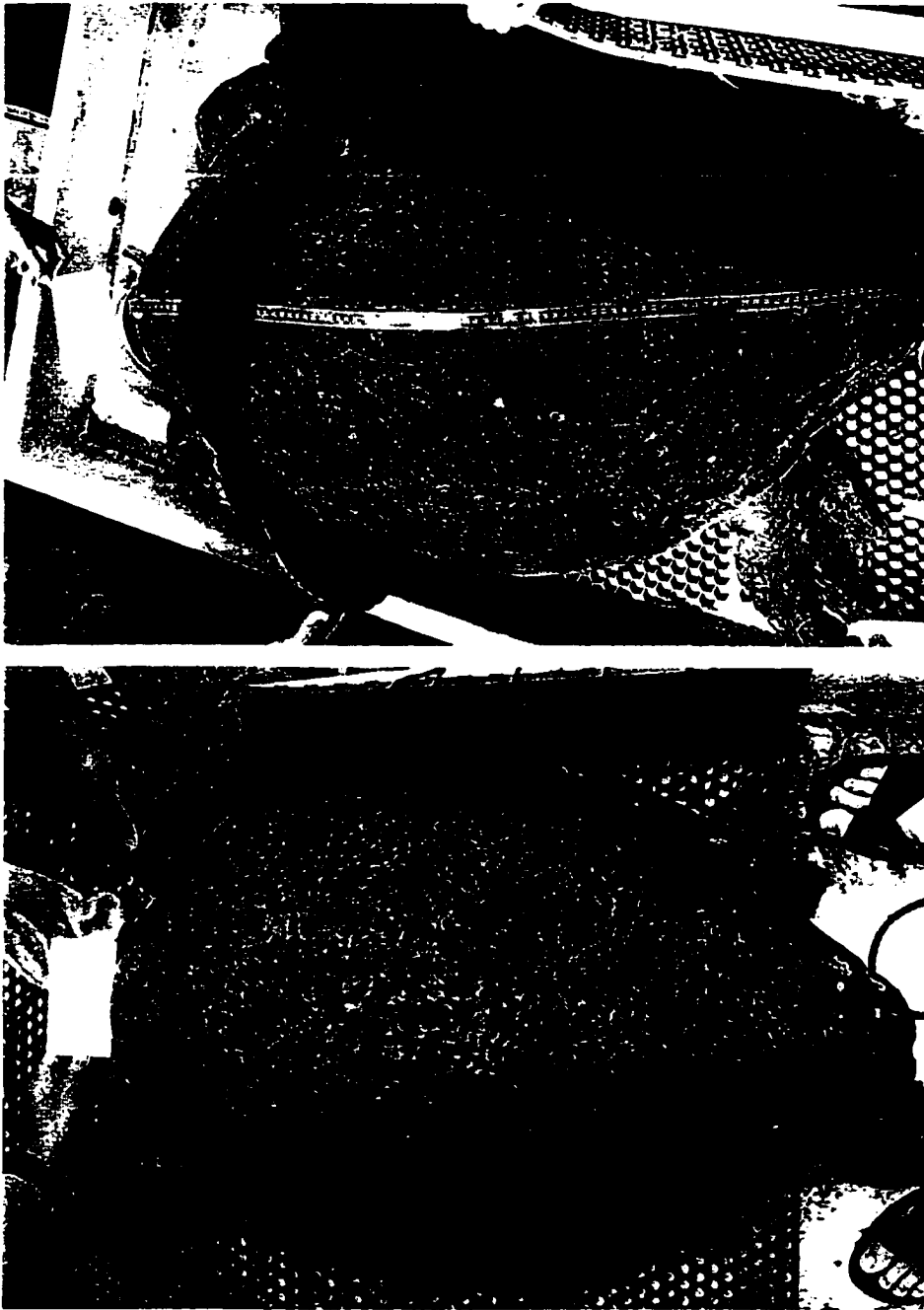


Fig. E.1. Photographs showing carapace color variation in *C. m. agassizii* (© J. A. Seminoff).

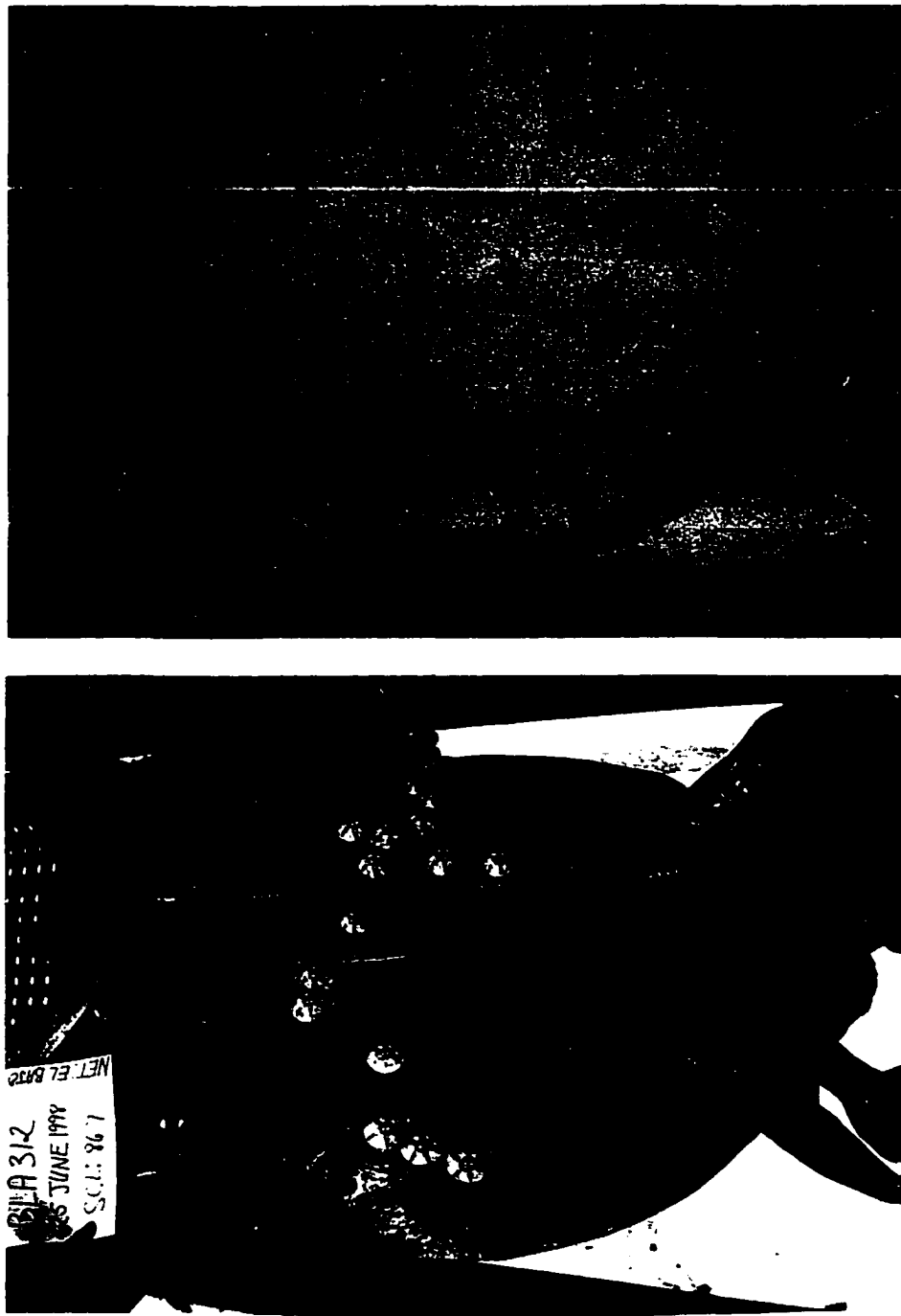
APPENDIX E. – *Continued*

Fig. E.2. Photographs showing plastron color variation in *C. m. agassizii* (© J. A. Seminoff)

APPENDIX E. - *Continued*

Fig. E.3. Photograph of *C. m. agassizii* head (© J. A. Seminoff)

APPENDIX F. SUMMARY OF OTHER SEA TURTLE SPECIES
CAPTURED AT BAHÍA DE LOS ANGELES STUDY SITE, 1996-1999

Table F.1. Capture date, sex, and size of Hawksbill turtles (*Eretmochelys imbricata*) at Bahía de los Angeles, 1995-1999. I = immature, F = adult female, M = adult male

Turtle ID#	Date capture	Sex	SCL (cm)
BLA 230	10/08/97	I	52.2
BLA 301	01/07/98	I	36.4
BLA 304	01/22/98	I	34.4
BLA 338	09/19/98	I	38.0
BLA 401	01/07/99	I	37.6
BLA 428	09/08/99	I	35.9

APPENDIX F. - *Continued*

Table F.2. Capture date, sex, and size of Loggerhead turtles (*Caretta caretta*) at Bahía de los Angeles, 1995-1999. I = immature, F = adult female, M = adult male

Turtle ID#	Date capture	Sex	SCL (cm)
BLA 221	09/04/97	I	69.4
BLA 233	10/31/97	I	49.7
BLA 331	08/22/98	M	75.4
BLA 404.5	02/04/99	F	92.7
BLA 429	09/06/99	I	43.5
BLA 436	09/19/99	I	63.0
BLA 441	12/15/99	I	45.8

APPENDIX F. - *Continued*

Table F.3. Capture date, sex, and size of Pacific Ridley turtles (*Lepidochelys olivacea*) at Bahía de los Angeles, 1995-1999.
I = immature, F = adult female, M = adult male

Turtle ID#	Date capture	Sex	SCL (cm)
BLA 217	08/13/97	F	61.0
BLA 218	08/15/97	F	62.4
BLA 335	09/07/98	F	60.0
BLA 345	10/01/98	I	56.3
BLA 416	07/31/99	I	46.1
BLA 421	08/03/99	I	49.5
BLA 435	09/18/99	F	58.0
BLA 440	09/22/99	F	65.8

APPENDIX G. SEA TURTLE TAGGING REGISTER FOR BAHIA DE
LOS ANGELES, GULF OF CALIFORNIA, MEXICO, 1995-1999.

Species

Cm = *Chelonia mydas agassizii*

Cc = *Caretta caretta*

Ei = *Eretmochelys imbricata*

Lo = *Lepidochelys olivacea*

Location

FL = front left

FR = front right

RL = rear left

RR = rear right

Tag type

P = plastic roto-tag, Modern Farm

All others Inconel Model 681, National Band and Tag Co.

Turtle ID#	species	Date capture	Notch	FL	FR	RL	RR
2	<i>Cm</i>	07/31/95		22p			
3	<i>Cm</i>	07/31/95			26p		
4	<i>Cm</i>	07/31/95		21p			
5	<i>Cm</i>	07/31/95			314p		
6	<i>Cm</i>	07/31/95			36p		
7	<i>Cm</i>	07/31/95		957p	958p		
8	<i>Cm</i>	06/29/96		954p	955p		
9	<i>Cm</i>	07/31/95			23p		
10	<i>Cm</i>	08/01/95		41p			
11	<i>Cm</i>	08/01/95			5p		
12	<i>Cm</i>	08/01/95		959p	960p		
13	<i>Cm</i>	08/01/95		321p			

APPENDIX G. - *Continued*

14	<i>Cm</i>	08/01/95	962p	961p	
15	<i>Cm</i>	08/01/95	392p	391p	
16	<i>Cm</i>	08/02/95		350p	
17	<i>Cm</i>	08/01/95	354p	353p	
18	<i>Cm</i>	07/01/96	393p	394p	
19	<i>Cm</i>	06/08/95	328p	316p	
20	<i>Cm</i>	08/09/99			BC 495 BC 496
21	<i>Cm</i>	06/05/96	327p	344p	
22	<i>Cm</i>	06/04/95	341p	343p	
23	<i>Cm</i>	06/04/95	323p	329p	
24	<i>Cm</i>	05/12/97	324p	303p	
101	<i>Cm</i>	05/03/96	357p	375p	
102	<i>Cm</i>	05/05/96	361p	360p	
103	<i>Cm</i>	05/06/96	362p	363p	
104	<i>Cm</i>	05/05/96	364p	365p	
105	<i>Cm</i>	05/07/96	340p	17p	
106	<i>Cm</i>	05/02/96	356p	355p	
107	<i>Cm</i>	05/04/96	359p	358p	
110	<i>Cm</i>	05/26/96	368p		
111	<i>Cm</i>	05/26/97	369p		
112	<i>Cm</i>	05/26/97	963p	964p	
113	<i>Cm</i>	06/06/96	320p	377p	
114	<i>Cm</i>	05/26/97	370p		
115	<i>Cm</i>	05/26/97	371p		

APPENDIX G. - *Continued*

116	<i>Cm</i>	05/26/97			BC 517	BC 516
117	<i>Cm</i>	05/26/97	373p			
118	<i>Cm</i>	05/26/97	366p			
119	<i>Cm</i>	06/08/96	379p	326p		
120	<i>Cm</i>	09/01/98			BC 703	BC 704
121	<i>Cm</i>	05/26/97	382p			
122	<i>Cm</i>	06/10/96			395p	389p
123	<i>Cm</i>	06/10/96			374p	
124	<i>Cm</i>	05/26/97			378p	
125	<i>Cm</i>	05/26/97			381p	
126	<i>Cm</i>	06/21/96	384p	383p		
127	<i>Cm</i>	06/21/96	351p	399p		
128	<i>Cm</i>	06/22/96			950p	951p
129	<i>Cm</i>	06/22/96	312p	308p		
130	<i>Cm</i>	06/23/96	952p	953p		
131	<i>Cm</i>	07/07/96	R4/L3			
132	<i>Cm</i>	07/08/96			955	956
133	<i>Cm</i>	07/13/96			965	966
134	<i>Cm</i>	07/17/96	R2/L2			
136	<i>Cm</i>	07/17/96			968	
137	<i>Cm</i>	07/18/96			967	
138	<i>Cm</i>	07/27/96	R1/L1			
139	<i>Cm</i>	07/27/96	R4/L4			
140	<i>Cm</i>	07/30/96	R2/L1			

APPENDIX G. - *Continued*

141	<i>Cm</i>	07/30/96	R3/L1		
142	<i>Cm</i>	07/30/96	R4/L1		
143	<i>Cm</i>	07/30/96	R1/L3		
144	<i>Cm</i>	07/30/96	R1/R2		
146	<i>Cm</i>	07/31/96	R1/R4		
147	<i>Cm</i>	08/01/96	R3/L3		
148	<i>Cm</i>	08/01/96	R2/L3		
149	<i>Cm</i>	08/01/96	R3/L2		
150	<i>Cm</i>	08/01/96	R3/R4		
151	<i>Cm</i>	08/02/96	midline		
152	<i>Cm</i>	08/02/96	L2/L3		
202	<i>Cm</i>	06/10/97		BC 502	BC 501
203	<i>Cm</i>	06/10/97		BC 504	BC 503
203	<i>Cm</i>	03/16/98		BC 503	BC 504
204	<i>Cm</i>	06/14/97		BC 512	BC 511
205	<i>Cm</i>	06/13/97		BC 510	
206	<i>Cm</i>	06/25/97		BC 519	BC 518
206	<i>Cm</i>	04/23/98		BC 518	BC 519
207	<i>Cm</i>	06/25/97		BC 521	BC 520
208	<i>Cm</i>	06/27/97		BC 523	BC 522
209	<i>Cm</i>	07/03/97		BC 525	BC 526
211	<i>Cm</i>	07/06/97		BC 530	BC 529
212	<i>Cm</i>	07/10/97		BC 532	BC 531
213	<i>Cm</i>	07/11/97		BC 534	BC 533

APPENDIX G. - *Continued*

215	<i>Cm</i>	07/12/97			BC 536	BC 535
216	<i>Cm</i>	07/27/97			BC 540	BC 539
219	<i>Cm</i>	09/18/97			BC 030	BC 031
220	<i>Cm</i>	08/18/97			BC 033	BC 032
222	<i>Cm</i>	09/17/97	BC 605	BC 606	BC 607	BC 608
223	<i>Cm</i>	09/20/97	BC 613	BC 614	BC 615	BC 616
224	<i>Cm</i>	09/29/98	BC 609	BC 610	BC 611	BC 612
225	<i>Cc</i>	09/23/97	BC 618	BC 619	BC 620	BC 621
228	<i>Cm</i>	10/06/97	BC 622	BC 623	BC 624	BC 625
229	<i>Cm</i>	10/06/97	BC 626	BC 627	BC 628	BC 629
230	<i>Ei</i>	10/08/97	BC 630			
231	<i>Cm</i>	09/26/98	BC 636	BC 635	BC 638	BC 637
232	<i>Cm</i>	10/10/97	BC 631	BC 632	BC 633	BC 644
302	<i>Cm</i>	01/11/98		BC 641	BC 642	BC 643
305	<i>Cm</i>	01/27/98			BC 646	BC 647
306	<i>Cm</i>	01/29/98		BC 650	BC 651	BC 652
308	<i>Cm</i>	06/19/98			BC653	BC654
309	<i>Cm</i>	06/24/98			BC 658	BC 657
310	<i>Cm</i>	06/24/98			BC 656	BC 655
311	<i>Cm</i>	09/12/99			BC 659	BC 660
312	<i>Cm</i>	09/07/98			BC 662	BC 661
313	<i>Cm</i>	06/25/98			BC 663	Bc 664
314	<i>Cm</i>	07/01/98			BC 666	BC 665
316	<i>Cm</i>	07/10/98			BC 667	BC 668

APPENDIX G. - *Continued*

317	<i>Cm</i>	07/14/98		BC 671	BC 672
318	<i>Cm</i>	07/14/98		BC 674	BC 673
319	<i>Cm</i>	07/15/98		BC 675	BC 676
320	<i>Cm</i>	07/15/98		BC 678	BC 677
321	<i>Cm</i>	07/15/98		BC 679	BC 680
322	<i>Cm</i>	07/15/98		BC 681	BC 682
323	<i>Cm</i>	07/18/98		BC 683	BC 684
324	<i>Cm</i>	07/19/98		BC 685	BC 686
325	<i>Cm</i>	07/15/98		BC 688	BC 687
326	<i>Cm</i>	07/28/98		BC 691	BC 692
327	<i>Cm</i>	07/28/98		BC 693	BC 694
328	<i>Cm</i>	07/28/98		BC 695	BC 696
329	<i>Cm</i>	09/06/99		BC 687	BC 698
330	<i>Cm</i>	08/11/98		BC 701	BC 702
333	<i>Cm</i>	09/14/98		BC 721	BC 722
334	<i>Cm</i>	09/14/98		BC723	BC 724
335	<i>Lo</i>	09/07/98	BC 705	BC 706	
336	<i>Cm</i>	09/15/98		BC 709	BC 710
337	<i>Cm</i>	09/15/98		BC 711	BC 712
339	<i>Cm</i>	08/20/99		BC 713	BC 714
340	<i>Cm</i>	09/26/98		BC 715	BC 716
341	<i>Cm</i>	09/19/99		BC 717	BC 456
342	<i>Cm</i>	09/29/98		BC 720	BC 721
343	<i>Cm</i>	09/29/98		BC 404	BC 403

APPENDIX G. - *Continued*

344	<i>Cm</i>	09/30/98		BC 402	BC 401
401	<i>Ei</i>	01/07/99		BC 407	BC 408
402	<i>Cm</i>	01/13/99		BC 412	BC 413
403	<i>Cm</i>	01/13/99		BC 411	BC 410
404	<i>Cm</i>	01/13/99		BC 416	BC 417
404.5	<i>Cc</i>	02/04/99	BC 418		
405	<i>Cm</i>	06/18/99		BC 419	BC 422
406	<i>Cm</i>	06/22/99		BC 423	BC 426
407	<i>Cm</i>	06/22/99		BC 376	BC 377
408	<i>Cm</i>	06/27/99		BC 442	BC 443
409	<i>Cm</i>	07/01/99		BC 457	BC 458
411	<i>Cm</i>	07/14/99		BC466	BC465
412	<i>Cm</i>	07/16/99		BC471	BC470
413	<i>Cm</i>	07/17/99		BC435	BC434
415	<i>Cm</i>	07/20/99		BC469	BC468
417	<i>Cm</i>	08/01/99		BC482	BC428
419	<i>Cm</i>	08/01/99		BC 429	BC382
420	<i>Cm</i>	08/03/99		BC484	BC483
422	<i>Cm</i>	08/05/99		BC 497	BC 498
423	<i>Cm</i>	08/09/99		BC 384	BC 385
425	<i>Cm</i>	08/17/99		BC 388	BC 389
426	<i>Cm</i>	08/21/99		BC 390	BC 391
427	<i>Cm</i>	09/05/99		BC 393	BC 394
429	<i>Cc</i>	09/06/99		BC 397	BC 398

APPENDIX G. - *Continued*

430	<i>Cm</i>	09/07/99		BC 395	BC 396
431	<i>Cm</i>	09/07/99		BC 427	BC 432
432	<i>Cm</i>	09/11/99		BC 439	BC 440
433	<i>Cm</i>	09/11/99		BC 454	BC 459
434	<i>Cm</i>	09/13/99		BC 479	BC 480
435	<i>Lo</i>	09/18/99	BC 487		
436	<i>Cc</i>	09/19/99		BC 205	BC 206
437	<i>Cm</i>	09/19/99		BC 488	BC 489
438	<i>Cm</i>	09/20/99		BC 490	BC 492
439	<i>Cm</i>	09/21/99		BC 201	BC 202
440	<i>Lo</i>	09/22/99	BC 204		
501	<i>Cm</i>	03/29/00		BC 209	BC 211
502	<i>Cm</i>	03/29/00		BC 224	BC 225
503	<i>Cm</i>	03/29/00		BC 213	
504	<i>Cm</i>	03/29/00		BC 214	
505	<i>Cm</i>	03/29/00		BC 215	

APPENDIX H. LISTING OF TURTLE RECAPTURES NEAR BAHÍA DE LOS ANGELES FORAGING, 1995-2000.

BTID	Capture #	Capture Site	SCL (cm)	Weight (lbs)	Release Date	Release Site	Comments	Interval (d)	Δ SCL (cm)	Δ Weight (lbs)	Distance (km)
BLA 008	19-Jun-95	1 El Cardon	69.4	92	18-Jun-96	Playa Blanca	w/ NEC				
	29-Jun-96	2 El Cardon	69.2	91	30-Jun-96	El Cardon		11	-0.2	-1	9
	22-Jul-96	3 El Cardon	doa	doa			tag return (plastic)	22			0
BLA 012	1-Aug-95	1 El Cardon	58.6	62.0	12-Jul-96	C. Archelon	in captivity 1 yr				
	15-Jul-96	2 La Silica		60.0	16-Jul-96	La Silica		3		-2	1.5
	23-Jun-97	3 Playa Blanca	60.5	67.0	23-Jun-97	El Cardon	rad tag	341	1.9	7	9
BLA 013	1-Jun-95	1 BLA	66.0	84.0	12-Jul-96	C. Archelon	in captivity 1 yr				
	30-Jul-96	2 C. Archelon	67.7	95.0		IN TANKS		18	1.7	11	0
BLA 018	12-May-95	1 Playa Blanca	80.9	168	13-May-95	Islas Gemelos					

APPENDIX H. – *Continued*

	1-Jul-96	2	El Cardon	84.0	169	2-Jul-96 El Cardon		359	3.1	1	5
BLA 020	4-Jun-96	1	El Cardon	76.5	158	5-Jun-95 El. Cardon					
	9-Aug-99	2	El Bajo	90.6	225	9-Aug-99 C. Archelon	adult male	1,160	14.1	67	9
BLA 021	5-Jun-95	1	El Cardon	66.4	101.0	6-Jun-95 El Cardon					
	27-Feb-97	2	Bahia San Rafael	doa	doa		tag return (plastic)	631			37
BLA 024	12-May-95	1	Playa Blanca	69.9	109	13-May-95 Playa Blanca					
	21-Jun-96	2	Playa Blanca	70.0	101.0	22-Jun-96 Playa Blanca	sick turtle	404	0.1	-8	n/a
BLA 102	5-May-96	1	El Cardon	72.1	115	6-May-96 El Cardon					
	8-Aug-98	2	Bahia Guadalupe	doa	80 kg		tag return (plastic)	459			20

APPENDIX H. – *Continued*

BLA 108	5-Jun-96	1	Confiscated	66.0		5-Jun-96 Central Bay	amputee				
	30-Jul-96	2	C. Archelon	66.0		31-Jul-98 C. Archelon		55	0		2
BLA 113	6-Jun-96	1	El Cardon	71.2	100.0	8-Jun-96 El Cardon					
	30-Jul-96	2	C. Archelon	doa	doa			52			2
BLA 116	26-May-96	1	Confiscated	48.2	31.0	12-Jul-96 C. Archelon					
	16-Jul-96	2	La Silica			IN TANKS		4			1.5
BLA 118	26-May-96	1	Confiscated	56.8	56.0	12-Jul-96 C. Archelon					
	16-Jul-96	2	La Silica	56.4	53	IN TANKS		4	0.4	-3	1.5
BLA 120	9-Jun-96	1	El Quemado	76.9	148	10-Jun-98 El Rincon					
	1-Sep-98	2	El Quemado	79.4	172	1-Sep-98 C. Archelon		447	2.5	24	0
BLA 124	26-May-96	1	Confiscated	60.0	62.0	12-Jul-96 C. Archelon					

APPENDIX H. -- *Continued*

	31-Jul-96	2	C. Archelon	60.0		1-Aug-96	C. Archelon		19	0		0
	22-Jul-97	3	C. Archelon	60.9	60	23-Jul-97	C. Archelon		356	0.9	-2	0
BLA 126	21-Jun-96	1	El Cardon	77.6	154	22-Jun-96	Estero					
	2-Aug-96	2	C. Archelon	77.5		3-Aug-96	C. Archelon	Rad tag	41	0	9	9
BLA 127	21-Jun-96	1	El Cardon	71	113	23-Jun-96	Estero					1.5
	7-Jul-96	2	C. Munoz	71.2	113	8-Jul-96	Campo Munoz		14	0.2	0	0
	8-Jun-97	3	C. Munoz	73.3	135	10-Jun-97	Campo Munoz		335	1.1	22	0
	24-Jun-97	4	C. Munoz			25-Jun-97	Campo Munoz	rad/son	14			0
BLA 137	18-Jul-96	1	La Silica	87.3	205	18-Jul-96	La Silica	TI. (44.2)				
	18-Aug-99	2	El Bajo	89.4	190	19-Aug-99	El Bajo		1125	2.1	-15	1
	8-Sep-99	3	El Bajo	89.4	190	13-Sep-99	El Bajo	Crittercam	25	0	0	0
BLA 203	10-Jun-97	1	La Silica	73.9	118	11-Jun-97	La Silica					
	16-Mar-98	2	Playa	79	139	17-Mar-98	Playa Blanca		268	5.1	21	10

APPENDIX H. – *Continued*

Blanca

BLA 206	25-Jun-97	1	El Cardon	88.7	200	26-Jun-97	El Cardon					
	23-Apr-98	2	El Bajo	90.8	230	24-Apr-98	El Bajo	303	3.1	30	9	
BLA 219	15-Aug-97	1	N. Isla Pata	77.3	148	18-Aug-98	N. Isla Pata					
	19-Sep-97	2	El Barco	77.6	149	21-Sep-97	El Barco	Crittercam	32	0.3	1	6
BLA 224	22-Sep-97	1	El Barco	73.8	120	29-Sep-97	El Barco	rad/son				
	29-Sep-98	2	El Bajo	74.6	117	1-Oct-98	C. Archelon	Crittercam	366	0.8	-3	6
BLA 228	6-Oct-97	1	El Barco	52.2	97	9-Oct-97	El Barco	rad/son				
	14-Jan-98	2	Bahia San Rafael	doa doa	doa			Tag return (metal)	88			37
BLA 231	10-Oct-97	1	El Barco	93.8	210	11-Oct-97	El Barco					
	27-Sep-98	2	El Barco	94.7	246	29-Sep-98	El Barco	Crittercam	341	0.9	36	0

APPENDIX H. – *Continued*

	24-Jul-00	3	Ped Barco	96.7	262	26-Jul-00	Ped del Barco	Crittercam	672	2	16	0.5
BLA 232	10-Oct-97	1	El Barco	72.1	91		El Barco					
	8-Jan-98	2	El Barco	71.8	-	9-Jan-98	El Barco	rad/son	91	-0.3		0
BLA 305	27-Jan-98	1	El Barco	86	188	28-Jan-98	El Barco	rad/son				
	29-Mar-00	2	Angelitos	86.4	175	29-Mar-00	El Bajo	Confiscated	792	0.4	-12	9
BLA 311	26-Jun-98	1	El Bajo	65.2	90	-	-					
	17-Aug-99	2	El Bajo	65.9	90		El Bajo		418	0.7		0
	12-Sep-99	3	El Bajo	65.9	90	14-Sep-99	El Bajo		26	0	0	0
BLA 312	25-Jun-98	1	El Bajo	86.7	197	26-Jun-98	El Bajo					
	18-Aug-98	2	El Bajo	87.0	210	18-Aug-98	C. Archelon		55	0.3	13	0
	7-Sep-98	3	El Bajo	86.7	210	8-Sep-98	El Bajo		22	0	0	0
BLA 314	1-Jul-98	1	El Bajo	71.4	110	2-Jul-98	El Bajo					

APPENDIX H. -- *Continued*

	30-Jun-99	2	El Bajo	72.1	110	1-Jul-99	El Bajo		394	0.7	0	0
	19-Aug-99	3	El Bajo	73	120	19-Aug-99	El Bajo		50	0.9	0	0
BLA 323	19-Jul-98	1	El Bajo	65.3	90	20-Jul-98	El Bajo	rad/son				
	30-Jul-98	2	N. Isla Ventana			30-Jul-98	N. Isla Ventana	rad/son	11	0	0	0
BLA 326	28-Jul-98	1	El Bajo	75.5	157	29-Jul-98	El Bajo					
	30-Sep-98	2	El Bajo	75.8	157	30-Sep-99	El Bajo		63	0.3	0	0
BLA 329	29-Jul-98	1	El Bajo	86.0	194	30-Jul-98	El Bajo					
	2-Aug-98	2	El Bajo	86.5	191	3-Aug-98	El Bajo		3	0.5	-3	0
	6-Sep-99	3	El Bajo	89	199	7-Sep-99	El Bajo		399	2.5	7	0
	20-Sep-99	4	El Bajo			21-Sep-99	El Bajo		14			0
BLA 339	22-Sep-98	1	El Bajo	80.2	180	24-Sep-98	El Bajo	Crittercam				
	20-Aug-99	2	El Bajo	81.9	184	20-Aug-99	El Bajo		330	1.7	4	0

APPENDIX H. – *Continued*

BLA 341	29-Sep-98	1	El Bajo	75.8	136	29 sep 98	El Bajo					
	19-Sep-99	2	El Bajo	76.5	-	20-Sep-99	El Bajo	355	0.7			0
BLA 406	22-Jun-99	1	El Bajo	82.5	165	27-Jun-99	El Bajo					
	29-Mar-00	2	Angelitos	84.7	171	29-Mar-00	El Bajo	307	2.2	6		5
	25-Jul-00	3	La Silica	85.7	189	27-Jul-00	El Bajo	118	1	18		1
BLA 407	22-Jun-99	1	El Bajo	92.5	225	24-Jun-99	C. Archelon					
	20-Aug-99	2	El Bajo	91.9	223	21-Aug-99	El Bajo	59	-0.6	0		0
BLA 419	1-Aug-99	1	La Silica	71.3	134	3-Aug-99	Silica					
	16-Aug-99	2	La Silica			17-Aug-99	Silica	13	-			0
BLA 422	5-Aug-99	1	El Bajo	67.5	97	7-Aug-99	El Bajo					
	18-Sep-99	2	Los Barriles	66.6	105	18-Sep-99	Los Barilles	42	0	7		7
	14-Aug-00	3	Ped Barco	68.4	110	16-Aug-00	Ped del Barco	330	1.8	5		2

APPENDIX H. – *Continued*

BLA 425	17-Aug-99	1	El Bajo	81.4	170	18-Aug-99	El Bajo					
	19-Sep-99	2	El Bajo			19-Sep-99	El Bajo		32			0
BLA 426	21-Aug-99	1	El Bajo	86.7	224	22-Aug-99	El Bajo					
	27-Jun-00	2	El Bajo	88.7	235	29-Jun-00	El Bajo	crittercam	309	2	11	0
BLA 507	7-May-00	1	El Bajo	76.4		8-May-00	El Bajo					
	16-Jul-00	2	El Bajo	77.6	155	18-Jul-00	El Bajo	rad/son	69	1.2		0

APPENDIX I. HOME RANGE AND MOVEMENT MAPS FOR TURTLES TRACKED IN BAHIA DE LOS ANGELES.

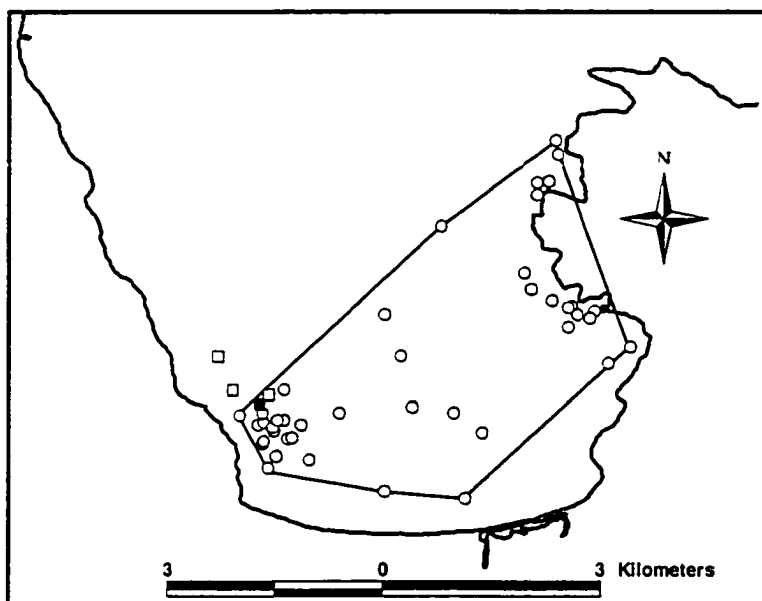


Fig. I.1.a. Minimum Convex Polygon home range for turtle 127. (Black square indicates site of initial capture, circles indicate relocation points, white squares indicate net recaptures outside tracking interval)

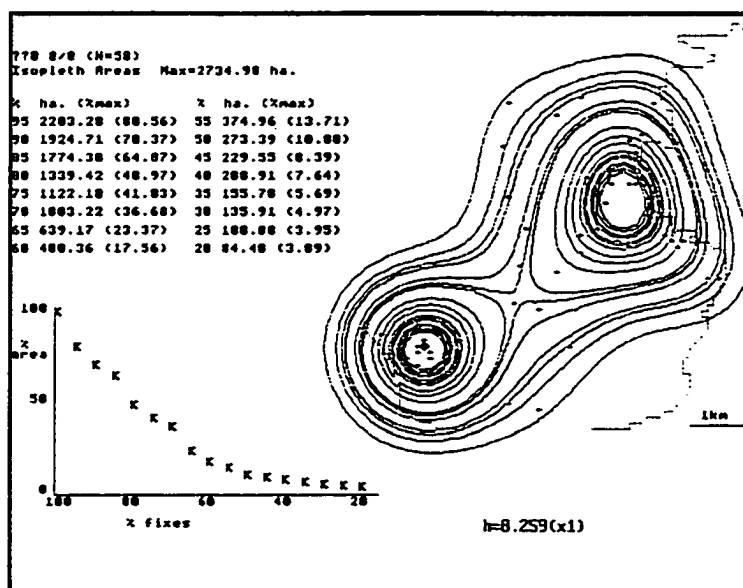


Fig. I.1.b. Kernel home range for turtle 225 Each line indicates 5% utilization isopleth starting with 20% from center.

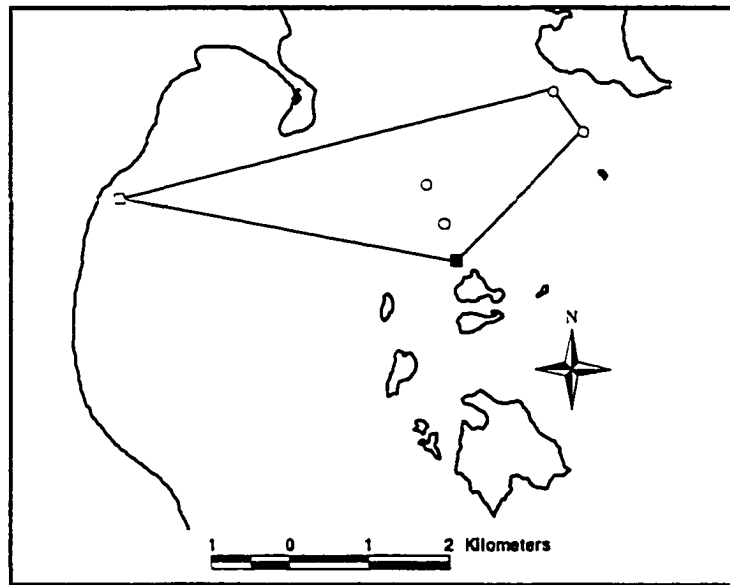
APPENDIX I. – *Continued*

Fig. I.2. Relocation polygon for turtle 219. See Fig. I.1.a. for explanation of symbols.

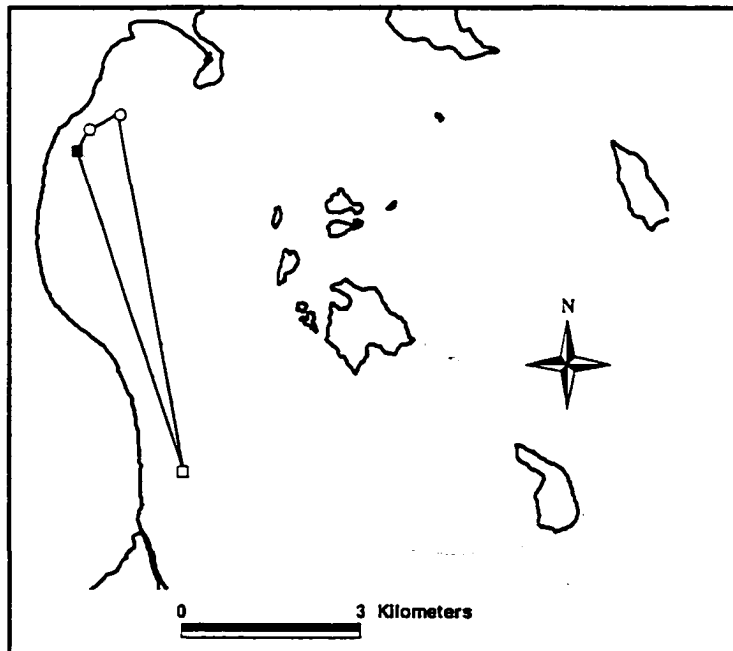


Fig. I.3. Relocation polygon for turtle 224. See Fig. I.1.a. for explanation of symbols.

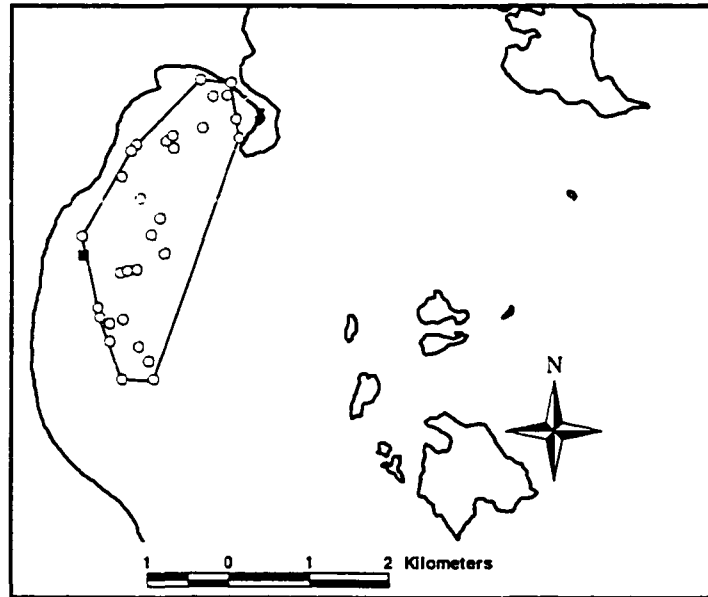
APPENDIX I. – *Continued*

Fig. I.4.a. Minimum Convex Polygon for turtle 225. See Fig. I.1.a. for explanation of symbols.

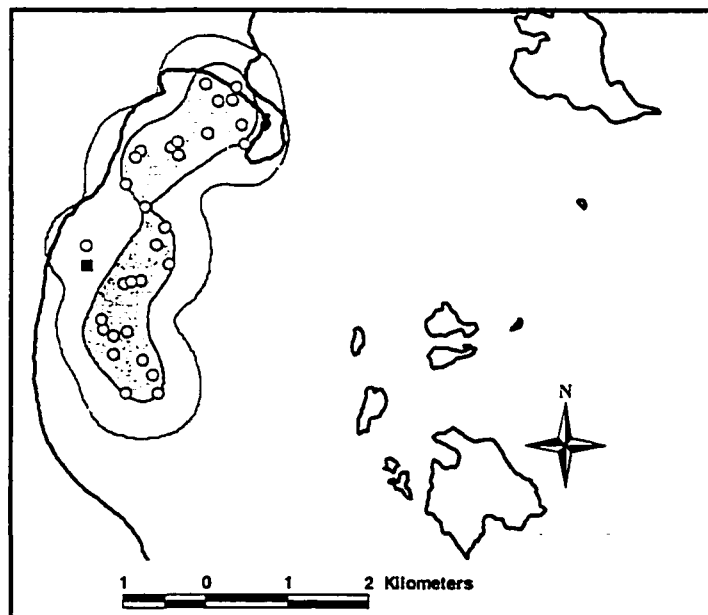


Fig. I.4.b. Kernel home range for turtle 225. Light gray Shading indicates 95% usage area; dark shading indicates core 50% usage areas. See Fig. I.1.a. for explanation of symbols.

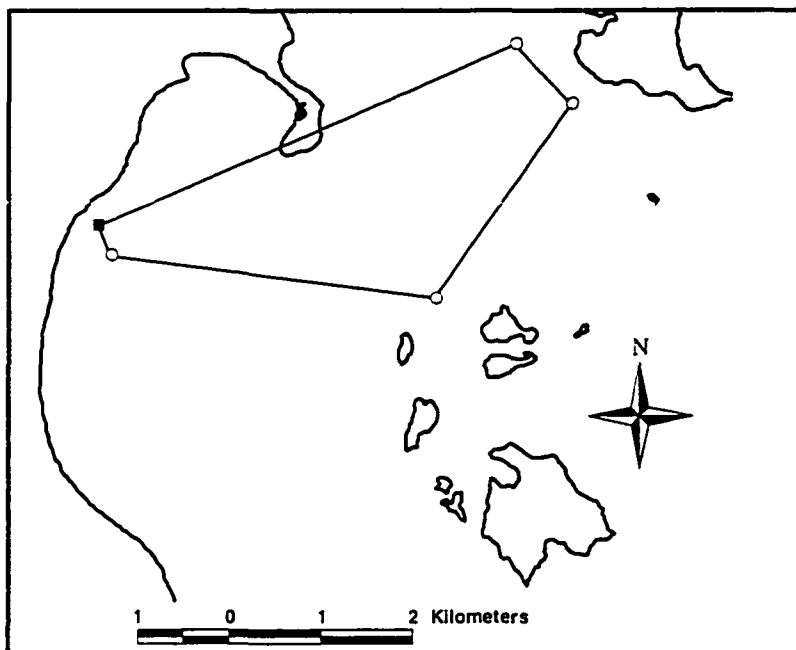
APPENDIX I. – *Continued*

Fig. I.5. Relocation polygon for turtle 228. See Fig. I.1.a. for explanation of symbols.

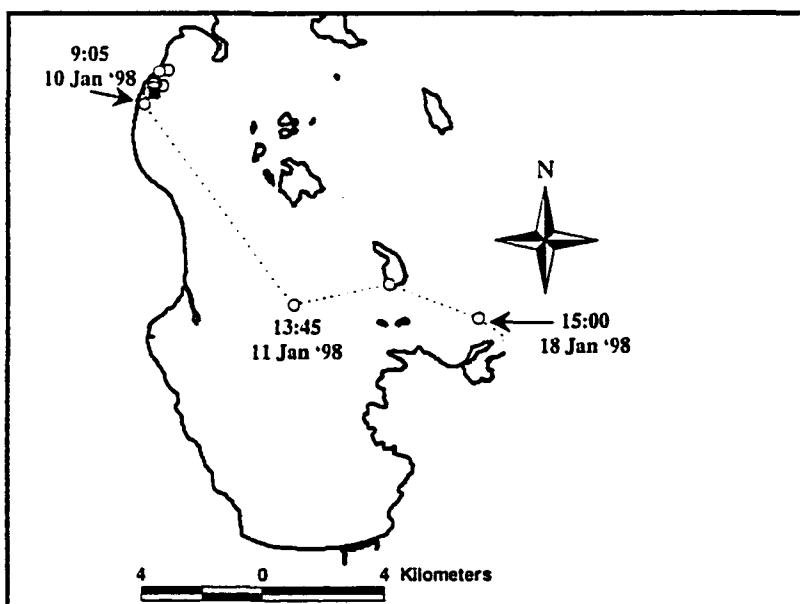


Fig. I.6. Movement path of turtle 230. See Fig. I.1.a. for explanation of symbols.

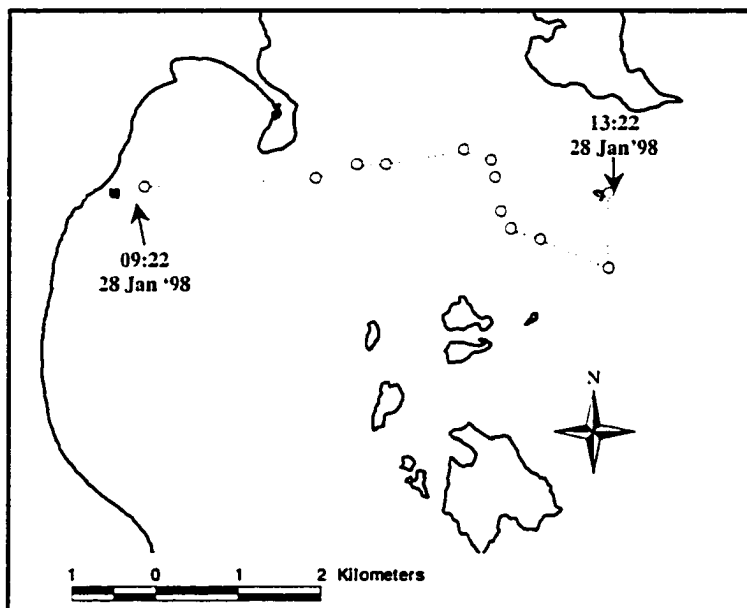
APPENDIX I. – *Continued*

Fig. I.7. Movement path of turtle 305. See Fig. I.1.a. for explanation of symbols.

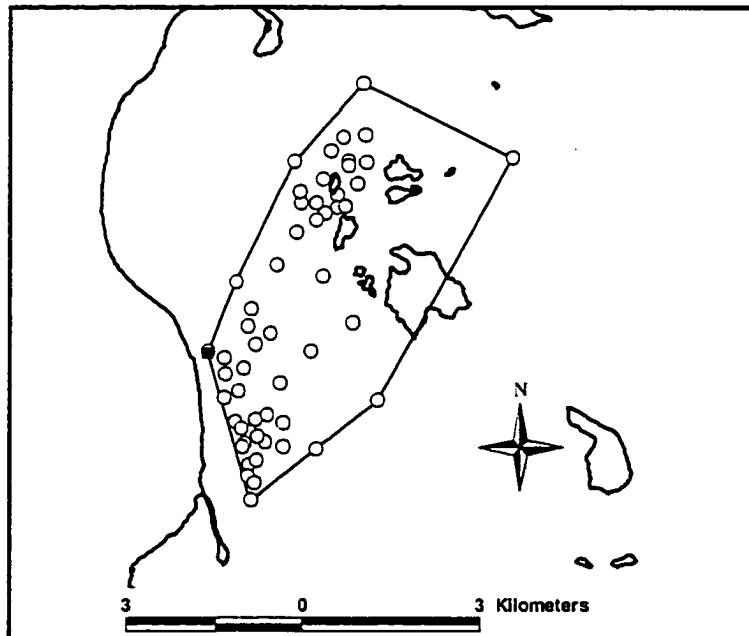


Fig. I.8.a. Minimum Convex Polygon home range for turtle 310. See Fig. I.1.a. for explanation of symbols.

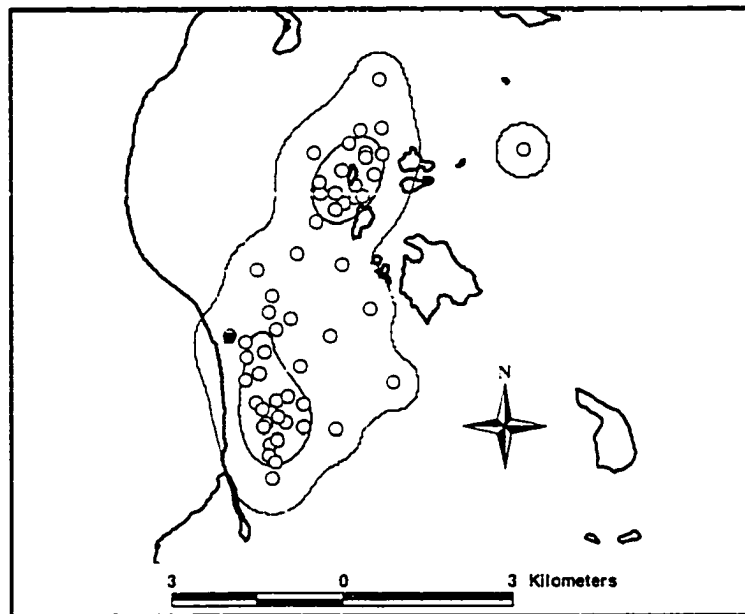
APPENDIX I. – *Continued*

Fig. I.8.b. Kernel home range for turtle 310. Light gray shading indicates 95% usage area; dark shading indicates core 50% usage areas. See Fig. I.1.a. for explanation of symbols.

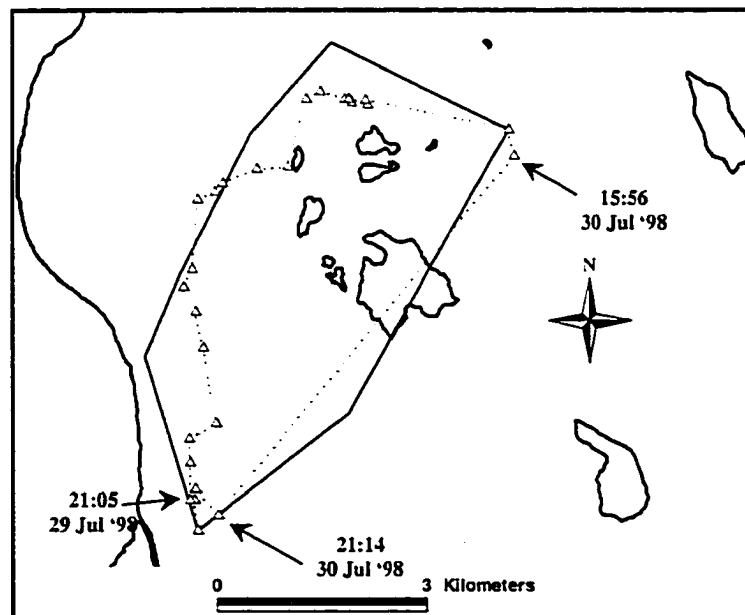


Fig. I.8.c. 24-h vagility path for turtle 310. Solid line indicates MCP outline, dotted line indicates path of 24-h track, triangles indicate relocations during tracking interval.

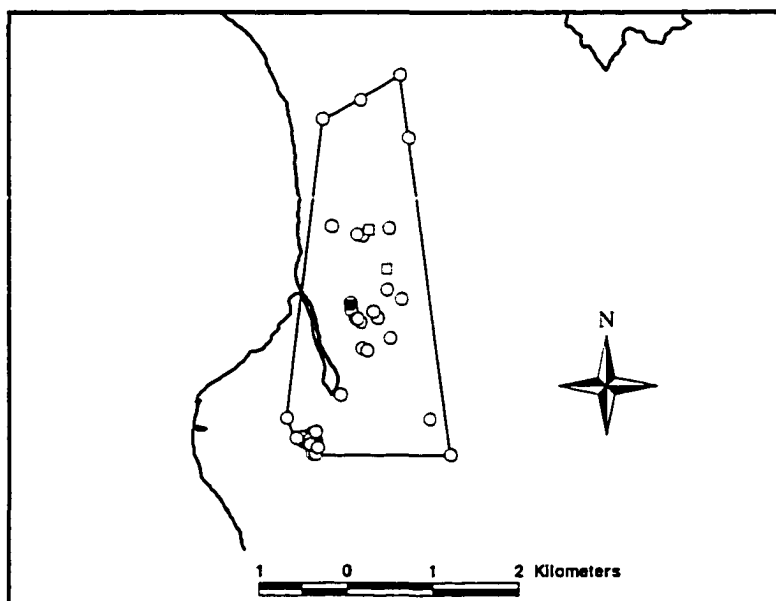
APPENDIX I. – *Continued*

Fig. I.9.a. Minimum Convex Polygon home range for Turtle 311. See Fig. I.1.a. for explanation of symbols.

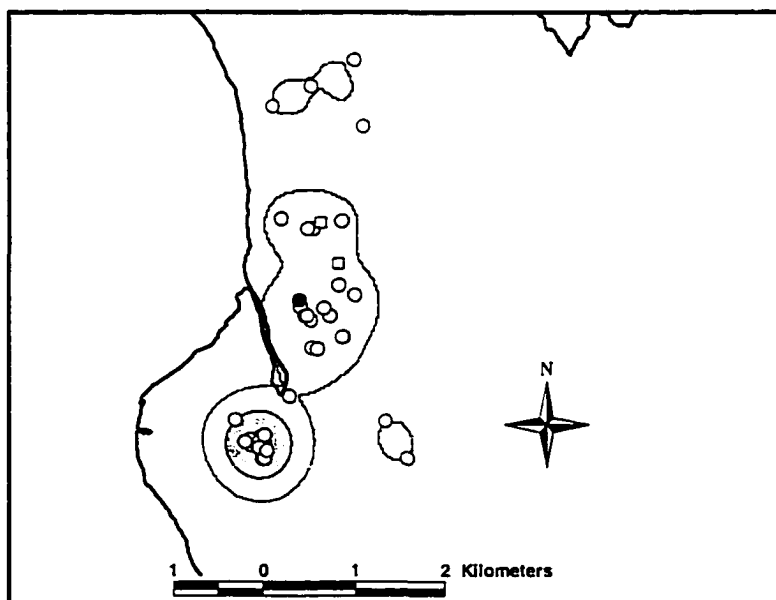


Fig. I.9.b. Kernel home range estimate for Turtle #311. Light gray shading indicates 95% usage area; dark shading indicates core 50% usage areas. See Fig. I.1.a. for explanation of symbols.

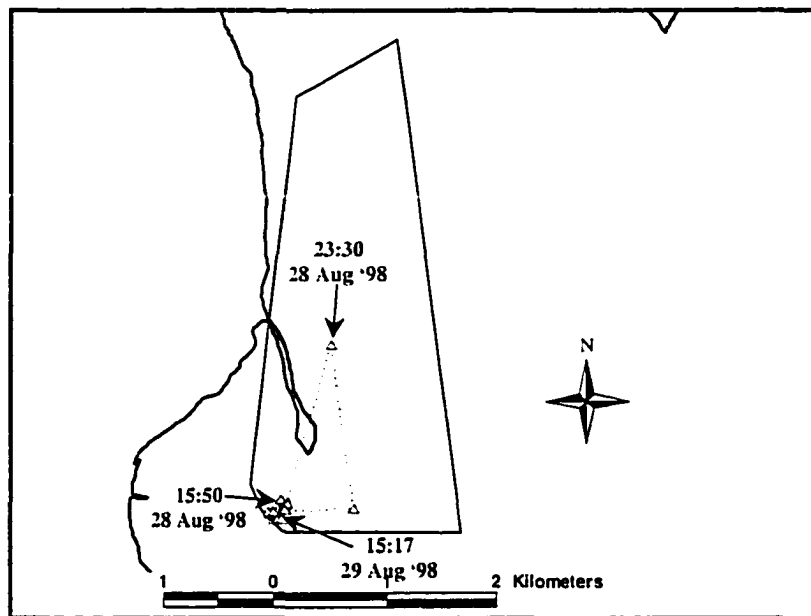
APPENDIX I. - *Continued*

Fig. I.9.c. 24-h vagility path for turtle 311. Solid line indicates MCP outline, dotted line indicates path of 24-h track, triangles indicate relocations during tracking interval

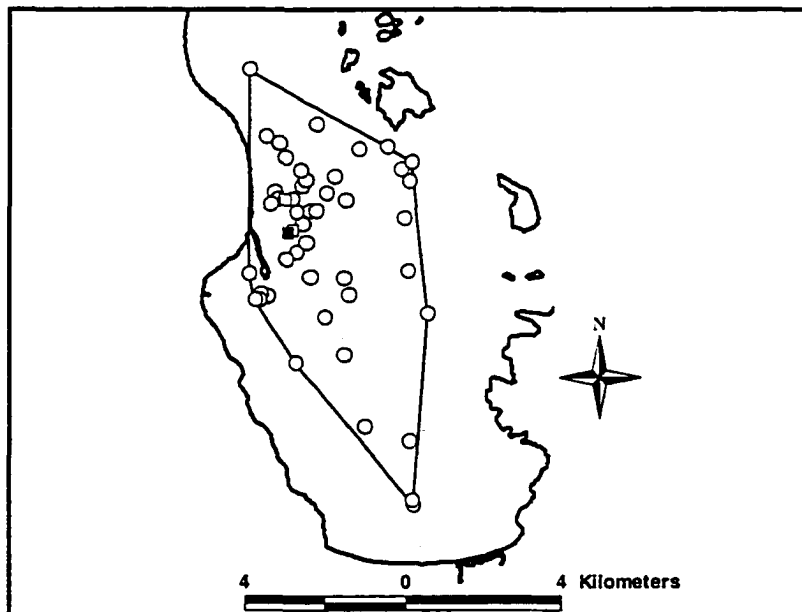


Fig. I.10.a. Minimum convex polygon home range for turtle 314. See Fig. I.1.a. for explanation of symbols.

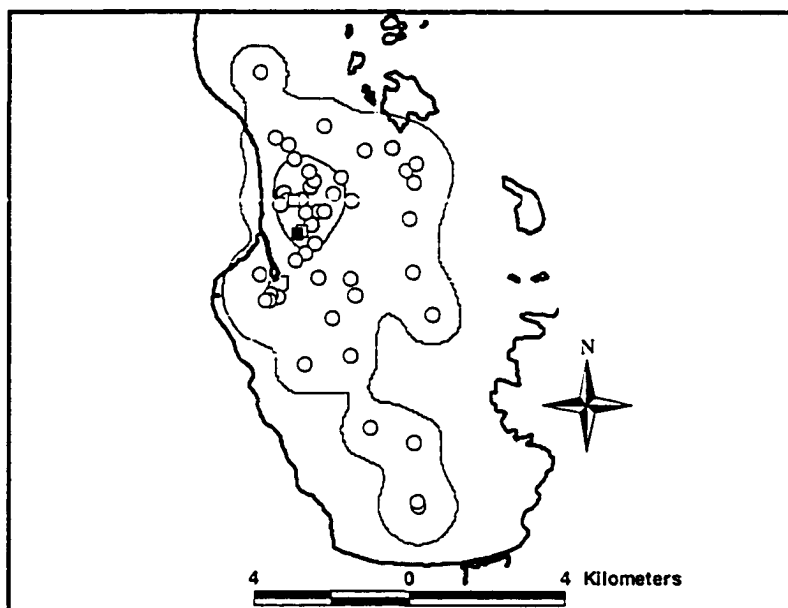
APPENDIX I. – *Continued*

Fig. I.10.b. Kernel home range for Turtle 314. Light gray shading indicates 95% usage area; dark shading indicates core 50% usage areas. See Fig. I.1.a. for explanation of symbols.

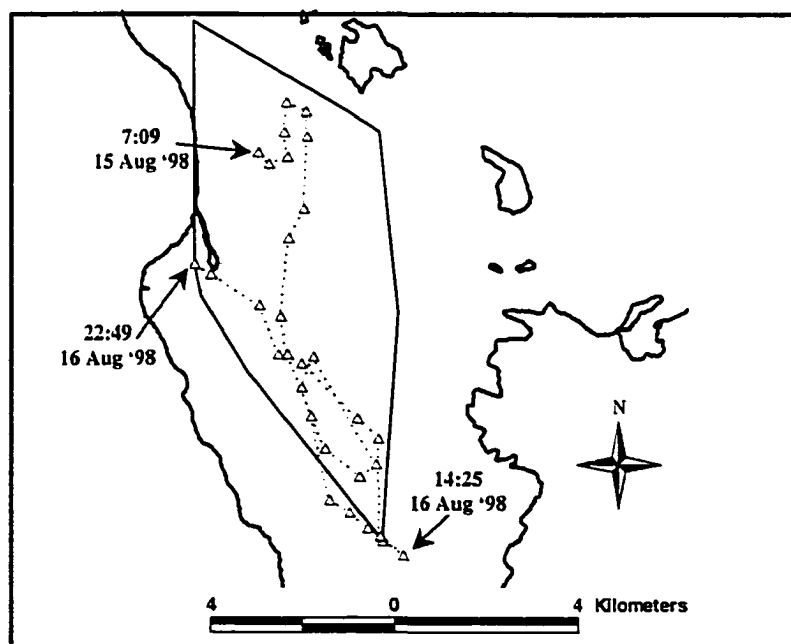


Fig. I.10.c. 24-h vagility path for turtle 314. Solid line indicates MCP outline, dotted line indicates path of 24-h track, triangles indicate relocations during tracking interval. See Fig. I.1.a. for additional explanation of symbols.

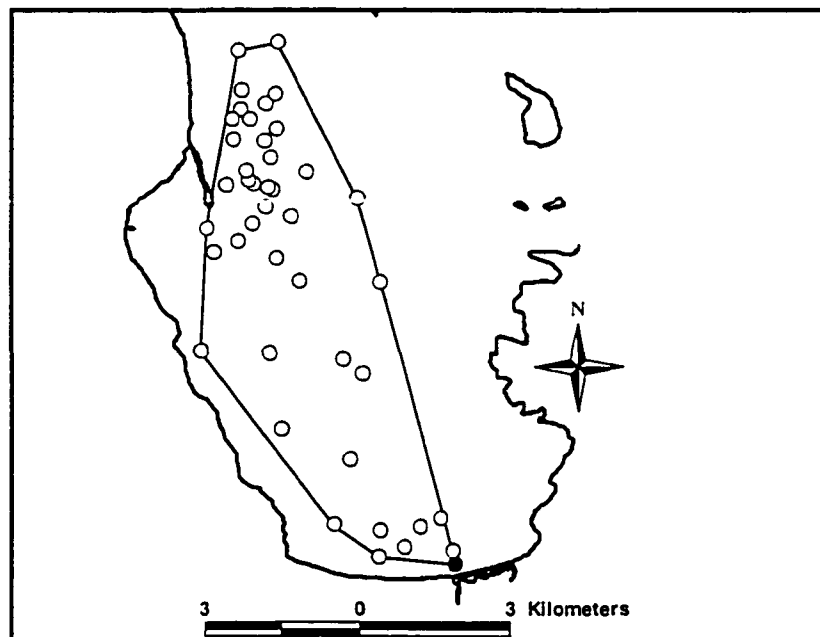
APPENDIX I. – *Continued*

Fig. I.11.a. Minimum Convex Polygon home range for turtle 316. See Fig. I.1.a. for explanation of symbols.

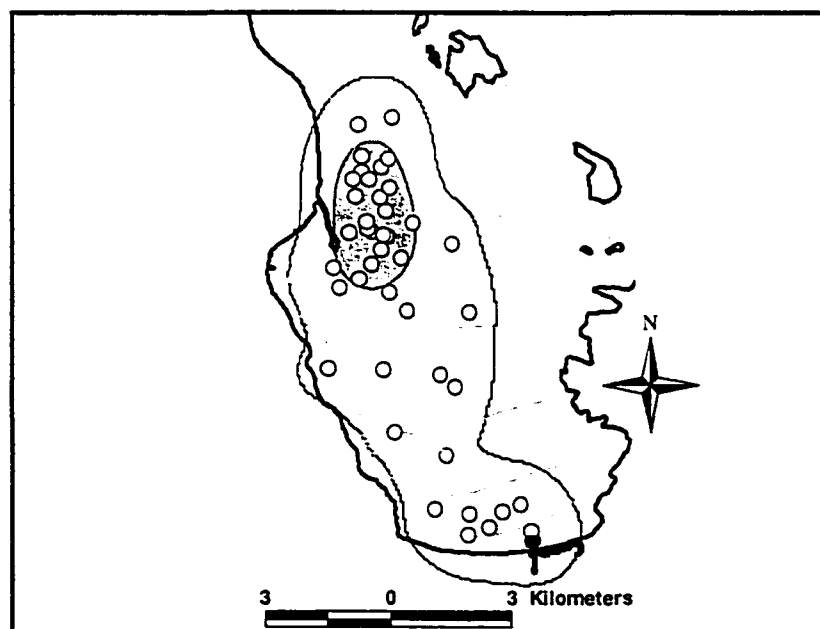


Fig. I.11.b. Kernel home range for turtle 316. Light gray shading indicates 95% usage area; dark shading indicates core 50% usage areas. See Fig. I.1.a. for explanation of symbols.

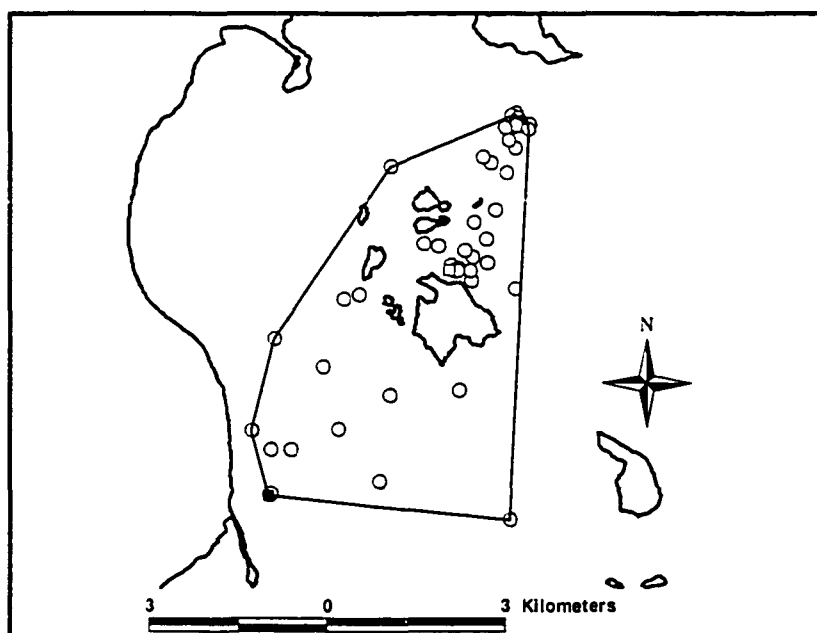
APPENDIX I. - *Continued*

Fig. I.12.a. Minimum Convex Polygon home range for turtle 323. See Fig. I.1.a. for explanation of symbols.

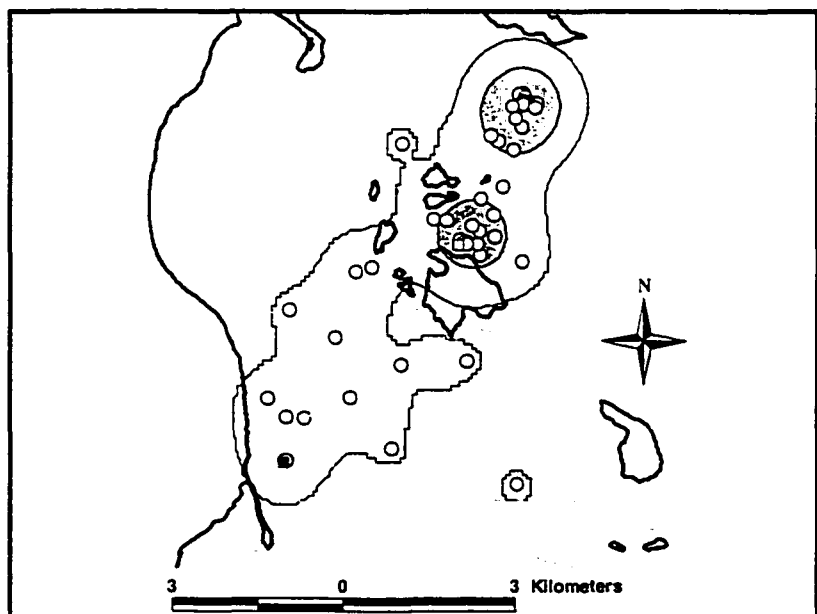


Fig. I.12.b. Kernel home range for turtle 323. Light gray shading indicates 95% usage area; dark shading indicates core 50% usage areas. See Fig. I.1.a. for explanation of symbols.

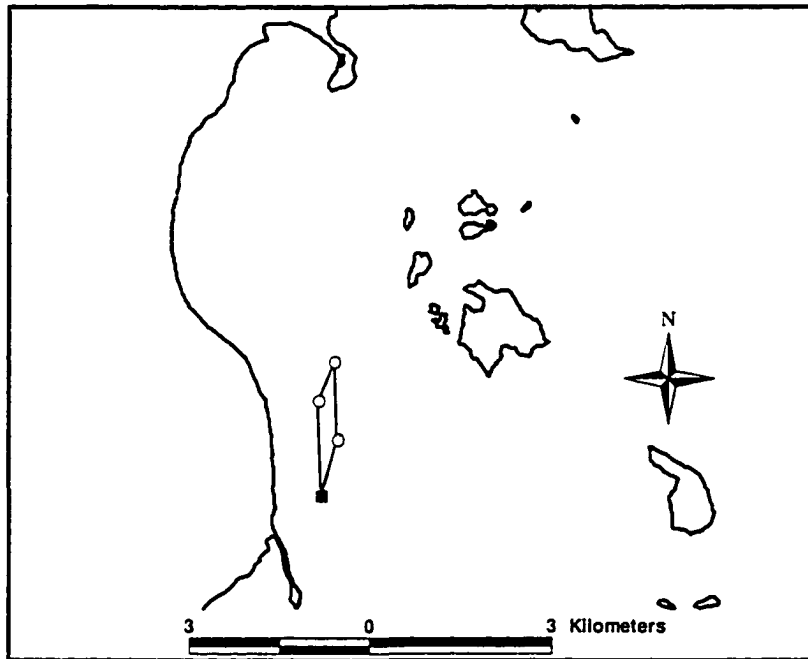
APPENDIX I. - *Continued*

Fig. I.13. Relocation polygon estimate for turtle 330.
See Fig. I.1.a. for explanation of symbols.

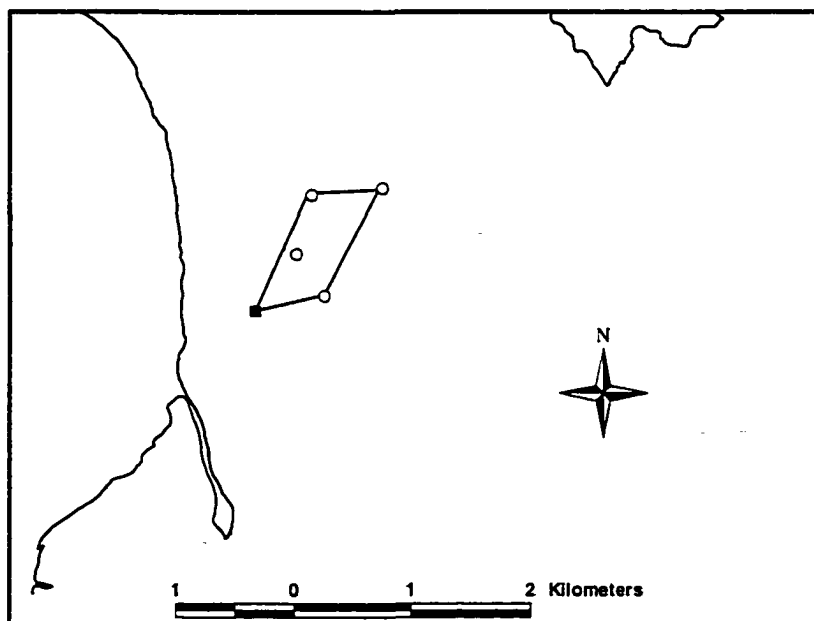


Fig. I.14. Relocation polygon estimate for turtle 405.
See Fig. I.1.a. for explanation of symbols.

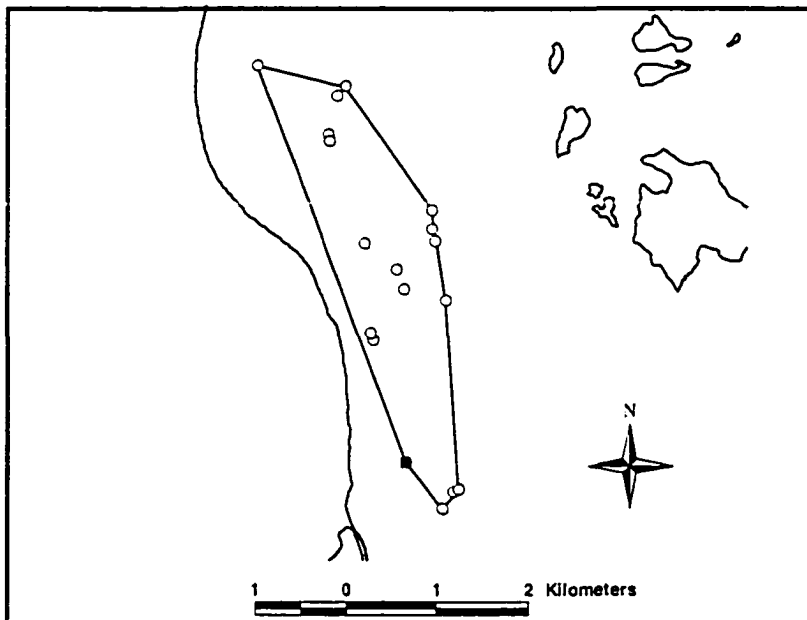
APPENDIX I. – *Continued*

Fig. I.15.a. Minimum Convex Polygon home range for turtle 406. See Fig. I.1.a. for explanation of symbols.

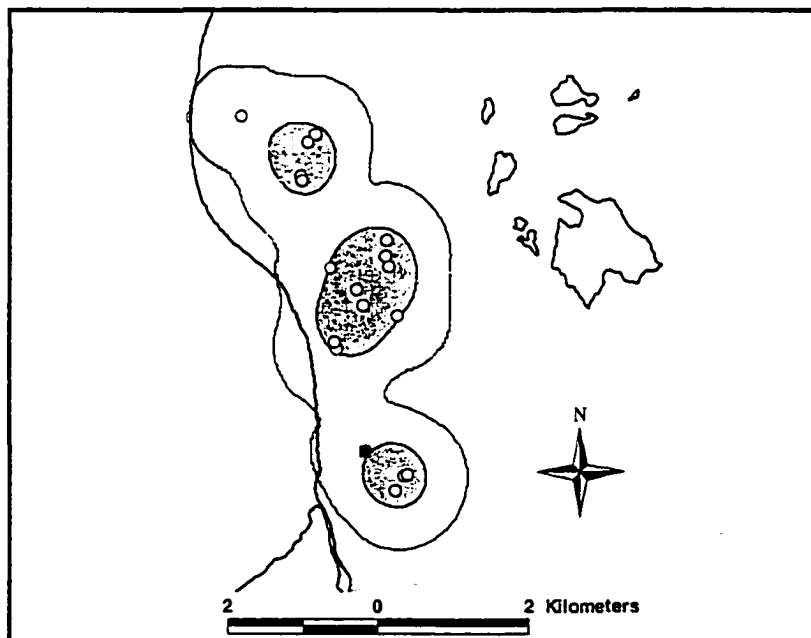


Fig. I.15.b. Kernel home range for turtle 406. Light gray shading indicates 95% usage area; dark shading indicates core 50% usage areas. See Fig. I.1a. for explanation of symbols.

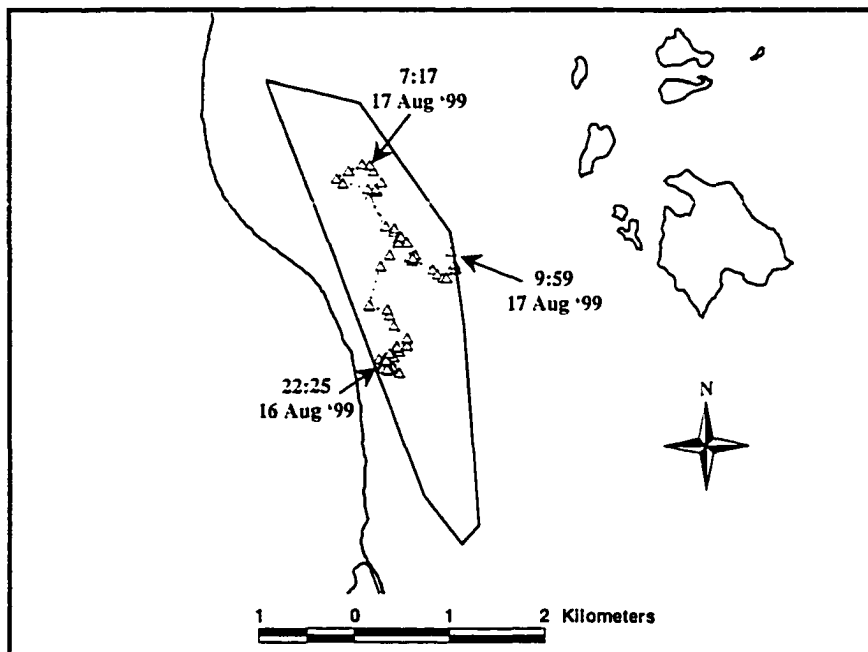
APPENDIX I. - *Continued*

Fig. I.15.c. 24-h vagility path for turtle 406. Solid line indicates MCP outline, dotted line indicates path of 24-h track, triangles indicate relocations during tracking interval.

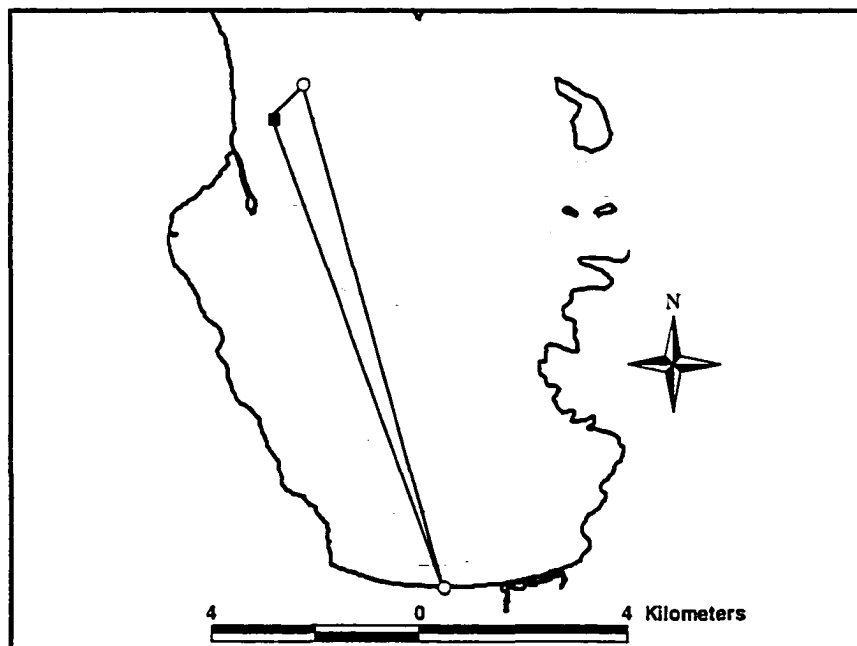


Fig. I.16. Relocation polygon for turtle 409. See Fig. I.1.a. for explanation of symbols.

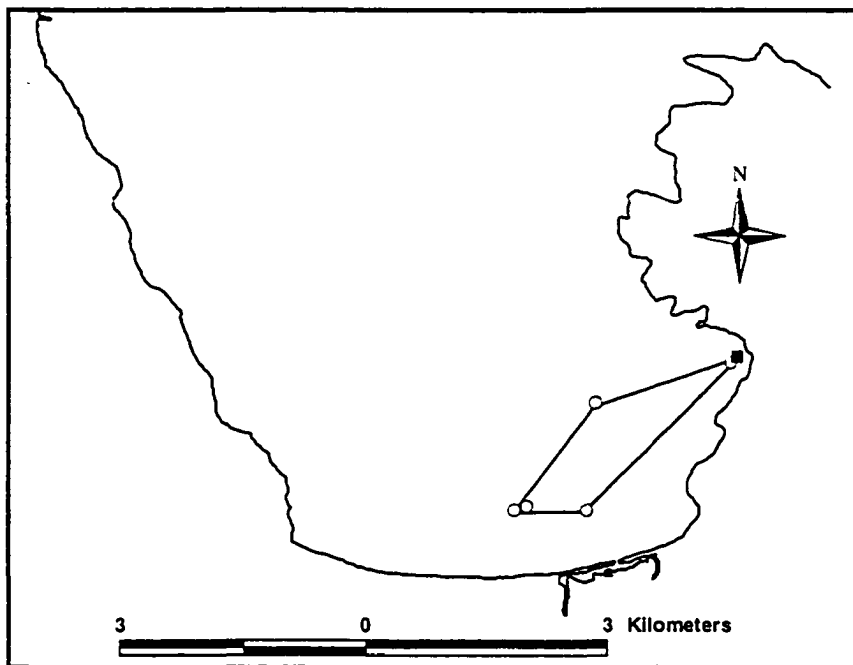
APPENDIX I. - *Continued*

Fig. I.17. Relocation polygon for turtle 411. See Fig. I.1.a. for explanation of symbols.

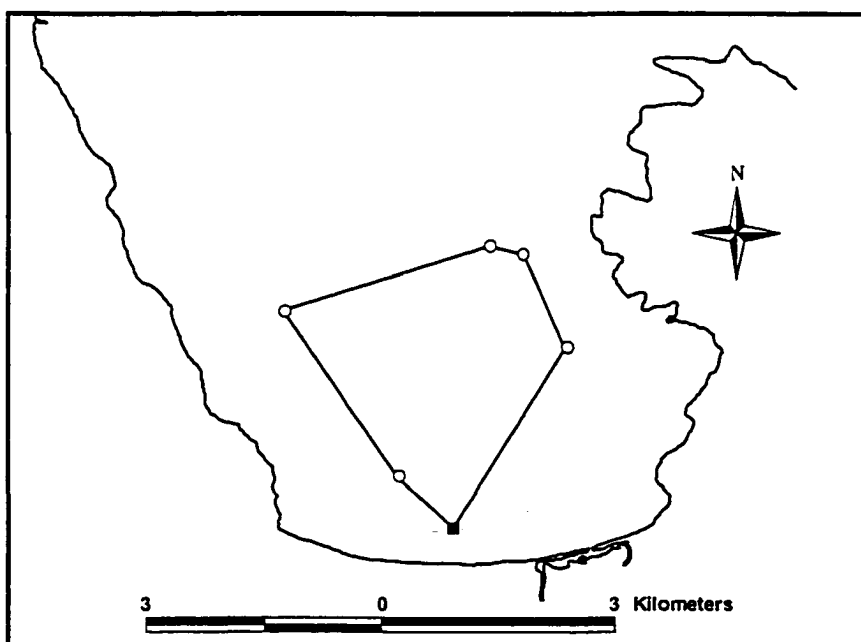


Fig. I.18. Relocation polygon for turtle 412. See Fig. I.1.a. for explanation of symbols.

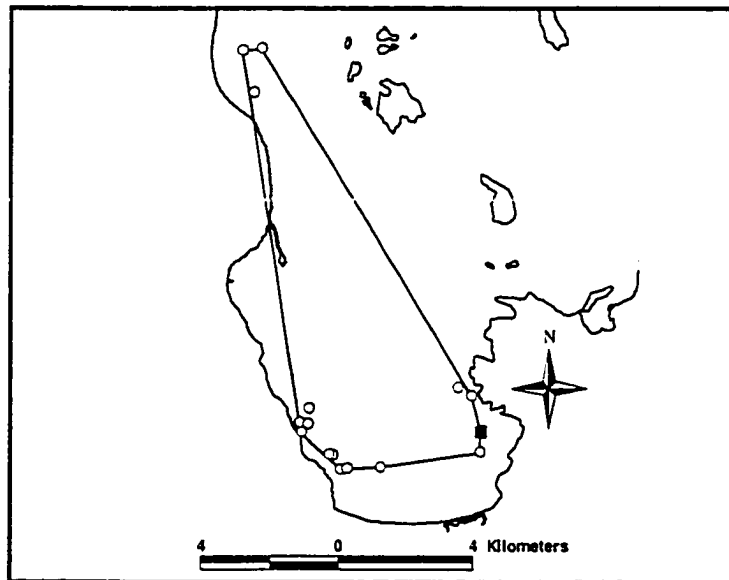
APPENDIX I. – *Continued*

Fig. I.19.a. Minimum Convex Polygon home range for turtle 413. See Fig. I.1.a. for explanation of symbols.

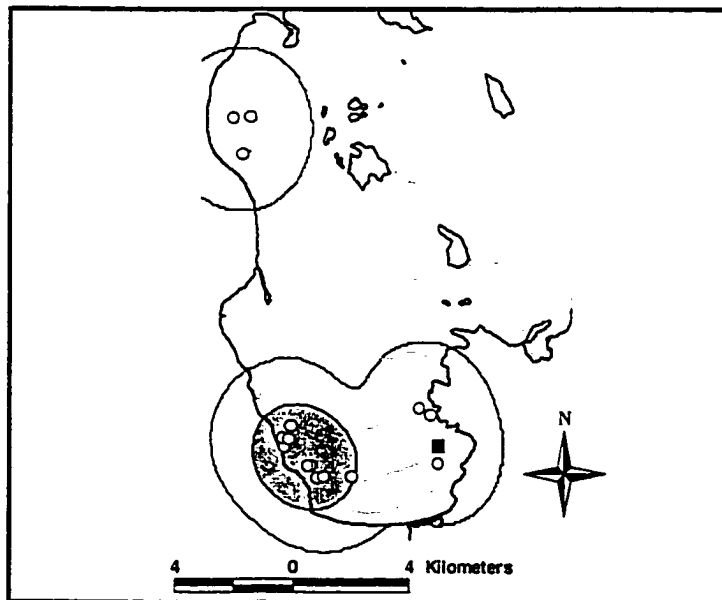


Fig. I.19.b. Kernel home range for turtle 413. Light gray shading indicates 95% usage area; dark shading indicates core 50% usage areas. See Fig. I.1.a. for explanation of symbols.

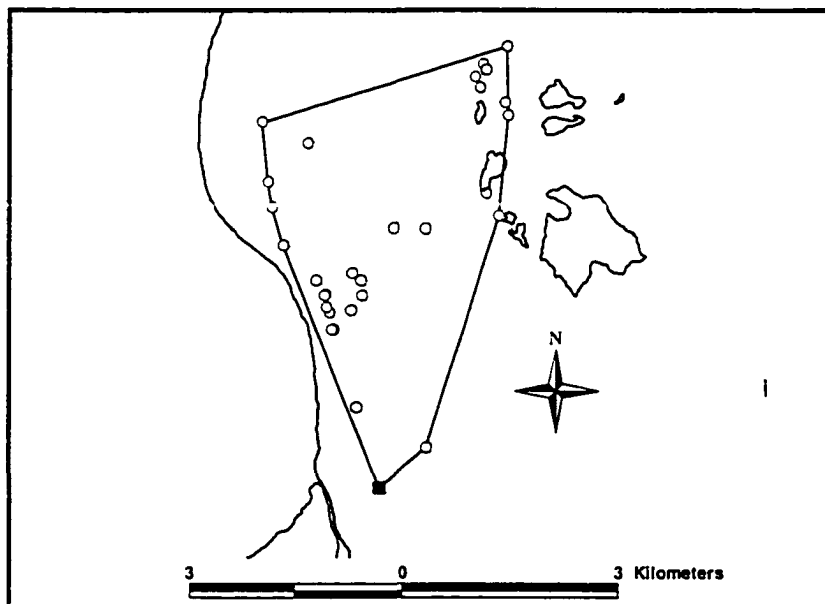
APPENDIX I. – *Continued*

Fig. I.20.a. Minimum Convex Polygon home range for turtle 415. See Fig. I.1.a. for explanation of symbols.

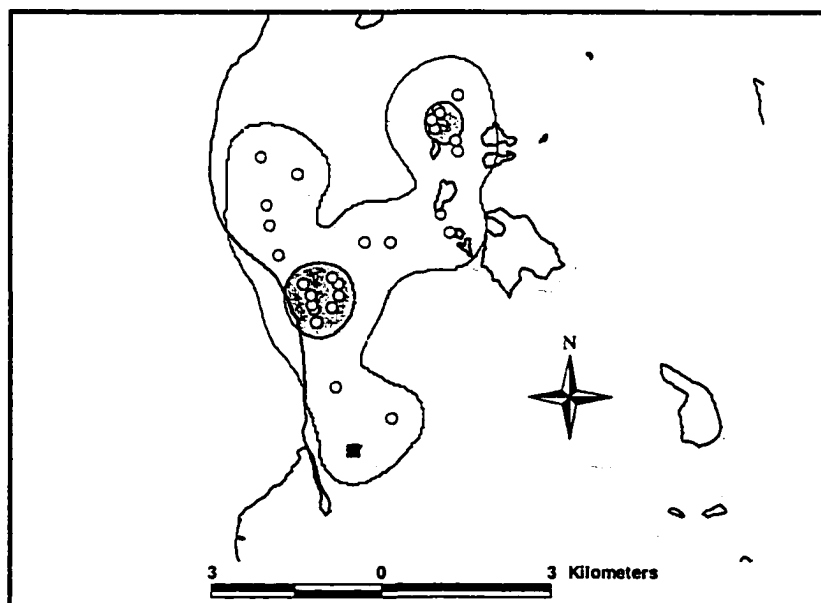


Fig. I.20.b. Kernel home range for turtle 415. Light gray shading indicates 95% usage area; dark shading indicates core 50% usage areas. See Fig. I.1.a. for explanation of symbols.

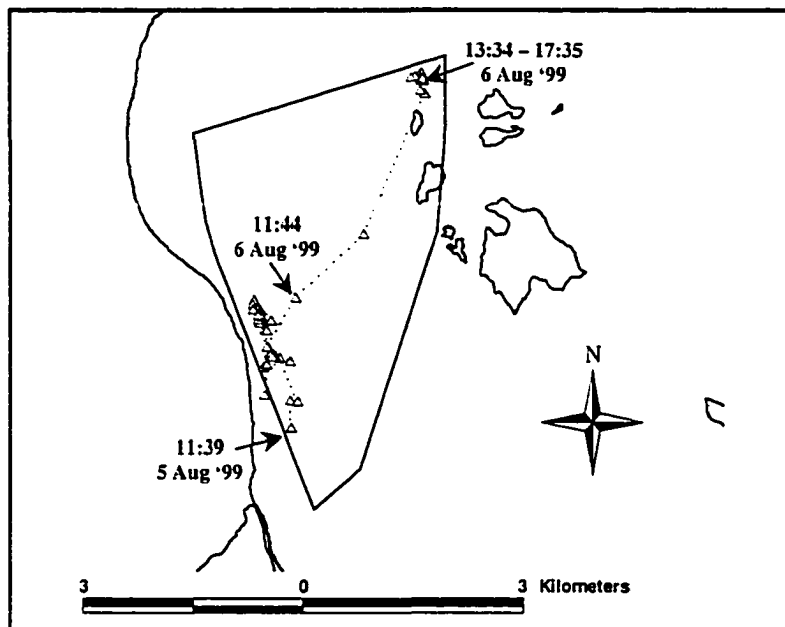
APPENDIX I. - *Continued*

Fig. I.20.c. 24-h vagility path for turtle 415. Solid line indicates MCP outline, dotted line indicates path of 24-h track, triangles indicate relocations during tracking interval. See Fig. I.1.a. for additional explanation of symbols.

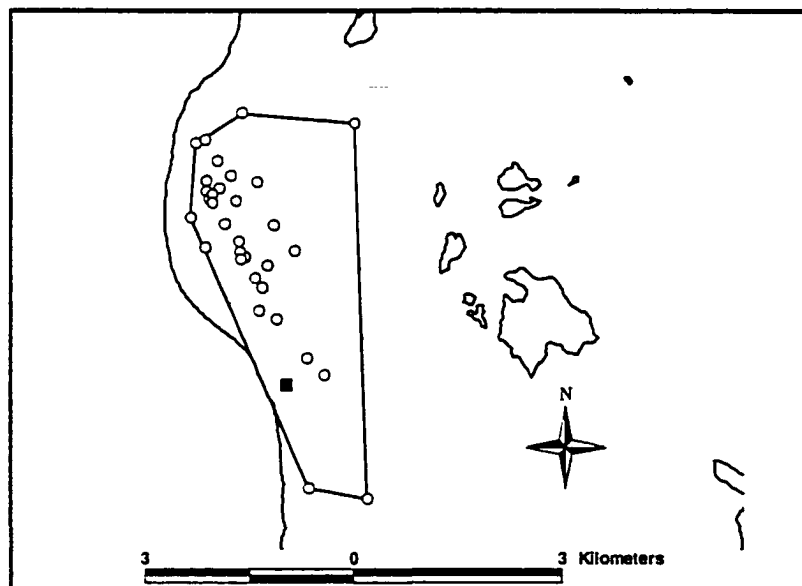


Fig. I.21.a. Minimum Convex Polygon home range for turtle 419. See Fig. I.1.a. for explanation of symbols.

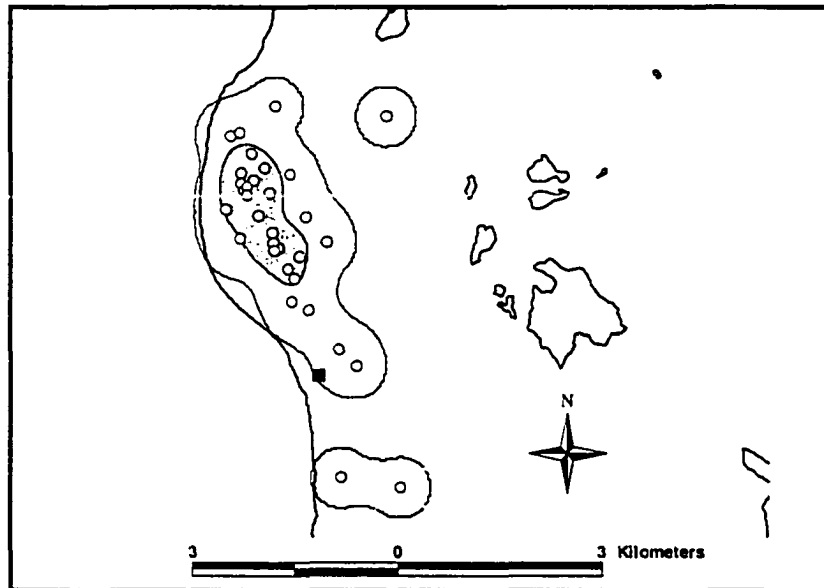
APPENDIX I. - *Continued*

Fig. I.21.b. Kernel home range for turtle 419. Light gray shading indicates 95% usage area; dark shading indicates core 50% usage areas. See Fig. I.1.a. for explanation of symbols.

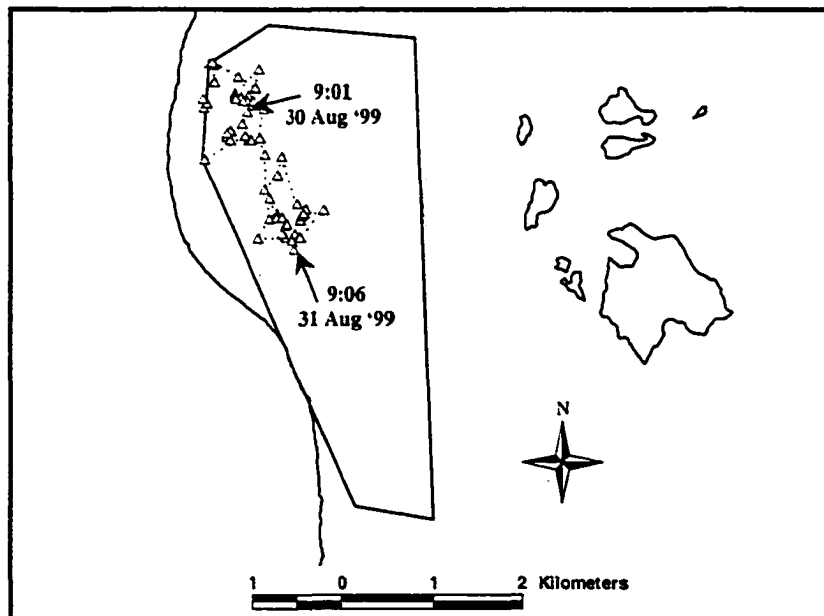


Fig. I.21.c. 24-h vagility path for turtle 419. Solid line indicates MCP outline, dotted line indicates path of 24-h track, triangles indicate relocations during tracking interval. See Fig. I.1.a. for additional explanation of symbols.

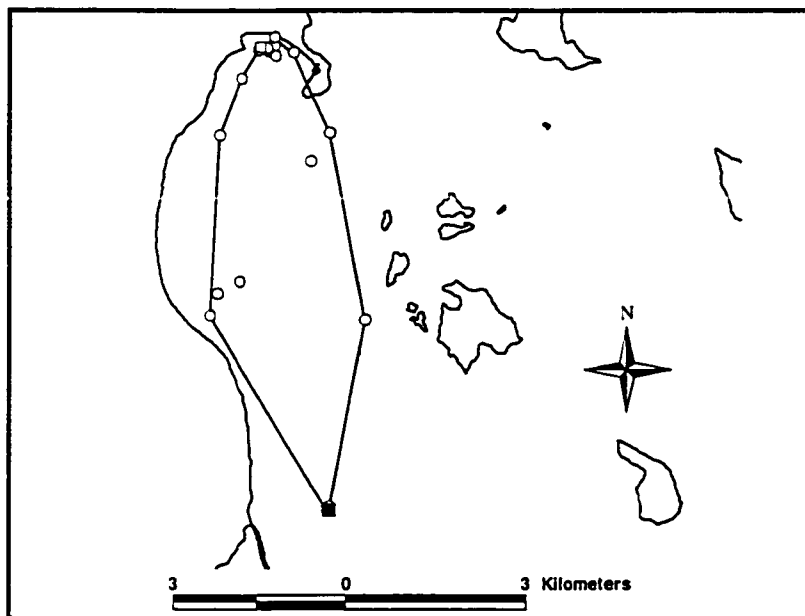
APPENDIX I. – *Continued*

Fig. I.22.a. Minimum Convex Polygon home range for turtle 422. See Fig. I.1.a. for explanation of symbols.

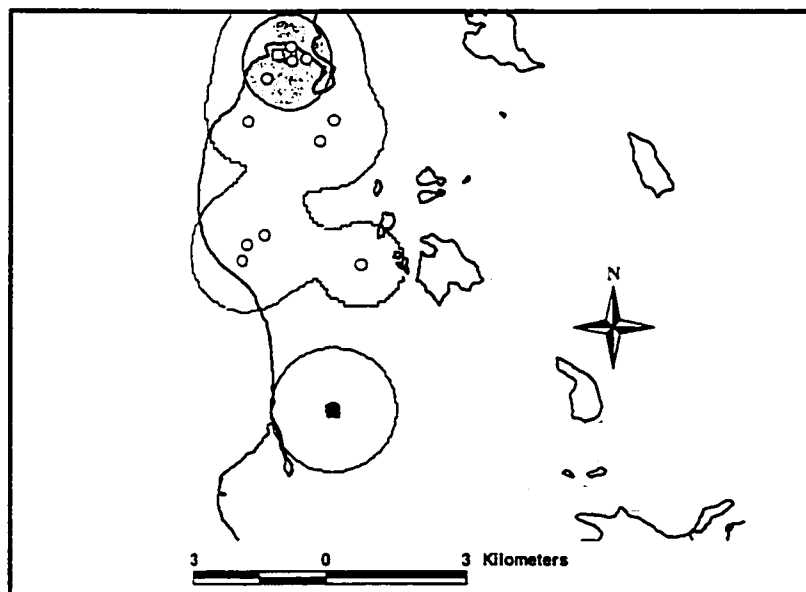


Fig. I.22.b. Kernel home range for turtle 422. Light gray shading indicates 95% usage area; dark shading indicates core 50% usage areas. See Fig. I.1.a. for explanation of symbols.

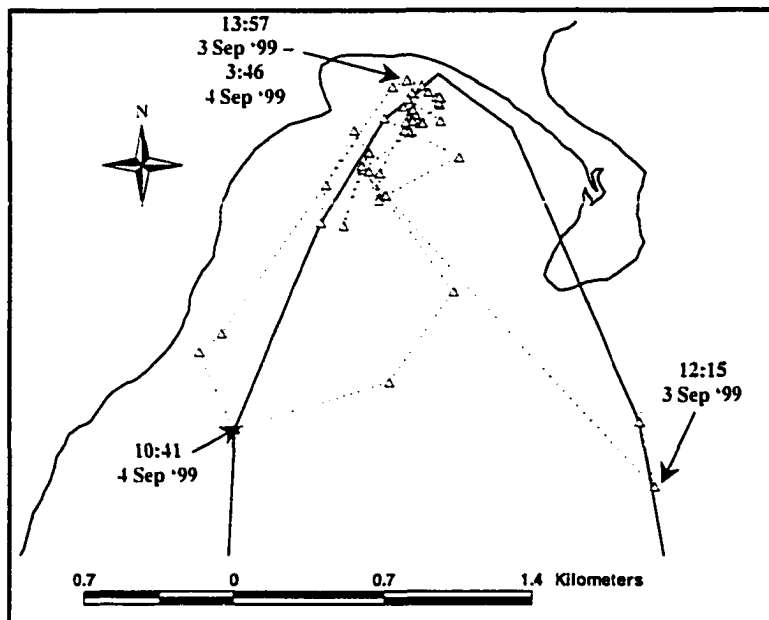
APPENDIX I. – *Continued*

Fig. I.22.c. 24-h vagility path for turtle 422. Solid line indicates MCP outline. dotted line indicates path of 24-h track, triangles indicate relocations during tracking interval. See Fig. I.1.a. for additional explanation of symbols.

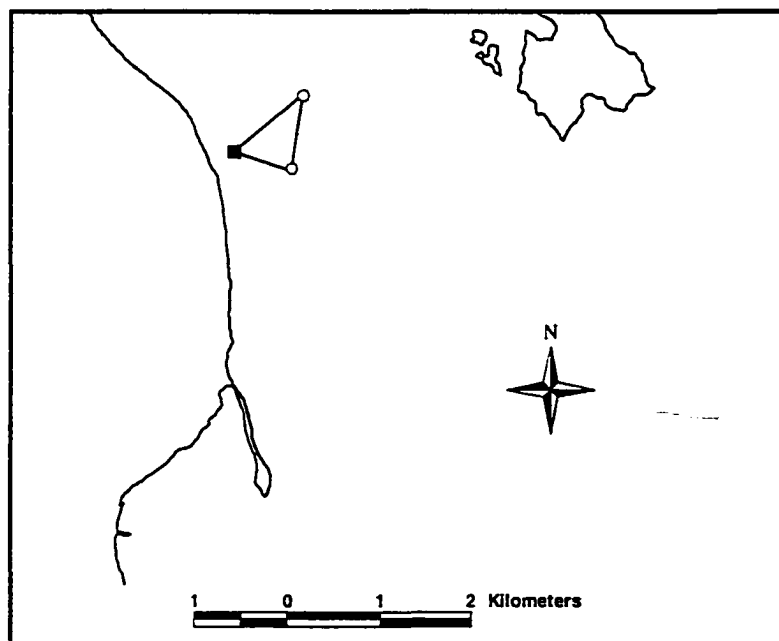


Fig. I.23. Relocation polygon for turtle 422. See Fig. I.1.a. for explanation of symbols and lines.

APPENDIX J. SEA WATER TEMPERATURES AT BAHIA DE LOS ANGELES DURING STUDY PERIOD

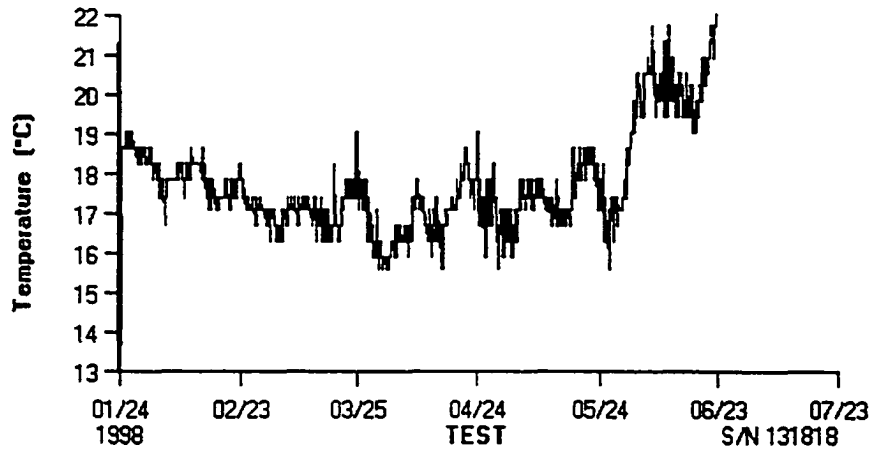


Figure J.1. Sea water temperature (± 0.5 C) at 1 m, El Bajo Shallows, Bahia de los Angeles, Gulf of California, Mexico. January 1998 – July 1998.

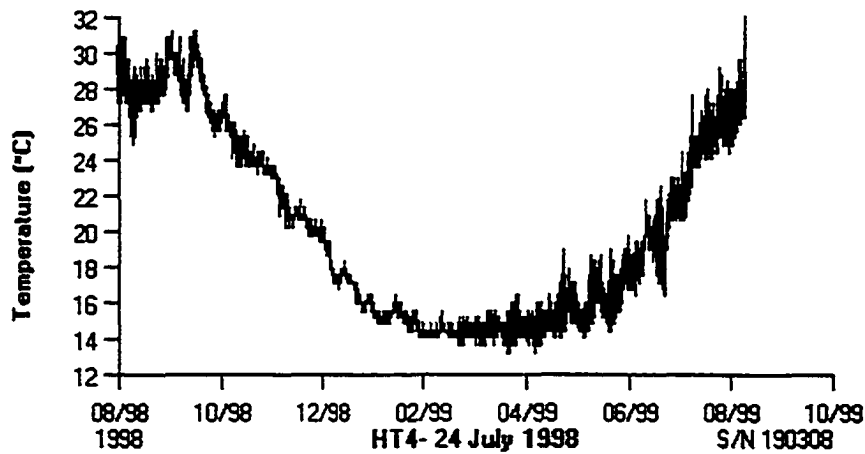


Figure J.2. Sea water temperature (± 0.5 C) at 5 m, Isla Gemelo E., Bahia de los Angeles, Gulf of California, Mexico. August 1998 – September 1999.

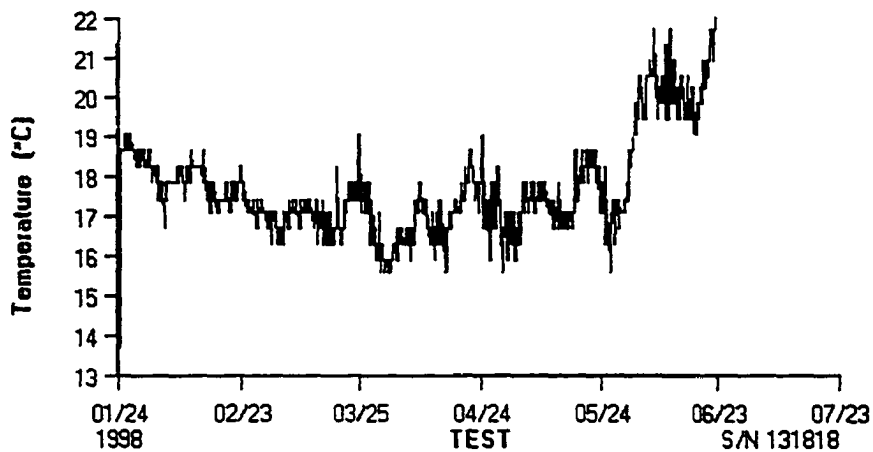
APPENDIX J. - *Continued*

Figure J.3. Sea surface temperature (± 0.5 C) at El Bajo Shallows, Bahia de los Angeles, Gulf of California, Mexico. January 1998 – August 1998

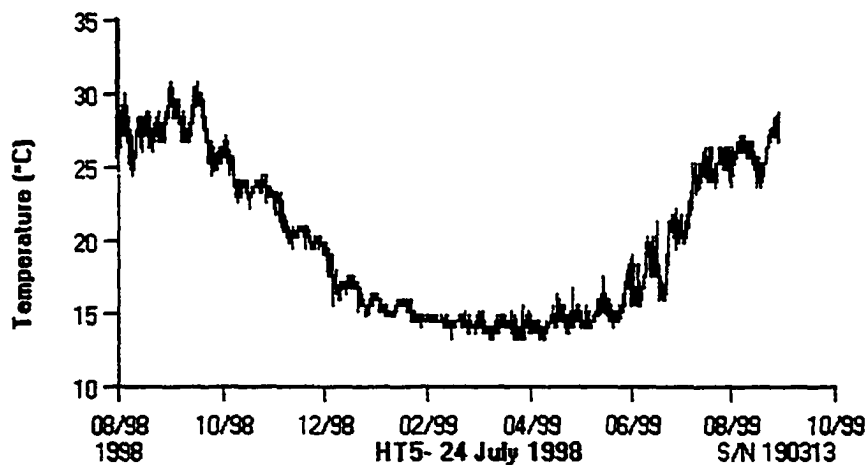


Figure J.4: Sea surface temperature at El Bajo Shallows, Bahia de los Angeles, Gulf of California, Mex. September 1998 – September 1999

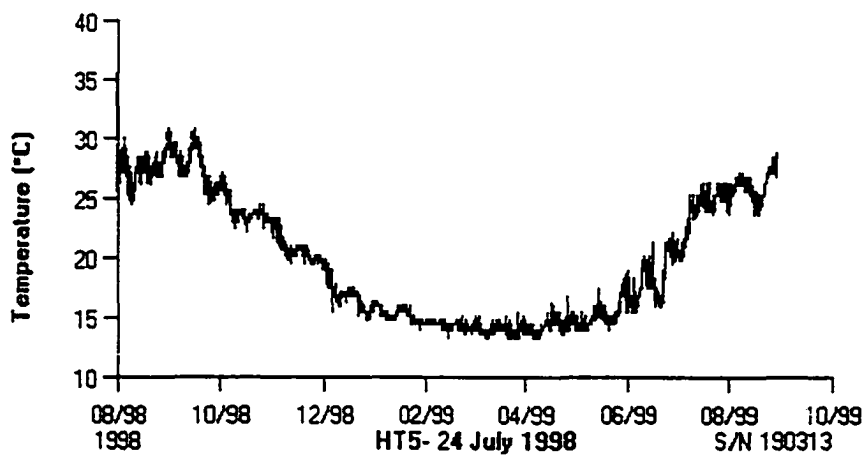
APPENDIX J. - *Continued*

Figure J.5. Water temperature at 7.5 m at El Bajo Shallows, Bahía de los Angeles, Gulf of California, Mexico. September 1998 – September 1999.

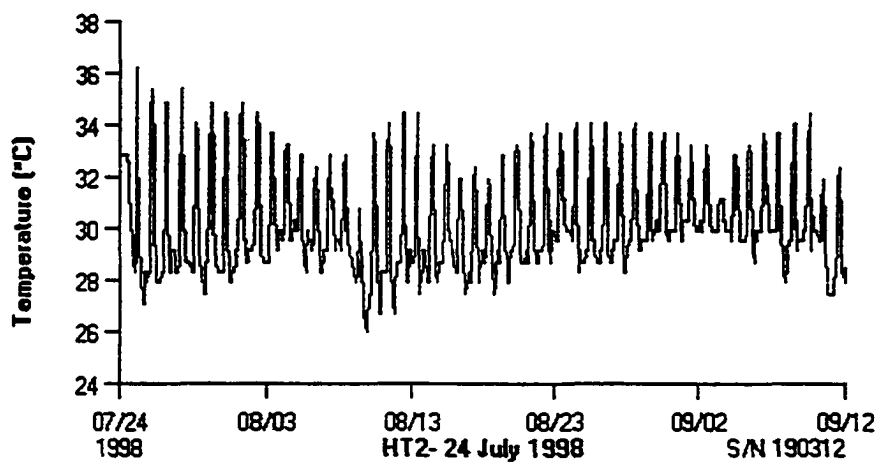


Figure J.6. Sea Surface Temperature (± 0.5 C) at 1 m, Playa Mona, Bahía de los Angeles, Gulf of California, Mexico. July 1998 – September 1998.

APPENDIX K. LIST OF PARTICIPATING INDIVIDUALS DURING THE COURSE OF THIS STUDY

Earthwatch Institute Team Members. 1996-1999

Dustin Agnew, Jane Alexander, Sharon Anderson, Michele Ashkin, Deborah Bailes, Lulu Bartley, Jeanine Beck, Matt Bianchi, Heather Blaikie, Andria Blattner, Chris Brady, Jessica Brady, Mark Breeze, Sharon Brockhoff, Martin Brown, Tamara Bryant, Erin Burger, Patricia Callan-McKinney, Janet Carpenter, Beatrice Child-Villiers, Kari Corneliuson, Monica Costello, Elise Cowan, Tim Crane, Carla Curbelo, Helen Czarski, Jeff Davis, Wilbur Dehart, Marie De-Lantsheere, Michael Deville, Heidi Dietz, Brigid Dineen, Nicky Dunleavey, Barbara Edwards, Hania Elkington, Freda Fan, Marilyn Feldhaus, Charlotte Fisher, Lucinda Fisher, Kevin Flebotte, Vincent Florack, Merritt Fog, Sue Frazer, Hollee Freeman, Amy Fiske, Maggi Fridman, Toby Fried, Shelagh Gamble, Beatrice Garnett, Laura Garzon, Gail Genzlinger, Brent Genzlinger, Peter Gerard, Sophie Gerard, Julie Gill, Kelly Goodwin, Merey Grearson, Staphanie Gregory, David Gross, Lana Gulden, Niko Gurda, Tim Hadsel-Mares, Catherine Harrison, Zoe Hart, Alan Hickenbottom, Beth Hiatt, Lindsay Hirsch, Caroline Hirtzberger, Kate Hodgson, Faith Hoffman, Jenny Holen, Anna Hollingsworth, John Horan, Brie Huidt, Amanda Jacksha, Lynn Jimenez, Jessica Jorgensen, Therese Khan, Sharon Keeble, Sara Kienast, Marissa Kobayashi, Rachel Kohls, Haruaki Kurachi, Karlyn Langjahr, Dominique Laurie, Richard Lawson, Shaina Lemmerman, Anne-Lise Lemche, Julio Lopez, Susan Luba, Terri Ludkowski, Chris Lunt, Anthony Lusk, Payal Luthra, Anna MacPherson, Michela

APPENDIX K. - *Continued*Earthwatch Institute Team Members, 1996-1999 – Continued

Mantani, Catherine Martens, Edward Martens, Elaine Massie, Robyn Matteson, David Mayer, Brad McHugh, Jeff Measamer, Maureen Mercury, Cathy Mohns, Ellen Nagel, Chris Napierski, Donna Naylor-Hansel, Moray Neame, Cytia Nevinson, Ben Ochstein, Jordan Okie, Salie Olson, Jamina Oomen, Marcus Orth, Noriko Oshima, Jay Patel, Nimishaben Patel, Kathryn Parkin, Lucy Patterson, Jenny Peltier, Helen Porter, Stephen Poss, Sara Ratzel, Alice Redwood, Helen Reeve-Johnson, Robynne Reeve-Johnson, Sarah Rentch, David Richardson, Aaron Roberts, Josh Rosen, Sharona Rowe, Ghazaleh Samandari, Monika Sarkar, Cheri Roe Schroder, Rachel Sevy, Amy Simon, Ryan Smith, Erica Snider, Samantha Sonnak, Desree Sowers, Thavalinh Sphabmixay, Rebecca Stang, Kate Stockdale, Bear St. Clair, Anne Steele, Laura Swartz, Gretchen Steidle, Dave Stephenson, Ellie Stewart, Alexandra Stirling, Molly St. George, Janet Sullivan, Louise Taylor, Jacob Teske, Mary Thorton, Megan Turner, Richard Timm, Pat Todd, Thomas Unger, Camila Valdes, Ryan Walther, Krista Ward, Elizabeth Werner, Shawn Wilder, Cassandra Williams, Julie Wood, Noy Xayaseng, and Lucy Yarnell.

Staff and Visiting Scholars, 1996-1999

Anna Barragan, Lulu Bartley, Lynne Barre, Marcos Blanco, Steve Collins, Scott Eckert, Lori Cragin, Kira Fuchs, Tony Galvan, Jenny Gilmore, Arturo Juarez, Sergio Juarez,

APPENDIX K. - *Continued*

Staff and Visiting Scholars, 1996-1999 - *Continued*

Lore Juarez, Brian Joder, Greg Joder, Sandra Lanham, Anthony Lusk, Jon Nelson, Dana Nichols, Jamina Oomen, Isai Pacheco Ruiz, Frank Paladino, Martin Pepper, Stephanie Presti, Robert Redecker, Antonio Resendiz, Betty Resendiz, Wendy Rice, Mauro Rosini, Patty Rosini, Francisco Savin, Javier Savin, Marta Savin, Cecil Schwalbe, Antonio Sepulveda, William Shaw, Travis Smith, Bob Snodgrass, Scott Snider, Yoshio Suzuki, Pat Thunder, Donald A. Thomson, and Lucy Yarnell.

Logistical Support Staff

Wizzy Bartley, Heather Bruce, Emmett M. Dodge, Kate Goldhammer, Mike Kelley, Greg Marshall, Jon Mount, Angelica Narvaez, Ashley Roberston-Hay, Rebecca Rowe, Wes Shaw, Marie Studer, Linda Wallace-Grey, Kathy White.

APPENDIX L. LIST OF SUPPORTING INSTITUTIONS FOR THIS RESEARCH PROJECT

American Museum of Natural History Lerner-Gray Foundation

Annual Sea Turtle Symposium

Chelonian Research Foundation

Coastal Conservation Foundation

Earthwatch Institute

Greenspace Productions

I.B.M., Inc.

National Geographic Society - Natural History Division

National Geographic Television

N.E.C., Inc.

One World Work Force

P.A.D.I. Foundation

Patagonia, Inc.

United States Fish and Wildlife Service

University of Arizona

Wallace Research Foundation

APPENDIX M. UNIVERSITY OF ARIZONA ANIMAL SUBJECTS RESEARCH
APPROVAL FORMS

*The University of Arizona
Institutional Animal Care & Use Committee
certifies that*

Jeffrey Feminoff
has on this date

May 31, 1998

*successfully completed the required
certification program on*

Law & Regulations

E. Sanders

Fusan Wilson-Sanders

Director

University Animal Care

APPENDIX M. – *Continued*Institutional Animal Care
Use Committee

THE UNIVERSITY OF
ARIZONA
 TUCSON, ARIZONA

Tucson, Arizona 85724

Verification of Review
 By The Institutional Animal Care and Use Committee (IACUC)

Final Approval Granted

PHS Assurance No. A-3248-01 – USDA No. 86-3

TITLE: PROTOCOL CONTROL #97-077

"Movement and Conservation Genetics of the Black Sea Turtle
 (Chelonia Mydas Agassizii) In the Gulf of California"

PRINCIPAL INVESTIGATOR/DEPARTMENT:

Jeffrey A. Seminoff & Wallace J. Nichols - SRNR - Wildlife Ecology

SUBMISSION DATE: June 2, 1997

APPROVAL DATE: July 8, 1997

GRANTING AGENCY:

Wallace Genetic Foundation, PADI Foundation, Earthwatch

The University of Arizona Institutional Animal Care and Use Committee reviews all sections of proposals relating to animal care and use. The above named proposal has been granted Final Approval according to the review policies of the IACUC.

NOTES:

- *** Full approval of this control number is valid through*: July 7, 2000
- * When projects or grant periods extend past the above noted expiration date, the Principal Investigator will submit a new protocol proposal for full review. Following IACUC review, a new Protocol Control Number and Expiration Date will be assigned.
- *** Continued approval for this project was confirmed: July 15, 1997
- *** Revisions (if any), are listed below:



Michael A. Cusanovich, Ph.D.
 Vice President for Research

DATE: July 15, 1997

APPENDIX N. 1999 MEXICAN RESEARCH PERMITS

DAN-02701 La Secretaría de Relaciones Exteriores saluda atentamente a la Embajada de los Estados Unidos de América y tiene el honor de hacer referencia a sus notas 0166 del 11 de enero, 574 del 19 de marzo y 1032 del 15 de junio del año en curso, con las que solicitó el permiso necesario para que los Señores Wallace J. Nichols y Jeffrey A. Seminoff de la *University of Arizona*, puedan realizar actividades científicas en jurisdicción nacional, del 15 de junio de 1999 al 31 de diciembre del año 2003.

La Secretaría comunica a la Embajada que el Gobierno de México concede el permiso de referencia sujeto a las siguientes condiciones:

1. El permiso es personal e intransferible y sólo podrá ser usado por los Señores Wallace J. Nichols y Jeffrey A. Seminoff de la *University of Arizona*.
2. El permiso es válido para el periodo comprendido del 15 de junio de 1999 al 14 de junio del año 2000.
3. El permiso se concede con la finalidad de llevar a cabo actividades científicas sobre Tortuga Prieta (*Chelonia agassizi*).
4. El área geográfica autorizada para el desarrollo de los trabajos científicos mencionados, queda confinada a los sitios del Golfo de California y del Pacífico Mexicano, especificados en el permiso de pesca de fomento adjunto número 280499.213.03 1565 del 1 de julio de 1999, expedido por la Dirección General de Administración de Pesquerías de la Secretaría de Medio Ambiente, Recursos Naturales y Pesca (SEMARNAP).

A la Embajada de los Estados
Unidos de América

APPENDIX N. – *Continued*

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5. Participarán durante el periodo citado en la cláusula dos de esta nota diplomática, el Oceanógrafo Antonio Reséndiz del Centro Regional de Investigación Pesquera (CRIP) del Instituto Nacional de la Pesca (INP), ubicado en Ensenada, Baja California, así como los Biólogos Manuel Garduño y Laura Sarti del INP.

5. Los titulares del permiso podrán colocar marcas sónicas, transmisores y radiotransmisores a las tortugas para estudiar sus movimientos. Asimismo, utilizar las frecuencias de operación para Radionavegación por Satélite 149.925 y 149.950 Mhz., con potencia máxima de emisión de 0.1 Watt; 156.800 para Llamada, Socorro y Seguridad, 156.050 y 156.300 Mhz., para Servicio Móvil Marítimo con potencia máxima de emisión de 5 Watts.

7. Los titulares del permiso deberán sujetarse a las demás condiciones y obligaciones contenidas en el permiso de pesca de fomento referido en la cláusula cuatro de esta nota diplomática.

8. Los titulares del permiso contraen la obligación de enviar a esta Secretaría por la vía diplomática, informes trimestrales en idioma español; el informe final en idioma español antes del 15 de septiembre del año 2000, el cual deberá incluir la descripción detallada de las actividades realizadas, las fechas en que se llevaron a cabo y la ubicación de los lugares de estudio, los resultados obtenidos, la metodología utilizada, la problemática del área trabajada, las conclusiones de la investigación y, si los hubiere, los cambios en el propósito original de la misma. Igualmente, deberán adjuntar las fotografías, las videograbaciones, las publicaciones y cualquier otro documento que se genere como consecuencia del presente permiso. También, deberán precisar el sitio en el que se concentrará la información y los materiales obtenidos y deberá brindar, si así se solicita, la asistencia para su interpretación.

APPENDIX N. – *Continued*

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9. No podrán efectuarse actividades que no se especifiquen en el presente permiso. El incumplimiento de los términos de la autorización será causa suficiente para su cancelación y para que, en lo sucesivo, no se concedan permisos de investigación a los señores Wallace J. Nichols y Jeffrey A. Seminoff, así como a la *University of Arizona*, además de que quedarán sujetos a la aplicación de las sanciones señaladas en la legislación nacional sobre la materia.

10. En caso de que surgiera algún cambio imprevisto en la investigación que se autoriza, éste deberá ser comunicado oportunamente a la Secretaría de Relaciones Exteriores.

11. Los titulares de esta autorización y los extranjeros que los acompañen deberán realizar los trámites migratorios correspondientes en la Delegación del Instituto Nacional de Migración de la Secretaría de Gobernación, más cercana al área en la cual los Señores Nichols y Seminoff efectuarán los trabajos científicos indicados en la cláusula tres de esta nota diplomática.

Por otra parte, la Secretaría agradecerá a la Embajada remitir las videograbaciones de la telemetría sónica, radial y satelital que efectuaron los Señores Nichols y Seminoff del 23 de junio al 31 de diciembre de 1998.

La Secretaría de Relaciones Exteriores aprovecha la oportunidad para renovar a la Embajada de los Estados Unidos de América el testimonio de su más alta consideración.



México D.F., 19 de julio de 1999.

APPENDIX N. – *Continued*

SECRETARÍA DE MEDIO AMBIENTE,
RECURSOS NATURALES Y PESCA

PERMISO DE PESCA DE FOMENTO No. 230499 213 03

FACULTA: MONITOREO Y MUESTREO PARA DESARROLLAR
UN ESTUDIO SOBRE LA TORTUGA PRIETA
(*Chelonia agassizi*) EN AGUAS DEL GOLFO DE
CALIFORNIA Y LA COSTA OESTE DE LA PENINSULA
DE BAJA CALIFORNIA.

ZONA: BAHIA DE LOS ANGELES, BAJA CALIFORNIA;
BAHIA KINO, SONORA; LORETO Y PUERTO SAN
CARLOS DE LA BAHIA MAGDALENA EN BAJA
CALIFORNIA SUR.

VIGENCIA: DEL 15 DE JUNIO DE 1999 AL 14 DE JUNIO DEL AÑO
2000

MEXICO, D.F.A. 01 JUN 1999

WALLACE J. NICHOLS Y JEFFREY A. SEMINOFF
SCHOOL OF RENEVABLE NATURAL RESOURCES
THE UNIVERSITY OF ARIZONA
325 BIOLOGICAL SCIENCES EAST BUILDING
TUCSON, ARIZONA 85721
E.U.A.

ME REFIERO A LAS GESTIONES REALIZADAS ANTE ESTA SECRETARIA, PARA OBTENER PERMISO DE PESCA DE FOMENTO, A FIN DE CONTINUAR LAS ACCIONES DE INVESTIGACION SOBRE LA TORTUGA PRIETA (*Chelonia agassizi*) EN AGUAS DEL GOLFO DE CALIFORNIA Y LA COSTA OESTE DE LA PENINSULA DE BAJA CALIFORNIA.

AL RESPECTO, COMUNICO A USTED QUE DE ACUERDO CON LA OPINION TECNICA DEL INSTITUTO NACIONAL DE LA PESCA, EMITIDA MEDIANTE OFICIO No. 0815 DE FECHA 6 DE ABRIL DE 1999 Y, CON FUNDAMENTO EN LO DISPUESTO EN LOS ARTICULOS 1o., 2o., 4o., 11o. Y 12 DE LA LEY DE PESCA; 3o., 5o. FRACCION I, 7o., FRACCION I, 9o., 10o., 11o., 12, 13, 14, 15 Y 16 DE SU REGLAMENTO; ARTICULO 24, FRACCION VI DEL REGLAMENTO INTERIOR DE LA SECRETARIA DE MEDIO AMBIENTE, RECURSOS NATURALES Y PESCA Y 194-F INCISO B DE LA LEY FEDERAL DE DERECHOS, ASI COMO EN EL ARTICULO 32 BIS., FRACCION XXXIX DE LA LEY ORGANICA DE LA ADMINISTRACION PUBLICA FEDERAL, ESTA DIRECCION GENERAL DE ADMINISTRACION DE PESQUERIAS LE CONCEDE PERMISO DE PESCA DE FOMENTO, SUJETO A LA OBSERVANCIA Y CUMPLIMIENTO DE LOS SIGUIENTES TERMINOS Y CONDICIONES:

1a. EL PRINCIPAL OBJETIVO DEL PERMISO ES CONTINUAR EL ESTUDIO DE LAS AREAS DE ALIMENTACION Y MOVILIZACION DE LA TORTUGA PRIETA (*Chelonia agassizi*), EN EL GOLFO DE CALIFORNIA Y LA COSTA OESTE DE LA PENINSULA DE BAJA CALIFORNIA, ESPECIFICAMENTE EN LAS ZONAS DE BAHIA DE LOS ANGELES, BAJA CALIFORNIA; BAHIA KINO, SONORA Y; LORETO Y PUERTO SAN CARLOS DE LA BAHIA MAGDALENA EN BAJA CALIFORNIA SUR, PARA INCREMENTAR EL CONOCIMIENTO CIENTIFICO SOBRE LA BIOLOGIA DE ESTA ESPECIE, Y AYUDAR EN LOS ESFUERZOS DE CONSERVACION QUE MEXICO REALIZA, ASI COMO APORTAR INFORMACION SOBRE AREAS DE FORRAJEAO DE ESTA ESPECIE.

APPENDIX N. – *Continued*

SECRETARIA DE MEDIO AMBIENTE
RECURSOS NATURALES Y PESCA

7a. QUEDA PROHIBIDO EL USO DE REDES DE ARRASTRE EN BAHIAS INTERNAS, ESTEROS Y EN AGUAS EN DONDE EXISTAN ESPECIES SEDENTARIAS.

8a. EL TITULAR DEL PERMISO QUEDA OBLIGADO A:

A) INFORMAR A LAS DELEGACIONES FEDERALES DE ESTA SECRETARIA EN BAJA CALIFORNIA, BAJA CALIFORNIA SUR Y SONORA DEL INICIO DE SUS ACTIVIDADES. PUDIENDOSE CONTACTAR CON DICHAS REPRESENTACIONES FEDERALES A LOS SIGUIENTES TELEFONOS Y NUMEROS DE FAX.

DELEGACION FEDERAL EN BAJA CALIFORNIA (TEL. 01 (65)534586, FAX 524998)

DELEGACION FEDERAL EN BAJA CALIFORNIA SUR (TEL 01 (112) 24414, FAX. 54945).

DELEGACION FEDERAL EN SONORA (TEL 01(62) 135273, FAX 135259).

B) LLEVAR EL ORIGINAL DE ESTE PERMISO EN TODAS LAS ACTIVIDADES DE CAMPO Y MOSTRARLO A LAS AUTORIDADES COMPETENTES QUE LO SOLICITEN.

C) REMITIR A ESTA DIRECCION GENERAL LOS INFORMES TRIMESTRALES DE LAS ACTIVIDADES DESARROLLADAS Y DE SUS RESULTADOS. DE LA MISMA FORMA DEBERA ENVIAR COPIA DE LOS RESULTADOS FINALES GENERADOS AL AMPARO DE ESTE PERMISO A MAS TARDAR EL 15 DE SEPTIEMBRE DEL AÑO 2000.

8a. OBTENER EL PERMISO MIGRATORIO DE LA DIRECCION DE NO INMIGRANTES DE LA DIRECCION GENERAL DE SERVICIOS MIGRATORIOS DE LA SECRETARIA DE GOBERNACION; ASIMISMO, DEBERAN OBTENER DICHO PERMISO LOS INVESTIGADORES PARTICIPANTES QUE SEAN EXTRANJEROS .

9a. ESTE PERMISO SE CONCEDE SIN PERJUICIO DE LOS PERMISOS O AUTORIZACIONES QUE REQUIERAN DE OTRAS AUTORIDADES COMPETENTES.

10a. LOS DOCUMENTOS NACIONALES O EXTRANJEROS QUE SE PUBLIQUEN COMO RESULTADO DE LAS ACTIVIDADES REALIZADAS, DEBERAN HACER REFERENCIA AL NUMERO DEL PERMISO CORRESPONDIENTE OTORGADO POR ESTA DEPENDENCIA.

11a. INFORMAR A ESTA DIRECCION GENERAL DE ADMINISTRACION DE PESQUERIAS SOBRE EL USO DEL PERMISO .

EN CASO DE QUE ESTE NO SEA USADO, EL BENEFICIARIO CONTRAE LA OBLIGACION DE INFORMAR SOBRE ESTA SITUACION EN UN PLAZO NO MAYOR DE 15 DIAS CONTADOS A PARTIR DE LA FECHA EN LA QUE INICIE LA VIGENCIA DE ESTE PERMISO Y SE DEBERA REMITIR A ESTA DEPENDENCIA. SITA EN PERIFERICO SUR No. 4209, 4o. PISO .

APPENDIX N. – *Continued*

SECRETARÍA DE MEDIO AMBIENTE
RECURSOS NATURALES Y PESCA

PARA COORDINAR LA PARTICIPACION DE LOS INVESTIGADORES MEXICANOS LOS PERMISIONARIOS DEBERAN PONERSE EN CONTACTO CON PERSONAL DEL INSTITUTO NACIONAL DE LA PESCA (TELEFONO Y FAX 604-48-87).

5a. LA ZONA DE MUESTREO AUTORIZADA SERA: LAS AGUAS DE JURISDICCION FEDERAL DE BAHIA DE LOS ANGELES, BAJA CALIFORNIA; BAHIA KINO, SONORA; LORETO Y LAS DE LA BAHIA MAGDALENA UBICADAS EN LAS INMEDIACIONES DE PUERTO SAN CARLOS EN BAJA CALIFORNIA SUR.

6a. ESTE PERMISO AUTORIZA LA REALIZACION DE LAS SIGUIENTES ACTIVIDADES:

A. EFECTUAR RECORRIDOS POR PLAYA EN BUSCA DE TORTUGAS VARADAS A LAS CUALES SE LES TOMARAN DATOS MORFOMETRICOS. SE DETERMINARA LA ESPECIE Y LA POSIBLE CAUSA DE MUERTE. PARA LO CUAL SE TOMARAN MUESTRAS DE TEJIDO, DEPENDIENDO DEL ESTADO DE DESCOMPOSICION DE LA TORTUGA.

B. UTILIZAR REDES ESPECIALES CON DIMENSIONES DE 100 MTS. POR 8 MTS. DE LONGITUD Y ABERTURA DE LUZ DE MALLA DE 60 CMS. PARA LA CAPTURA DE LAS TORTUGAS. LAS REDES DEBERAN SER MONITOREADAS CADA 15-30 MINUTOS. PARA EVITAR EL AHOGAMIENTO DE LAS TORTUGAS ENMALLADAS. LOS EJEMPLARES CAPTURADOS SE LIBERARAN EN EL SITIO EN QUE FUERON CAPTURADOS.

C. REGISTRAR LAS CARACTERISTICAS MORFOMETRICAS DE LAS TORTUGAS CAPTURADAS. TALES COMO TALLA, COLOR, PRESENCIA DE ANOMALIAS EXTERNAS, PRESENCIA DE EPIBIONTES, MARCAS, ETC.

D. APLICAR UNA MARCA MONEL EN EL BORDE MARGINAL DE LAS ALETAS ANTERIORES EN LAS TORTUGAS QUE NO CUENTAN CON UNA MARCA

E. OBTENER 100 MUESTRAS DE TEJIDO Y SANGRE PARA ESTUDIOS GENETICOS.

F. COLECTAR MUESTRAS DE CONTENIDO ESTOMACAL PARA SU POSTERIOR SEPARACION, DETERMINACION Y ANALISIS. A TRAVES DE LA OBSERVACION DE LA BOCA Y LAVADOS ESTOMACALES.

G. COLOCAR VIDEOCAMARAS A 6 TORTUGAS. PARA LO CUAL SE EMPLEARA PEGAMENTO EPOXICO.

H. COLECTAR MUESTRAS DE TEJIDO DE CAPARAZON PARA ESTUDIOS DE PRESENCIA DE METALES PESADOS.

I. COLOCAR MARCAS SONICAS Y RADIOTRANSMISORES A DOCE TORTUGAS CON LO CUAL SE PODRAN ESTUDIAR MOVIMIENTOS LOCALES. LOS RADIOS SERAN COLOCADOS A LAS TORTUGAS USANDO PEGAMENTO EPOXICO. ASI COMO PERFORACIONES EN EL BORDE MARGINAL DEL CAPARAZON Y ABRAZADERAS PLASTICAS.

J. COLOCAR TRANSMISORES DE SATELITE A SEIS TORTUGAS PARA ESTUDIOS DE MOVIMIENTOS DE LARGA DISTANCIA.

APPENDIX N. – *Continued*

SECRETARÍA DE MEDIO AMBIENTE
RECURSOS NATURALES Y PESCA

LOS OBJETIVOS ESPECIFICOS DEL PROYECTO SON:

- A) COLECTAR Y ANALIZAR 100 MUESTRAS GENÉTICAS DE TORTUGA PRIETA EN BAHIA DE LOS ANGELES, BAJA CALIFORNIA ASI COMO DE OTRAS AREAS DE ALIMENTACION. USANDO TÉCNICAS DE ANALISIS DE DNA.
- B) OBTENER DATOS MORFOMETRICOS DE CADA TORTUGA MUESTREADA.
- C) COLOCAR AL MENOS 8 MARCAS DE SATELITE SOBRE LAS TORTUGAS MARINAS A LO LARGO DE LA COSTA DE BAJA CALIFORNIA.
- D) COLOCAR 10 ETIQUETAS RADIOSONICAS SOBRE TORTUGAS PRIETAS DENTRO DE LAS AREAS DE ESTUDIO DE BAHIA DE LOS ANGELES Y SAN CARLOS.
- E) COLECTAR 50 MUESTRAS DE TEJIDO DE CAPARAZON PARA EL ANALISIS DE CONTAMINACION POR METALES PESADOS EN BAHIA DE LOS ANGELES, LORETO Y SAN CARLOS
- F) COLOCAR TEMPORALMENTE CAMAPAS SUMERGIBLES EN LOS CAPARAZONES DE 10 TORTUGAS MARINAS EN EL AREA DE ESTUDIO DE BAHIA DE LOS ANGELES.

2a. LA VIGENCIA DE ESTE PERMISO COMPRENDERA DEL 15 DE JUNIO DE 1999 AL 14 DE JUNIO DEL AÑO 2000.

LO ANTERIOR, SIN PERJUICIO DE QUE LOS INTERESADOS PRESENTEN SOLICITUDES DE PERMISO ANUALES HASTA COMPLEMENTAR EL PROYECTO. DICHAS SOLICITUDES DEBERAN HACERSE DEL CONOCIMIENTO DE ESTA DIRECCION GENERAL POR LOS CANALES DIPLOMATICOS CONDUCENTES, TRES MESES ANTES DE LA FECHA EN QUE SE DESEA CONTINUAR LA INVESTIGACION. ASI TAMBIEN, DEBERA ADJUNTARSE A LA NUEVA SOLICITUD EL INFORME DE RESULTADOS ALCANZADOS AL AMPARO DEL PRESENTE PERMISO.

3a. EL PERMISO SE OTORGA CON CARACTER DE INTRANSFERIBLE A LOS SRES . WALLACE J. NICHOLS Y JEFFREY A. SEMINOFF, DE LA ESCUELA DE RECURSOS RENOVABLES DE LA UNIVERSIDAD DE ARIZONA EN TUCSON, ESTADOS UNIDOS DE AMERICA

4a. EL PERMISO QUEDA CONDICIONADO A LA PARTICIPACION DE TRES INVESTIGADORES DEL INSTITUTO NACIONAL DE LA PESCA POR LO QUE LOS TITULARES DEL PERMISO DEBERAN PRESTAR LOS APOYOS NECESARIOS.

EL CITADO INSTITUTO SUGIERE QUE EL OCEANOLOGO ANTONIO RESENDIZ, INVESTIGADOR DEL CRIP-ENSENADA PARTICIPE EN LAS ACTIVIDADES DE CAMPO A REALIZARSE EN BAHIA DE LOS ANGELES; ASI TAMBIEN, PROPONE A LOS CC. BIOLOGOS LAURA SARTI Y MANUEL GARDUÑO PARA PARTICIPAR EN LAS ACTIVIDADES DE INVESTIGACION QUE SE DESARROLLARAN EN BAHIA KINO Y BAHIA SAN CARLOS, RESPECTIVAMENTE.

APPENDIX N. - *Continued*

SECRETARÍA DE MEDIO AMBIENTE
RECURSOS NATURALES Y PESCA

FRACCIONAMIENTO JARDINES EN LA MONTAÑA. DELEGACION TLALPAN. C P 14210. MEXICO D.F.. EL ORIGINAL PARA SU CANCELACION.

SUFRAGIO EFECTIVO. NO REELECCION
EL DIRECTOR GENERAL DE
ADMINISTRACION DE PESQUERIAS

DR. JERONIMO RAMOS SAENZ PARDO.

SECRETARIA DE MEDIO AMBIENTE
RECURSOS NATURALES Y PESCA
INSTITUTO NACIONAL DE PESQUERIAS

★ JUL 1991 ★

CORRESPONDENCIA
DESDECHADO

- C.C. P. LIC. CARLOS CAMACHO GAOS. SUBSECRETARIO DE PESCA.
- DR. ANTONIO DIAZ DE LEON CORRAL. PRESIDENTE DEL INSTITUTO NACIONAL DE LA PESCA.
- M en C. OSCAR M. RAMIREZ FLORES. DIRECTOR GENERAL DE INVESTIGACION EN PROCESOS PARA EL DESARROLLO SUSTENTABLE. INSTITUTO NACIONAL DE LA PESCA.
- DR. FELIPE RAMIREZ RUIZ DE VELASCO. DIRECTOR GENERAL DE VIDA SILVESTRE. INST. TUTO NACIONAL DE ECOLOGIA.
- LIC. MARA MURILLO CORREA. DIRECTORA GENERAL DE POLITICA Y FOMENTO PESQUERO.
- M. EN C. LUIS FUEYO MACDONALD. DIRECTOR GENERAL DE INSPECCION VIGILANCIA DE LOS RECURSOS PESQUEROS Y MARINOS DE LA PROFEPA PERIFERICO SUR 5000. COL. INSURGENTES. CUIQUILCO, MEXICO. D.F..
- LIC. HUGO ABEL CASTRO BOJORQUEZ. DELEGADO FEDERAL DE LA SEMARNAP EN BAJA CALIFORNIA..
- LIC. CARLOS FERNANDO ACEVES GARCIA. DELEGADO FEDERAL DE LA SEMARNAP BAJA CALIFORNIA SUR.
- LIC. JUAN CARLOS RUIZ RUBIO. DELEGADO FEDERAL DE LA SEMARNAP EN SONORA.
- SECRETARIA DE GOBERNACION. SUBDIRECCION DE NO INMIGRANTES. DIRECCION GENERAL DE SERVICIOS MIGRATORIOS.-ALBAÑILES No. 19 ESQUINA EDUARDO MOLINA COL. PENITENCIARIA C.P. 15280 MEXICO. D.F.
- SECRETARIA DE RELACIONES EXTERIORES.-DIRECCION GENERAL PARA AMERICA DEL NORTE.- RICARDO FLORES MAGON No. 1. NONOALCO-TLATELOLCO. MEXICO. D.F.06995

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