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Western pond turtle (Clemmys marmorata pallida) nesting behavior and habitat use

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WESTERN POND TURTLE (*Clemmys marmorata pallida*)

NESTING BEHAVIOR AND HABITAT USE

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ABSTRACT

WESTERN POND TURTLE (*Clemmys marmorata pallida*)

NESTING BEHAVIOR AND HABITAT USE

by Donald E. Crump, Jr.

Sixteen adult female western pond turtles in a California coastal stream and permanent pond were radio-tagged and monitored for movement associated with nesting for one to three years during the summers of 1996, 1997 and 1998. A minimum of ten (61%) of the turtles were gravid at least once during the study, and nc evidence of double clutching was observed. Nest site fidelity was found in three turtles monitored in 1996 and 1997. Three turtles explored two different nesting areas in a single nesting season. Observed nesting habitat occurred primarily in agricultural fields and a single horse pasture. Most upland activities began between 1205-1800 hours and lasted until at least the following day. All of the major age classes were present in the population, but certain practices, such as plowing and irrigation, may threaten nests. Therefore, most of the management efforts should focus on the agricultural fields and horse pasture.

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Introduction

The western pond turtle (*Clemmys marmorata*) is a freshwater turtle native to the pacific coast of North America. There are two subspecies, the northwestern pond turtle (*C. m. marmorata*) and the southwestern pond turtle (*C. m. pallida*), with the designation supported by morphological and genetic evidence (Gray 1995). The northwestern pond turtle range includes the western portions of Washington and Oregon and Northern California. The southwestern pond turtle ranges from central and southern California to the northwest portion of Baja California. The San Francisco Bay is the coastal boundary between these two populations (Stebbins, 1985). Holland (1994) concluded that there is considerable mixing of these two subspecies in the central portion of California.

Currently, both subspecies are in decline throughout their range. Elimination, alteration and disturbance of western pond turtle populations and their critical habitat have been the primary cause of this decline (Jennings et al. 1991). In 1991, biologists drafted a petition to place the western pond turtle on the federal threatened and endangered species list (Jennings et al. 1991). This petition was denied by the United States Fish and Wildlife Service due to insufficient knowledge of the biology of this turtle.

Despite the decline of western pond turtles, the nesting ecology and nesting requirements are not well understood. There have been few nesting studies on this turtle compared to the amount of research on the four eastern species in the genus *Clemmys*. This study focuses on nesting frequency, timing and habitat use of a coastal population of southwestern pond turtles near the northern part of its range (Santa Cruz County). Most turtle studies focus on aquatic habitat and the riparian corridor. However, knowledge of nesting requirements is necessary for management, since upland nesting habitats may be the most vulnerable habitats at many sites.

There is substantial variation in basic reproductive parameters within and between different western pond turtle populations (Holland 1994). Some individuals in central and southern California nest every year and some produce multiple clutches within a single nesting season. Other individuals nest every other year or possibly every third year. Factors that may affect whether or not a female is gravid in a given season are available food supply, seasonal temperature, age, size and weight of the animal and location in the range. Some individuals exhibit nest site philopatry or the tendency to return to the same site to nest. This pattern can exist in annual, biannual and even triennial nesting.

The smallest recorded reproductive western pond turtle female was from southern California and had a carapace length of 111 mm and was presumably 6-7 years old (Holland 1994). Most females become reproductive by 120 mm and 8-10 years of age. In the northern part of the western pond turtle range, the smallest reproductive individual was 131 mm.

Oviposition dates in western pond turtles range from late April to early August. Most turtles produce shelled eggs in June and July (Holland 1994). There is often considerable variation in timing of nesting in a given season for a single population. Timing of the onset of nesting can also vary considerably from season to season. Variation in seasonal temperatures and water levels most likely account for these differences (Holland 1994). There is some indirect evidence of large-scale synchronous nesting of northwestern pond turtles in the Willamette Valley of Oregon. Three turtles were found nesting in the same general area at the same time (Holland 1994). Holland (1994) found a group of nests excavated by predators that contained eggs deposited within a day of each other. No direct evidence of large-scale synchronous or colony nesting has been found for western pond turtles.

Female turtles exhibit some variation in their upland nesting movements. Some individuals make multiple explorations or "walkabouts" to the same location with the last walkabout resulting in a nest (Rathbun et al. 1992). Others make multiple walkabouts to different locations with the last walkabout resulting in a nest. Aquatic movements also vary as some turtles make a direct and rapid movement to their nesting areas while others move slowly and indirectly toward their nesting areas. Age of the individual and the number of prior successful nesting attempts in past years may account for these differences. The distance female turtles will travel to reach their nesting grounds varies. The maximum distance traveled by a female turtle during the nesting season in one study was 1550 meters (Bury 1972). Rathbun et al. (1993) reported similar distances for two female turtles.

Nesting by gravid southwestern pond turtles often takes place far above the banks of the stream or pond in which the turtle resides. Holland (1994) reported distances ranging from one to 402 meters from the nearest water source. Females are potentially at risk from predation during these upland nesting forays. Several factors, or combination of factors, may contribute to female turtles making such long, risky journeys. They are: 1) the presence of warmer south-facing slopes outside the riparian corridor; 2) selection of thermal sites as part of the life-history of a species with temperature-determined sex;

3) nesting above the floodplain of the stream; and 4) spacing of nests to avoid detection by egg predators (Rathbun et al. 1993).

Female turtles most often leave the water during afternoon and early evening hours to begin exploring nesting areas and/or to nest, but early morning explorations are also common (Holland 1994). Rathbun et al. (1992) reported that six females began their nesting walkabouts between 1600 and 1800 hours, while two females engaged in nesting forays between 0800 and 1000 hours. Rain also appeared to be the environmental cue that triggered upland nesting walkabouts in eastern mud turtles (*Kinosternon subrubrum*), according to Burke et al. (1994). Rain preceded the upland nesting movements of three northwestern pond turtles in the Columbia Gorge in Washington (Holland 1994). It rarely rains during the breeding season of the southwestern pond turtle, so clearly other cue(s) are involved.

Female pond turtles occasionally remain upland for more than a single day. It is not clear whether this is a normal behavior or a result of observer disturbance during the nesting walkabouts. Prolonged upland stays also occur for two species of mud turtles (*Kinosternon*) and for Blanding's turtles (*Emydoidea blandingi*) (Holland 1994). Female turtles are wary during their nesting walkabouts. They are alert and continuously survey their surroundings while they are moving and while they are resting. If a nesting turtle is disturbed it may remain upland for a prolonged period of time, or quickly return to the water and attempt another walkabout at a later date. This second walkabout may take place at a different nesting ground (Holland 1994). This shift might be an important anti-predator response to the disturbance.

Adult, egg and hatchling predation is common in many populations of western pond turtles (Holland 1994). Adults may exhibit their alert and wary behavior to protect themselves and/or their nests from predation. Egg predation is believed to take place within the first forty-eight hours of the nesting effort (Holland 1994). Known predators of western pond turtles include raccoon (*Procyon lotor*), spotted skunk (*Spilogale putorius*) and coyote (*Canis latrans*). Suspected predators include crow (*Corvus brachyrhynchos*), raven (*Corvus corax*), opossum (*Didelphis virginianus*), fox (*Vulpes fulva, Urocyon cinereoargenteus*) and various species of snakes (*Lampropeltus getulus, L. zonata, Pituophis melanoleucus* and *Coluber constrictor*). Rodents such as the gopher (*Thomomys* spp.) as well as mice and voles may be potential egg predators (Holland 1994).

Study Area

The study area was a coastal watershed located about 80 km south of San Francisco, CA. The area includes two permanent water sources, Waddell Creek and Turtle Pond, and several seasonal water sources. The downstream portions are within Big Basin Redwoods State Park and private land (Fig. 1). The upstream portions are largely within the State Park (Fig. 2). U.S. Highway One runs through the lowest portion of the watershed at Waddell State Beach. The entire study area was approximately 238 hectares in size.

Waddell Creek runs north to south for approximately sixteen kilometers. The study area spanned the first 5.4 channel kilometers from the mouth of the stream to the confluence of the east and west forks. The first 1.1 kilometers of Waddell Creek upstream from the Highway One Bridge is subject to tidal action during high tide and usually forms a lagoon behind a partial or complete summer sandbar (Figure 1). The lagoon is bordered by marsh vegetation and by a riparian tree border of willows (*Salix* spp.), white alder (*Alnus rhombifolia*), California boxelder (*Acer negundo californicum*), and redberry elder (*Sambucus racemosa*) which begins about 0.2 km upstream. The understory of the riparian forests contains poison oak (*Toxicondendron diversiloba*), California blackberry (*Rubus vitifolius*), German ivy (*Senecio mikanoides*) and stinging nettle (*Urtica dioica*). Marsh vegetation consists primarily of cattails

(*Typha* spp.), sedges (*Carex* spp.) and rushes (*Juncus* spp.). Several open fields surround the lagoon area inland of the marsh. These fields consist primarily of non-native grasses. On the east an agricultural field borders the upstream end of the lagoon and on the west a small horse pasture. The agricultural area supported crops of pumpkins (1996-97) and irrigated lettuce (1998) during this study. The open fields contain several man-made structures, including a Nature Center run by California State Parks and private residences. Upland habitats contain chaparral species, such as coyote brush (*Baccharus pilularis*), coastal sagebrush (*Artemisia californica*), and stands of Monterey pines (*Pinus radiata*).

East of the lagoon area is Turtle Pond, a permanent pond resulting from the construction of an access road paralleling the east side of the lagoon (Figure 1). Bulrush (*Scirpus* spp.) grows throughout most of the pond with only a few areas of open water. Monterey Pines cover the hills above the pond, and a single grassy field known as Turtle Meadow lies east of the pond.

For 1.8 km upstream of the Lagoon, a riparian forest and inland agricultural fields (tomatoes, pumpkins and irrigated lettuce) border Waddell Creek (Figures 1-2). Further upstream, a coastal redwood (*Sequoia sempervirens*) forest borders the riparian forest. The coastal redwood forest also contains Douglas fir (*Pseudotsuga menziesii*), California bay (*Umbellularia californica*) and tanbark oak (*Lithocarpus densiflorus*).

Because western pond turtles use sparsely vegetated, sunlit habitats for nesting, available nesting habitat is apparently confined to grasslands and agricultural fields at Waddell Creek and Turtle Pond. The available potential nesting habitat makes up 16.2% of the total study area, with agricultural fields making up 2.5% of the total study area, or 15.4% of the available potential nesting habitat. Turtle Meadow, a sandy meadow on the southeastern corner of Turtle Pond, is approximately 0.3 hectares and makes up 0.8% of the study area. The remaining area, comprising 83% of the watershed, is densely vegetated with brushland or forest and is unsuitable for nesting.

Methods

I studied sixteen female turtles at various times during the 1997 nesting season. Twelve of these sixteen turtles were also monitored in 1996 by J. Abel and C. Davis, San Jose State University, (unpublished data) and their data are included here for comparison. Five of these turtles that had nesting activity in 1996 and/or 1997 were monitored in 1998. Four of the five turtles were monitored by J. Smith, San Jose State University, in 1999 and 2000. The data are included for comparison, where appropriate. Eleven of the sixteen turtles were captured prior to this study, and were part of earlier watershed and turtle habitat use projects (Smith et al. 1997, Davis 1998). Turtles were captured in baited hoop traps or by hand while snorkeling in Waddell Creek or Turtle Pond. The traps were roughly 1.5 meters long and had a 40-centimeter funnel-like tube on one end with 2.5-centimeter nylon mesh. Floats were placed on one end of the trap to keep it slightly above water to prevent drowning the captured turtles. The traps were baited with punctured sardine cans, which were replaced every three to four days. Four of the turtles were captured in a weir migration trap immediately upstream of the lagoon.

Since the minimum size and age of nesting turtles varies, length of captured turtles was measured with a specially designed wooden caliper. The growth rings or annuli on the plastron were counted to estimate age (Appendix A). Scotch tape was placed on the plastron and the growth rings were traced and then transferred to a record sheet to allow re-aging on recapture to confirm that the rings represented annual marks.

To identify individuals, all turtles were marked with 2-4 millimeter triangle shaped notches on different marginal scutes according to a marking system used by Smith et al. (1997). Each turtle also carried an implanted passive integrated transponder (PIT) tag, which was inserted anterior to the base of the turtle's right leg.

To track movements, turtles were fitted with radio-transmitters (manufactured by Advanced Telemetry Systems, Isanti, MN). The transmitters were attached and coated with dental acrylic stained with black copier toner. Rathbun et al. (1993) used 5-minute epoxy resin and dental acrylic to fasten the transmitters to the carapace. The use of epoxy was discontinued in this study when the resin was found to apparently contribute to shell rot under the epoxy (Smith et al. 1997, Davis 1998). The transmitters were 45 x 20 x 15 mm in size, including an internal antenna, and weighed 20 grams. Transmitter range was approximately one kilometer line-of-sight. Internal antennas have a reduced transmission range but are less likely to hang up in vegetation or be damaged. Transmitters were placed on females on the anterior portion of the carapace to prevent interference with mating.

To identify turtle locations, Waddell Creek was marked by flagging every 25 channel meters for the first 3800 meters of the stream, upstream of the Highway One Bridge. Distances were estimated further upstream to the forks (5400 m). The summer movements of female turtles were recorded throughout the study to compare pre-nesting and nesting movements. Turtle Pond was measured off, flagged stakes were installed around the pond perimeter, and then turtle positions in the pond were estimated by triangulating from these points.

The lagoon often had a bottom salt water layer which blocked transmitter signals, but, when possible, female turtles were located twice daily and location, time, general habitat and behavior were noted. The fourteen turtles in Waddell Creek were recaptured by hand and palpated to detect the presence of eggs roughly every month, but difficulty of capture prevented regular checks. The two turtles in Turtle Pond were almost never recaptured due to the thick layer of dead tules floating on most of the surface of Turtle Pond. This allowed turtles to swim under the tule mat and evade capture. When turtles emerged onto land from Waddell Creek or Turtle Pond to walkabout or nest, they were monitored extensively until they returned to the water. If possible, observations were made from a distance using a spotting scope to avoid disturbing the turtles. When no visual contact was established with an upland turtle, its position was estimated by triangulating the transmitter signal from various points around the turtle's position. The turtle's position was monitored until nightfall; transmitters automatically switched off between 21:00 and 09:00. Monitoring resumed the following morning and continued until the turtle returned to the stream or pond. The turtle was then caught and palpated as soon as possible to verify whether or not it was still gravid.

Nesting efforts were divided into five categories: certain nest, very probable nest, probable nest, possible nest and no detectable nesting activity (Table 2). A "certain" nest meant nesting was actually observed and the nest was found. A "very probable" nest meant a turtle was known to be gravid, went upland and then returned to the stream not gravid; the general location of the nest is known. A "probable" nest meant a turtle was detected upland but it was never caught and verified to be gravid at any point in the nesting season or a turtle was caught and found gravid but was never found upland; in the first case, a particular nest site is suspected, in the second case it is not. A "possible" nest meant there was only slight circumstantial evidence to suggest that a turtle nested. A turtle found upland in a new area or a turtle found near a nesting area where it nested in a previous year would be an example of a "possible" nest. A "no detectable nesting activity" nest rank referred to a turtle with no evidence of nesting. The turtle was never confirmed as gravid, never found upland, and showed a random movement pattern in the stream or pond where it spent the summer. Some or all of these turtles did not nest, but they could not be checked often enough for eggs to be certain.

Results

Fate of Nesting Turtles in Turtle Pond and Waddell Creek

Table 2 shows a detailed breakdown of every turtle monitored during the study. Nine (75%) out of the twelve turtles had detectable nesting efforts in 1996 and 8 (50%) out of sixteen turtles had detectable nesting efforts in 1997 (Table 2). Five turtles were monitored for an additional year in 1998 and three turtles (60%) had detectable nesting efforts. The high percentage of detectable nesting efforts in 1998 was likely because all five turtles had nested at least once in the previous two years. Although only three nests were found, in ten other instances the likely site of nesting was known.

Use of Nesting Macrohabitat along Waddell Creek and near Turtle Pond

All detected walkabouts and nesting attempts for the lagoon and upstream turtles were in human-altered habitats, including a pumpkin field, a tomato field, irrigated lettuce fields and a horse pasture (Table 3). Open areas of all types represented 38.3 hectares or 16.2% of the total study area. Detected nesting effort in this study was confined to 6.1 hectares of open habitat or 2.5% of the total study area. Hatchlings were found in North Pond and were probably produced by a nesting effort outside of the detectable nesting and/or open areas in this study. The nineteen walkabouts ranged from 10 to 108 m upland of the nearest water source, with a mean distance of 69 m ($\pm$7 SE).

The upland agricultural areas that turtles in this study used were found along the edge of an irrigated lettuce field between 2000 and 2800 channel meters upstream of Highway One and a tomato field between 1500 and1650 channel meters in the upstream region of Waddell Creek. They also used a field between 800 and 900 channel meters in the lagoon region, that was a dryland pumpkin field in 1996-97 and an irrigated lettuce field in 1998. A horse pasture on the western bank of the lagoon region between 800 and 900 channel meters was the most heavily used site (24% of the walkabouts and 31% of the probable nests). Two other agricultural fields, one on the western bank of the upstream region between 1700-1800 channel meters and a small field next to a residence on the eastern bank, were apparently not used by any turtle in this study. The western bank field did not have any crops in 1996 or 1997, but was used for pumpkins in 1998.

Some turtles remained throughout the year in Turtle Pond, while others overwintered there but foraged in the lagoon during summer (Davis 1998). Two radio-tagged females remained in the pond and apparently nested in Turtle Meadow at the southeast corner of the pond, or other nearby habitats in 1996 and 1997. The only evidence of possible nesting away from the meadow was the walkabout near the nature center.

Five turtles (17, 21, 61, 71 and 177) had detectable nesting efforts where the likely nest habitat was known in 1996 (Tables 2-3). Four others (15, 93, 118, 169) apparently nested at unknown locations. Six turtles (15, 18, 61, 71, 93 and 177) had detectable nesting efforts with likely nest locations known in 1997. Two others (118 and 169) may have nested at unknown locations. Three turtles (71, 93 and 177) had detectable nesting efforts with two likely nest locations known in 1998 (Table 3).

Several turtles were found upland at more than one area in a given year or in different areas in different years. Three turtles (15, 93 and 169) made walkabouts in 1997 at one location and then moved to a different nesting area to nest (Table 3). In 1997, Turtle 93 made an initial walkabout at the tomato field, then a second walkabout at the pumpkin field before returning a third time to nest at the pumpkin field. In 1998, Turtle 93 was detected at the same field, which in that year was irrigated for lettuce. This turtle may have nested at the lettuce field or at another location. Turtle 118 did a walkabout at the horse pasture in 1996 and returned to the stream gravid. It then made three walkabouts, without nesting, during movement to and from a site almost at the forks (5050m). The location of its later probable nesting is unknown. Turtle 169 made a walkabout into the southwestern portion of the open field below the nature center in 1997, but returned to the pond gravid. Turtle 169 was not gravid when recaptured in August 1997, so its nest location remained unknown. In 1997, Turtle 15 conducted a walkabout in the pumpkin field and then apparently nested in the horse pasture two days later. Turtle 169 made walkabouts at Turtle Meadow in both 1996 and 1997 and a separate walkabout at the nature center in 1997. Turtle 61 nested in Turtle Meadow in 1996 and apparently nested in Turtle Meadow in 1997.

Other turtles apparently did not explore alternate sites. Turtle 177 moved downstream to nest in the upstream tomato field in 1996, 1997 and 1998. Turtle 17 was upland and probably nested in the pumpkin field at the upstream end of the lagoon in 1996. Turtle 18 was upland and probably nested in the pumpkin field in 1997, and was in the lagoon near the pumpkin field in 1996, but was never detected upland. It may have nested undetected. Turtle 71 nested in the horse pasture in the lagoon region in 1996, and apparently also nested in the horse pasture in 1997 and 1998. Turtle 21 nested in the upstream-irrigated lettuce field in 1996 but was not detected upland in 1997 or 1998.

Four of the five individual turtles monitored in 1998 (71, 93, 118 and 177) were followed in 1999 and 2000 by another researcher (Jerry Smith, SJSU, pers. comm.). Turtle 71 was found in the stream near the horse pasture on 25-30 June 1999 and 18 July 2000 so it may have nested there for an additional two consecutive years. Turtle 177 was not found near a nesting area in 1999 but was found near the tomato patch on 18 July 2000 where it may have nested, as it had annually from 1996 to 1998. These two turtles indicated a strong preference for a particular nest area each year and appeared to nest almost every year. Turtle 93 made a walkabout in the tomato field on 15-16 July 1999 and a second walkabout at the horse pasture on 20 July where it apparently nested. Turtle 93 made a walkabout and probably nested again in the horse pasture on 15 July 2000. Turtle 93 made walkabouts and possibly nested on three different nesting grounds from 1997 to 2000. Turtle 15 was found accidentally (its transmitter was dead) at the horse pasture on 15 July 2000. It was disturbed by the discovery and returned to the stream (Smith, pers. comm.). This turtle had previously nested in the horse pasture in 1997.

Stream and Turtle Pond Movements

There were nine distinct movement patterns of stream habitat use prior to nesting activities during the study (Table 4). There were; 1) turtles that remained in the lower lagoon; 2) turtles that remained upstream during the nesting season; 3) turtles that made random movements within the upper and lower lagoon and/or midstream areas; 4) turtles that moved briefly to upper lagoon then back to lower lagoon after possible nesting; 5) turtles with a prolonged stay in the upper lagoon before moving to the lower lagoon after possible nesting; 6) turtles that moved from the tomato field area to the lower lagoon; 7) turtles that went from far upstream down to the tomato field area and back; 8) turtles that moved from the lower lagoon to the irrigated lettuce field area and then back to the lower lagoon; 9) turtles that moved from the lower lagoon to far upstream then back to the lower lagoon. These movement patterns were not necessarily the same from year to year for a given turtle. Turtle 118 displayed three different movement patterns during the three-year study.

Turtles exhibiting movement patterns 1-3 (11 of 29, 38%) showed little movement or random movements without clear precursor movement prior to nesting. Those apparently remaining in the lower lagoon may have nested during brief upland movements, but none were detected. The lack of precursor movements may have made detection unlikely. However, the presence of hatchlings in North Pond indicates that some turtles do nest in the lower lagoon. Turtles exhibiting movement patterns 4-9 (18 of 29, 62%) showed substantial detectable movements that appeared to be associated with nesting. Movement pattern 9 was exhibited only by Turtle 118 in 1996. This turtle went from the lower lagoon to the horse pasture. It then went very far upstream doing at least three walkabouts and returned to the lower lagoon still gravid. It is not clear if the movements resulted from researcher disturbance in the horse pasture and at upstream sites. Nesting sites for Turtle 118 in 1996 and 1997 are unknown and may reflect wariness of this turtle.

Some turtle movements clearly indicated nesting intention. In all three years, Turtle 177 came from upstream down to the tomato field and then returned to its upstream location. Turtle 71 went rather directly from the lower lagoon to the horse pasture to nest and then quickly returned to the lower lagoon in all three years. Most patterns involved some portion of time spent in the lower lagoon. This often took place before and/or after a nesting movement, because all of the detected nesting areas were upstream of the lower lagoon. It appeared that the abundance of basking sites and food in the lower lagoon was much greater, and most turtles spent most of their time there.

The two Turtle Pond females engaged in various movements throughout the pond in spring. During summer of both 1996 and 1997, they moved to the southern portion of the pond nearest to Turtle Meadow. In 1996, Turtle 61 moved from an open water area 30m from the southeastern edge of the pond. After returning to the pond following nesting, she returned to the open area. Turtle 169 had a similar pattern in 1996. However in 1997, Turtle 61 went to the southeastern edge as before, and after a long upland walkabout above the pond, returned to the pond at the northeastern edge. This turtle remained in the northeastern portion of the pond for the remainder of the 1997 breeding season.

Timing and Duration of Upland Movements

Detected upland movements began in the afternoon, and most lasted overnight. In 1996, one turtle, Turtle 61, was upland for only 3.5 hours and nested at 1900 hours in Turtle Meadow. A second turtle, Turtle 71, was upland for 2.5 hours and nested between 1900 and 2130 hours. However, both turtles had previously made walkabouts at the eventual nest site. Fourteen of the 21 detected walkabouts or nesting attempts continued overnight and averaged 22 hours long (16-30 hours). They began from 1205 to1800 hours on the first day and ended from 1130 to1953 hours on the next day. Five other upland movements averaged 48 hours (45-53 hours), and they began from 1205 to1803 hours on the first day and ended from 1130 to1805 hours two days later. Turtle 21 nested at 1400 on 17 August 1996. The time of day or night of the other nine nesting efforts is unknown since the turtles were upland overnight.

Dates of Nesting

Nesting activity was confined to a brief period from mid June to mid August. The earliest confirmed gravid date was 17 May. The last apparent nest was dug on 17 August (Fig. 3). The initiation of the nesting seasons varied from year to year. The 1997 breeding season was a somewhat early year for walkabouts and nesting as compared to 1996. Walkabouts in 1997 started on 3 June. This was 18 days earlier than the 21 June 1996 walkabout. Monitoring of turtles in 1998 was not begun until 15 July, so the start of activity was not monitored. Walkabouts in 1997 ended on 25 July. This was 22 days earlier than the 17 August 1996 walkabout and 13 days earlier than the 8 August 1998 walkabout (Fig. 3). The first apparent nesting in 1997 was on 23 June. This was 5 days earlier than the 28 June 1996 nesting date and 22 days earlier than the 16 July 1998 nesting date. However, in 1998, Turtle 177 had apparently nested earlier and Turtle 118 may have. Monitored nesting in 1997 ended on 25 July. This was 22 days earlier than the 17 August 1996 nesting date and 13 days earlier than the 8 August 1998 nesting date (Fig. 3).

Individual turtles also showed variation in nest dates among years. Turtle 177 had nested by 16 July in 1998, and probably nested on 14 July in 1996 and 24 June in 1997.

Turtle 71 nested on 2 August 1996 and was detected nesting 30 June 1997 and on 8 August 1998. Turtle 93 apparently nested on 23 July 1997 and 25 July 1998.

Nesting Patterns

There were seven year to year nesting patterns in the twelve turtles monitored in both the 1996 and 1997 breeding seasons (Table 5). Six of sixteen turtles apparently nested in consecutive years. Three of the turtles (61, 71 and 177) had detectable nesting efforts in the same nesting area in both years, and two of them (71 and 177) were monitored in 1998 and again nested in the same area. Two other turtles (118 and 169) had detectable nesting efforts both years, but in unknown locations, and the one turtle monitored in 1998 again nested in an unknown location. Four turtles (15, 17, 18, and 21) had a single detectable nesting effort in a known location. One turtle (93) nested twice but the location was known in only one year. Two turtles (16 and 173) had no detectable nesting efforts in 1996 or 1997 (Table 5).

Where nest sites were known, the evidence for fidelity is strong. Turtle 61 exhibited nest site fidelity for at least two years. Turtles 71 and 177 exhibited nest site fidelity for three years (Table 5). Turtle 93 may have exhibited nest site fidelity for 1997 and 1998. It nested in the pumpkin field in 1997 and did a walkabout there in 1998 when it was converted to an irrigated lettuce field. It may have nested there or at some other location.

The two smallest turtles in the study were 121mm (235g) and 130mm (285g) long and were not detected as gravid and never went upland during any part of this study. Ten of the 14 turtles larger than 135mm nested at least once during the study. Three of the turtles that apparently did not nest were monitored only one year.

The 10 turtles that were verified as gravid at least once during the study apparently had only one clutch during a single season. The length of time for egg development may be indicated by the longest time turtles were found to have developing eggs. Turtle 118 was gravid for 55 days, and was caught 10 different times while gravid.

Two other turtles were gravid for 37-39 days and were captured and verified as gravid five times during this period. It appears that Waddell Creek turtles require 40-55 days to develop eggs, which is approximately as long as the entire detected nesting season in 1996 (50 days) and 1997 (32 days).

Discussion

Timing and Amount of Reproductive Effort

There is evidence of early nesting and double clutching in southwestern pond turtles in the southern portions of their range in the Los Angeles basin and in coastal streams in San Luis Obispo County (Goodman 1997, Rathbun et al. 1993). Goodman (1997) reported three of seven gravid females laid their first clutch between 4 May-14 May and second clutches were laid between 10 June-20 June. Lovich and Meyer (unpub. data) also report nesting for southwestern pond turtles in the Mojave Desert as ranging from late May to early June. Three out of 15 radio-tagged gravid females double clutched in a study along the central coast of California (Rathbun et al. 1993). Holland (1994) suggested a latitudinal gradient for double clutching and showed that the nesting season began earlier in the southern portion of the range. Where the season is long, double clutching provides for substantially increased reproductive potential. Double clutching was not found in northwestern turtle populations (Holland 1994). At Waddell Creek, none of the turtles showed any evidence of a second nesting attempt. The earliest nesting date in the Waddell Creek study was 23 June, and egg development took 40-55+ days. There appears to be insufficient time to allow for development of a second clutch of eggs. Holland (1994) stated that most of the nesting efforts for western pond turtles occurred in June and early July, but started as early as April in the southern portion of the range. My study area was toward the middle of the geographical range for western pond turtles, as this site is near the northern boundary of the southwestern pond turtle. Cooler coastal conditions may also have been a factor in the lack of double clutching.

Changing conditions from year to year may also affect the timing of nesting. The somewhat earlier 1997 season reported in this study was probably due to less rainfall in late winter and spring at the study area compared to 1996 and 1998. During droughts, like in 1987-1991, it is possible that nesting would occur much earlier than observed in 1996-1998. Mean monthly air temperatures were also lower from February to April in 1997 as compared to 1996 (Davis 1998), but if cool temperatures affected nesting, it should have occurred later rather than earlier. Holland (1994) reported that local variation in weather and water levels can affect the timing of nesting.

Nest site fidelity between nesting seasons appears to be common throughout the range (Holland 1994). However, nest site fidelity within a single season has not been documented at any location. The three gravid turtles that laid two clutches in the Pico and San Simeon creek studies in central California nested in different locations in the same nesting season (Rathbun et al. 1993). Nest site fidelity can be an important factor in identifying the most critical nesting areas for a given population (Holland 1994). This was important in this study as four of the five nesting areas detected had a female that returned to nest in the same area. The number of consecutive seasons that an individual is gravid and nests varies from individual to individual in a given population and for different areas. Goodman (1997) reported that out of 15 western pond turtle females, two (15%) nested for two consecutive years and 1 (7%) nested for three consecutive years. In this study, five (42%) of the 12 turtles monitored from 1996 to 97 nested in the same nesting area for both of those years. Two of these five turtles nested in the same location in 1998 and in 1999 or 2000 as well. The other three turtles were not part of the 1998 study.

It is not known what the different benefits are in nesting at the same nesting site year after year versus nesting at different sites. Some turtles appear to use more than one nesting area during a single nesting season or during subsequent nesting seasons. If turtles are disturbed while nesting at an initial nesting area, they may move to another nesting area to nest. Turtle 93 has explored three different nesting areas from 1996 to 2000. Nesting in multiple areas may keep the nests from being tracked by nest predators. Alternatively, a female may continue to nest at a particular nesting ground until she is disturbed by a predator, loud noises, or the presence of a researcher or any other person or large animal on the nesting ground during a walkabout. Nesting at different nesting grounds may increase the variety of nesting thermal environments. This may be important as the sex of this species of turtle is determined by nest incubation temperature (Holland 1994).

In 1996, 9 of 12 (75%) turtles had detectable nesting efforts, and 8 of 12 (67%) of those turtles also apparently nested in 1997. All 4 turtles added to the study in 1997 apparently failed to nest. Environmental stress, the availability of food and its quality may affect how many individuals in a population are gravid from year to year. There is some evidence in southern California that during the 1987-1991 drought years there was a higher proportion of non-gravid females (greater than 80%) than in previous years (Holland 1994).

Nest Sites and Nesting Movements

This study was consistent with other studies in that most western pond turtles moved upland in the afternoon and evening hours. As in other studies, these forays or walkabouts can be completed within one day, although turtles can stay upland for up to four days (Rathbun et al. 1992, Rathbun et al. 1993, Holland 1994). The longest foray in this study was for three days. The distance traveled away from water was consistent with other studies (Holland 1994). Waddell turtles nested 30 to 100m upland at sites with low risk of winter inundation. Most Waddell turtles also moved 700 to 2200m up or downstream to reach nesting areas.

Most detected walkabout times were long, as they involved the turtle being upland overnight and returning to the stream the next day. The detection of mostly longer walkabouts in this study may be biased, as shorter walkabouts may not be detected. Turtles 61 and 71 nested within 2 to 3 hours in 1996, but in each case, they had already made a walkabout at the nest site. Other turtles may have nested undetected because they were on land for only a few hours.

The "detection of nests" in this study was somewhat subjective and some of the nest locations may be incorrect. In the strictest sense, only three nests were actually verified. Verification of actual nests was extremely difficult due to the sensitivity of female turtles when they were on or near their nesting grounds. Most of the nesting data in this study was based upon the female being gravid and/or the presence of the turtle on one of the five nesting grounds, especially if it had been at the same nesting ground in a previous year. This may overestimate the number of turtles nesting in the study, but gravid turtles probably nested, even if the location was uncertain. However, some turtles apparently nest in the lower lagoon areas, as hatchlings have been found upland. The short distance to nesting sites and/or lack of upstream precursor movements apparently prevented detection of lower lagoon nesting.

Palpation was the sole method for determining whether a female was gravid. Other studies have used palpation in combination with x-ray radiography to determine the presence and number of eggs in females. Keller (1998) demonstrated that a significantly higher frequency of gravid females was detected by radiography than by palpation alone in a sample of 387 Mediterranean Turtles (*Mauremys leprosa*). His study showed that palpation was biased toward larger clutches of calcified eggs and that smaller, less calcified eggs could be missed. In my study, some of the females first found to be gravid had soft, gelatin-like eggs present, but others had calcified eggs. Earlier eggs may have been missed and this would have affected my conclusions of timing of egg development and the number of gravid females.

Nesting sites picked at Waddell Creek reflect delayed emergence of hatchlings and the need to avoid nest sites that would be flooded with water. J. Abel and C. Davis, SJSU, (unpub. data) found that two of the three observed nests survived with two hatchlings at Waddell Creek in 1996. The hatchlings of Turtle 61 overwintered in the nest chamber and emerged in April of the following year. Two of the hatchlings of Turtle 71 died but empty shells indicated that two others emerged from the nest before the nest cage was in place in March. Most hatchlings in southern California emerged in late fall of the year they were laid, while most in the northern part of the range emerged the following spring (Holland 1994). Depari (1996) reported that delayed emergence was caused by soil substrates and that sandy substrates led to emergence in the fall in hatchling painted turtles (*Chrysemys picta picta*).

Soil characteristics may also affect nest sites or nest survival. Turtle 61's nest was on sandy soil, forty meters from the pond with a general northwestern slope in the middle of Turtle Meadow. Holland (1994) reported that only three of 250 western pond turtle nests previously found were in sandy soil, but for Turtle Pond turtles the only close sparsely vegetated site was in the sandy meadow. Turtle 71's nest was in the horse pasture. The soil was hard packed clay and silt and was typical for this species (Holland 1994), however this turtle had difficulty digging in the compacted soil. Turtle 21's nest was just inside the fence along the northern edge of the upstream irrigated lettuce field, and had hard and compact soil. No hatchlings emerged, possibly due to irrigation, which can cause eggs to burst (Holland 1994), or to predation from a mole (*Scapanus ssp.*), whose tunnel ran through the nest area.

Population Concerns

Although the degree of nesting success at Waddell Creek is unknown, it appears sufficient to support this isolated coastal population. The extensive trapping efforts at Waddell Creek have captured more than 230 western pond turtles of all of the age/size classes in the stream and adjacent pond (C. Davis and J. Abel, SJSU, unpub. data).

Management Implications

Farming and development in this century have altered the Waddell Creek watershed. Recent agriculture has produced more open habitat but past fires cleared the forest and opened areas, exposing bare ground for nesting turtles. The lack of recent fires has resulted in few sparsely vegetated areas except those disturbed by agriculture. Most Waddell Creek western pond turtles were found to nest in agricultural fields and in a horse pasture. Some turtles may use undetected nest areas with different habitat characteristics. Sites disturbed by humans appear to be important for Waddell Creek turtles. Since turtles can use more than one nesting area, all of the identified nesting areas may be important as alternate nesting locations. All of these nesting areas should be protected in case one or more of them becomes unsuitable for nesting. Management of plowing and irrigation practices may be critical for the success of western pond turtle nests. Lettuce requires substantial irrigation, but pumpkins and tomato crops were irrigated only at the beginning of the season. Irrigation can expose eggs to excess moisture and cause them to burst. The presence of agriculture where fire has been suppressed can maintain open areas and prevent succession to forest or brush areas that are unsuitable for nesting. Since western pond turtles require forested areas for overwintering sites (Davis 1998), the level of agriculture along Waddell Creek may provide an artificial balance of the amount of forested and open areas.

Pond turtles nest and hatch in summer, but hatchlings do not emerge until early spring of the following year. The delayed emergence of hatchlings presents some difficulty in managing nests in agricultural areas. The nest is "active" during much of the agricultural season when plowing and irrigation take place. However, if plowing and irrigation occurs only in late spring, that would occur after hatchlings emerge and before adults begin to nest. The one nest found in an agricultural field was on the edge of the field and was safe from plowing. Fields are sometimes plowed in the center portion with a narrow band of unplowed soil along the edge. The unplowed soil is the most likely place for a nest, although turtles have been seen wandering throughout agricultural fields. Even if the entire field is plowed, the edge is not planted and the lack of plant cover makes it a good site for turtle nests. It is possible to divert irrigation away from a known nest but hidden nests might become flooded. It appears that nests are most likely on the outer rim of the field so that irrigation could be avoided in this area.

Management of the horse pasture also appears necessary for it to remain a suitable nesting area for turtles. The horse pasture that was heavily used in 1996-1998 has not been grazed since 2000. Vegetation growth and encroachment may make this valuable nesting area unsuitable unless mowing or grazing are used as management tools.

Attracting predators into an area is another management issue. Garbage left by park visitors can attract both crows (*Corvus corax*) and raccoons (*Procyon lotor*), which are both predators of western pond turtles. These predators were apparently not a problem during this study, but could become a problem in the future if predators increased due to increases in campground garbage or other sources of food.

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TABLES

Table 1. Identification numbers and locations of individual turtles studied in 1996-98 at Waddell Creek.

Turtle #	Location	Monitored in 1996	Monitored in 1997	Monitored in 1998
15	Lagoon	X	X	
16	Lagoon	X	X	
17	Lagoon	X	X	
18	Lagoon	X	X	
21	Upstream	X	X	X
30	Lagoon		X	
61	Turtle Pond	X	X	
71	Lagoon	X	X	X
93	Lagoon	X	X	X
118	Lagoon	X	X	X
122	Lagoon		X	
169	Turtle Pond	X	X	
173	Upstream	X	X	
177	Upstream	X	X	X
183	Lagoon		X	
200	Lagoon		X	
Turtles in Study	16	12	16	5
Waddell Creek				
Upstream	3	3	3	2
Lagoon	11	7	11	3
Turtle Pond	2	2	2	0

Table 2. Number and percent of pond turtles with different nesting effort catagories at Waddell Creek in 1996-1998 Numbers in parentheses are the individual turtle identification numbers. Asterisks denote those individuals where the likely site of nesting is known

Year	Number Of Turtles	Certain Nest	Very Probable Nest	Probable Nest	Possible Nest	No Detectable Nesting Activity
1996	12	3-25% (#21*,61*,71*)	1-8% (#17*)	3-25% (#93,118,177*)	2-17% (#15,169)	3-25% (#16,18,173)
1997	16	0	3-19% (#71*,93*, 177*)	4-25% (#15*,18*, 61*,118)	1-6% (#169)	8-50% (#16,17,21,30, 122 173,183,200)
1998	5	0	1-20% (#71*)	1-20% (#93)	1-20% (#177*)	2-40% (#21,118)

Table 3. Nesting areas investigated ("walkabouts") and used by female pond turtles in the Waddell Creek watershed in 1996-1998. Numbers are turtle identification numbers. Asterisk indicates probable nesting

Region	Nest Area	1996	1997	1998	Totals
Upstream	Irrigated Lettuce Field	21*			1
	Tomato Field	177*	93,177*	177*	4
	Stream side	118,118,118			3
Lagoon	Pumpkin Field +	17*	15,18*,93*		4
	Irrigated Lettuce Field			93	1
	Horse Pasture	71,71*,118	15*,71*	71*	6
	Turtle Meadow	61,61*,169	61*,169		5
	Nature Center		169		1
Totals		9	10	3	25

+ The Lagoon Pumpkin Field was an irrigated lettuce field in 1998

Table 4. Stream movement patterns of Waddell Creek pond turtles in 1996-1998

Movement type	1996	1997	1998
Turtles that remained in lower lagoon		30,200	
Turtles that remained upstream during nesting season	173	183	
Turtles that made random movements within the upper and lower lagoon and/or midstream areas	16	16,17,21,122	21,118
Turtles that moved briefly to upper lagoon then back to lower lagoon after possible Nesting	17, 71	18,71,93,118	71,93
Turtles with a prolonged stay in upper lagoon before moving to lower lagoon after possible nesting	15,18,93	15	
Turtles that moved from the tomato field area to the lower lagoon		173	
Turtles that moved from far upstream down to tomato field area and back	177	177	177
Turtles that moved from the lower lagoon to the irrigated lettuce field area then back to the lower lagoon	21		
Turtle that moved from lower lagoon to far upstream then back to lower lagoon	118		

Table 5. Year to year nesting patterns for sixteen turtles monitored in 1996 or 1997 with observations of only 5 turtles in 1998

Nesting Patterns	Totals	Turtle Number
Nested two consecutive years at same location	3	61, 71*,177*
Nested two consecutive years but location known 1 year only	1	93**
Nested two consecutive years-unknown locations	2	118***, 169
Nested with known location in 1996 but no detectable nesting in 1997	2	17, 21***
Nested once with known location in 1997 but no activity in 1996	2	15,18
No detectable nesting activity in both years	2	16,173
Monitored 1997 only with no detectable activity	4	30,122,183,200

* Also nested in the same location in 1998

** Also nested in 1998

*** No detectable nesting in 1998

FIGURES

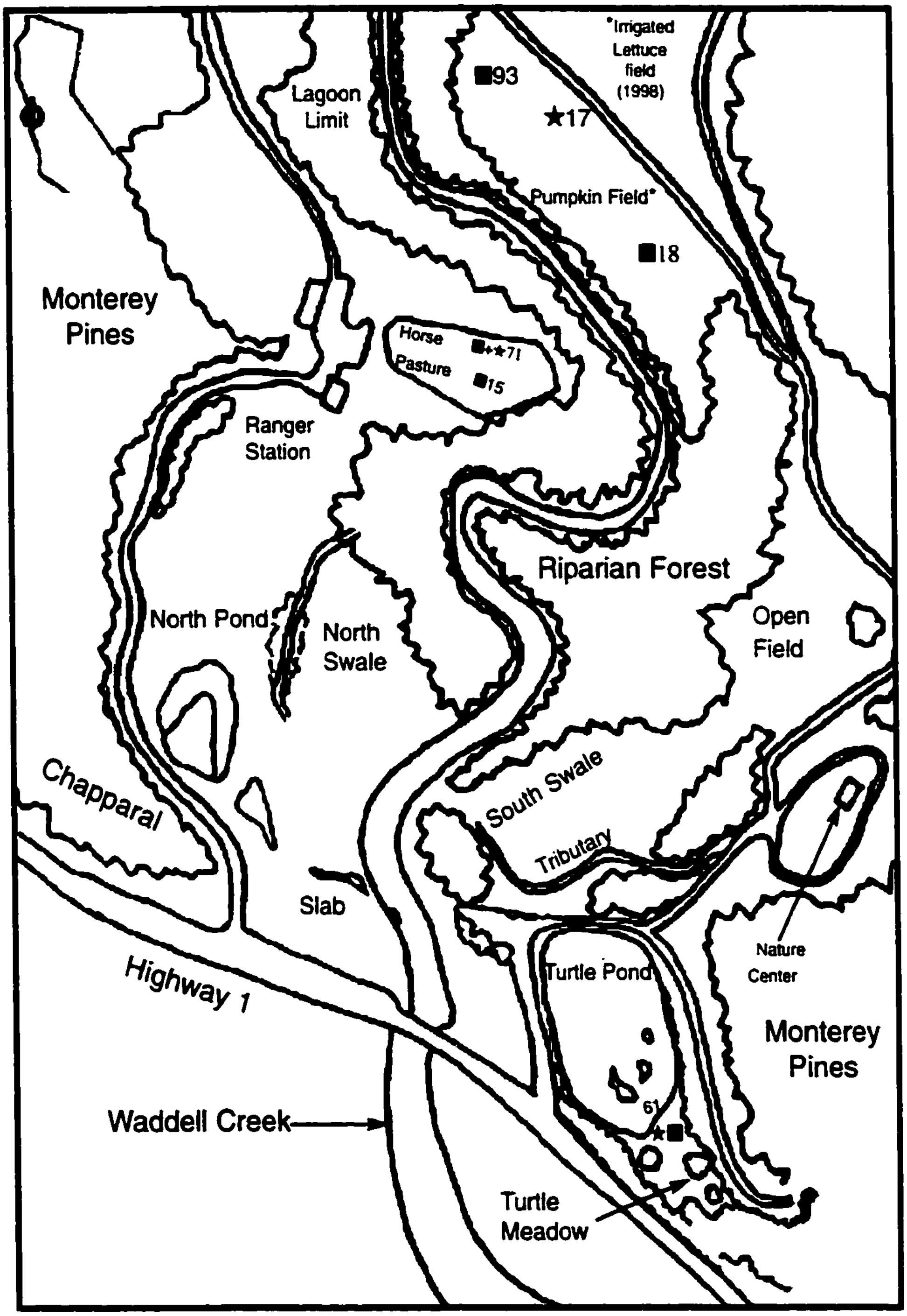


FIGURE 1 Downstream Nesting Areas of Waddell Creek
★1996 nests ■1997 nests +1998 nests

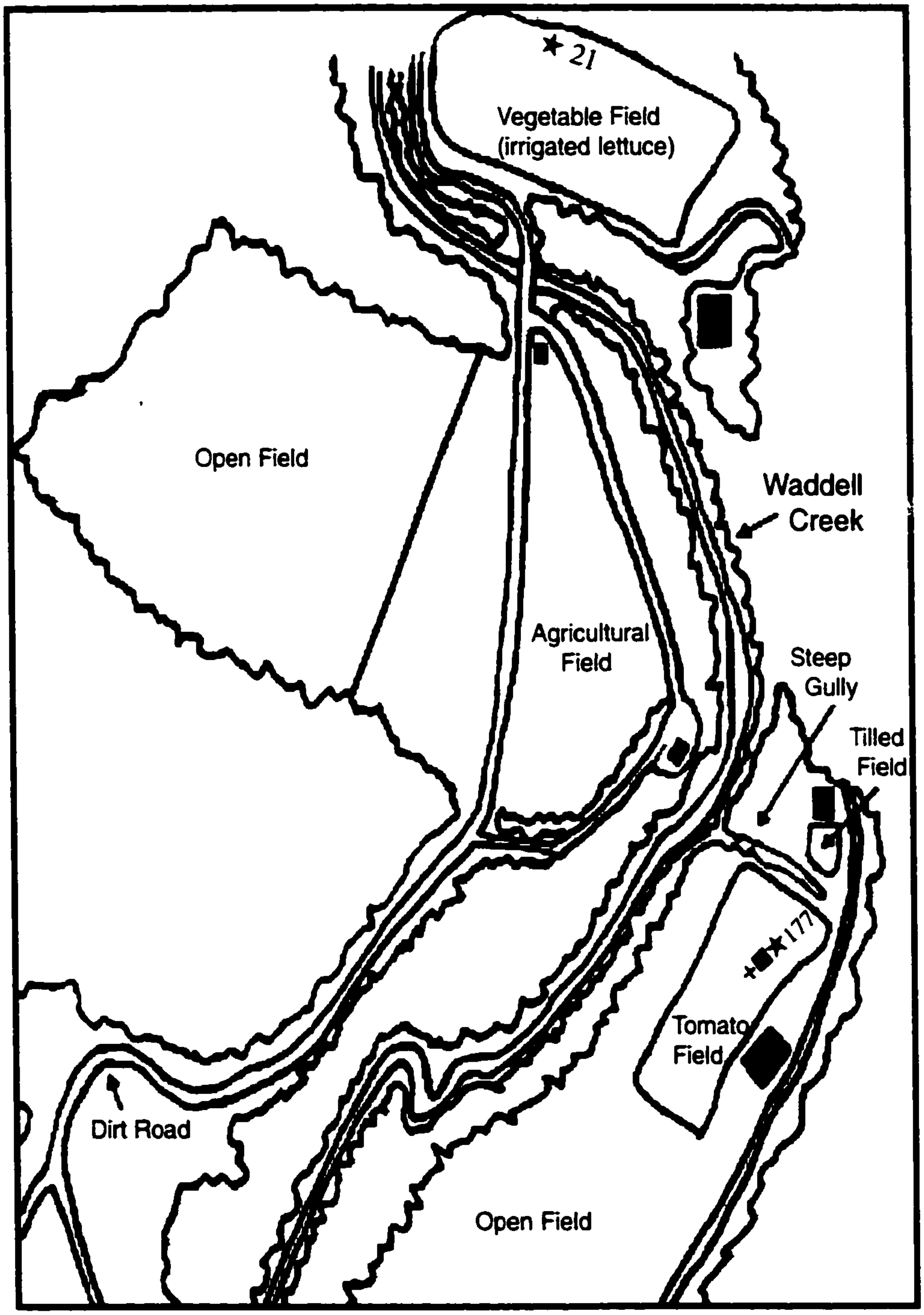
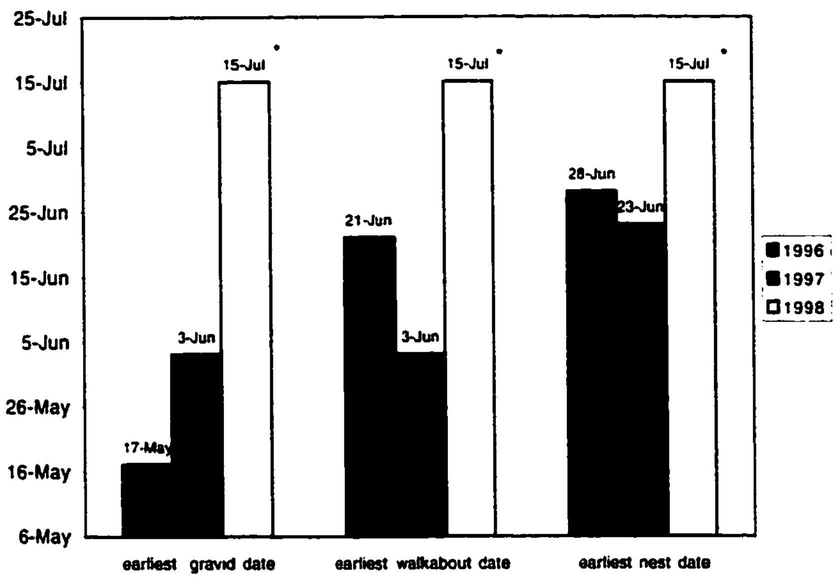


FIGURE 2 Upstream Nesting Areas of Waddell Creek
★1996 nests ■ 1997 nests + 1998 nests

EARLIEST NESTING DATES BY SEASON



LATEST NESTING DATES BY SEASON

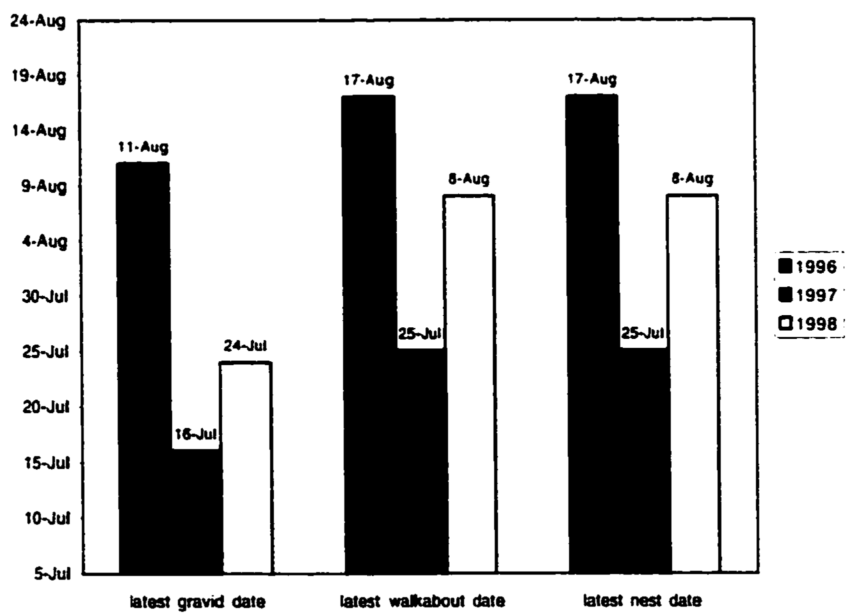
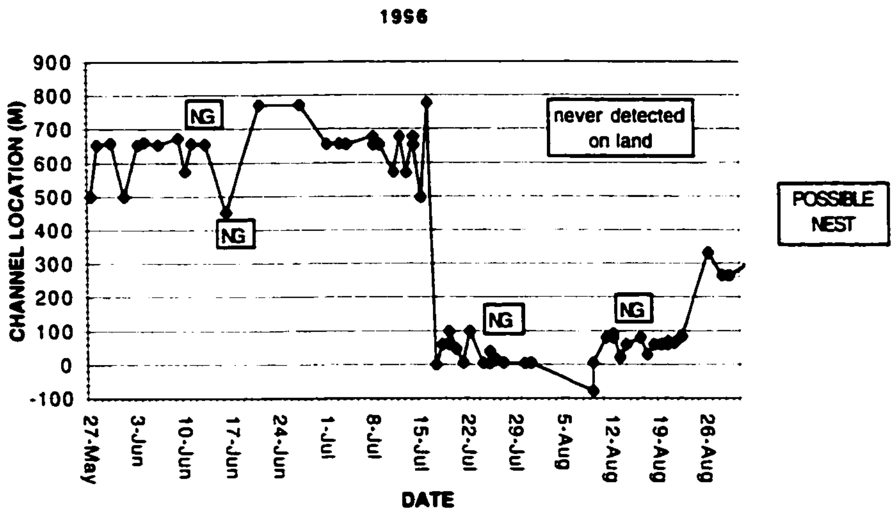


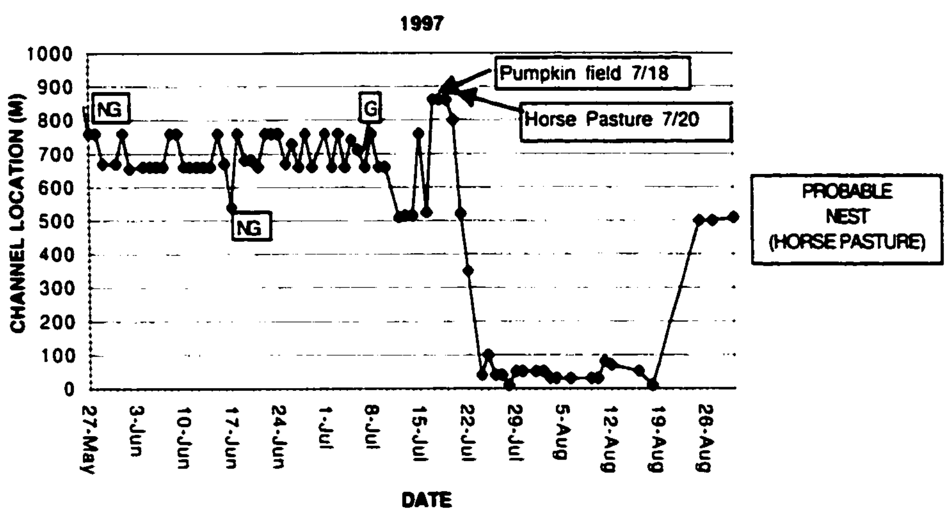
Figure 3 **Timing of nesting activity for female turtles during 1996-1998.**
*** Work in 1998 did not start until 15 July.**

Appendix A. Sizes, weights and annuli counts for individual female turtles used in Waddell Creek nesting study

Turtle #	Carapace length (mm)	Annuli count	Weight (g)	Stream/ Trap location	Capture location	First capture date	First transmitter date
15	164	worn	605	100m	Lagoon	6/16/94	8/21/95
16	168	worn	715	100m	Lagoon	6/16/94	8/28/95
17	167	worn	710	100m	Lagoon	6/20/94	9/2/95
18	148	9	438	1100m	Lagoon	6/27/94	8/21/95
21	159	worn	648	1100m	Lagoon	6/13/94	4/9/96
30	156	10	550	10m	Lagoon	7/31/95	7/15/97
61	138	13	385	TP-4	Turtle Pond	8/7/95	9/25/95
71	156	15	565	100m	Lagoon	8/11/95	9/2/95
93	142	8	350	390m	Lagoon	8/30/95	8/30/95
118	160	worn	603	1100m	Lagoon	6/22/94	4/9/96
122	162	worn	598	825m	Lagoon	9/29/95	3/24/97
169	138	15	378	TP-4	Turtle Pond	5/9/96	5/9/96
173	130	worn	285	2350m	Upstream	6/21/96	6/21/96
177	164	worn	645	1100m	Lagoon	7/2/96	7/2/96
183	121	12	235	1550m	Upstream	7/17/96	7/17/96
200	143	worn	460	475m	Lagoon	10/18/96	10/18/96

Appendix B
Stream Movements and Nesting Activities of Individual Turtles





Turtle 15 stream movements and nesting activity.
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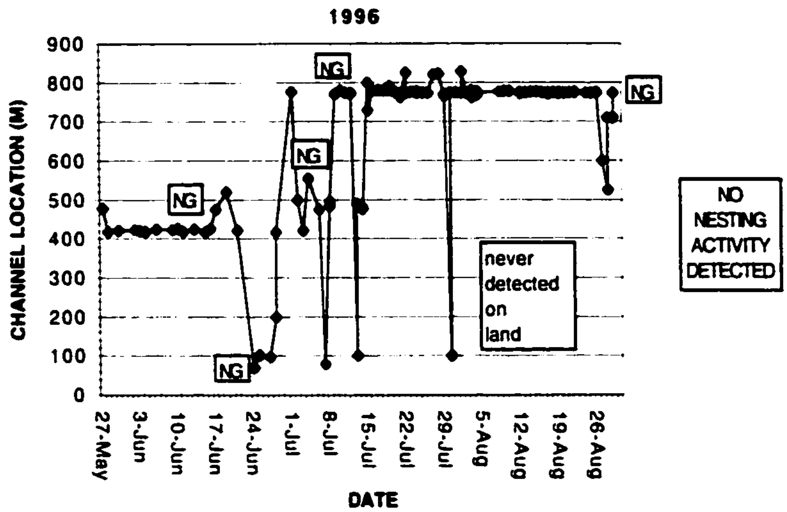

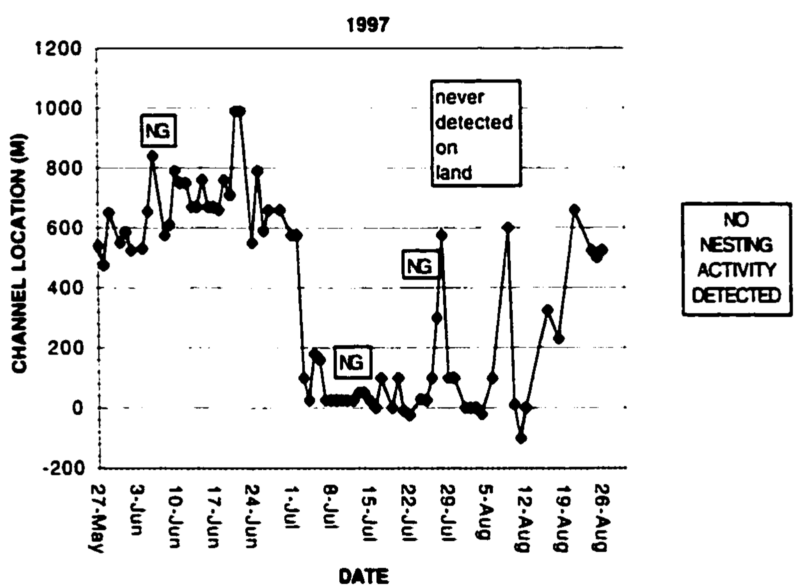

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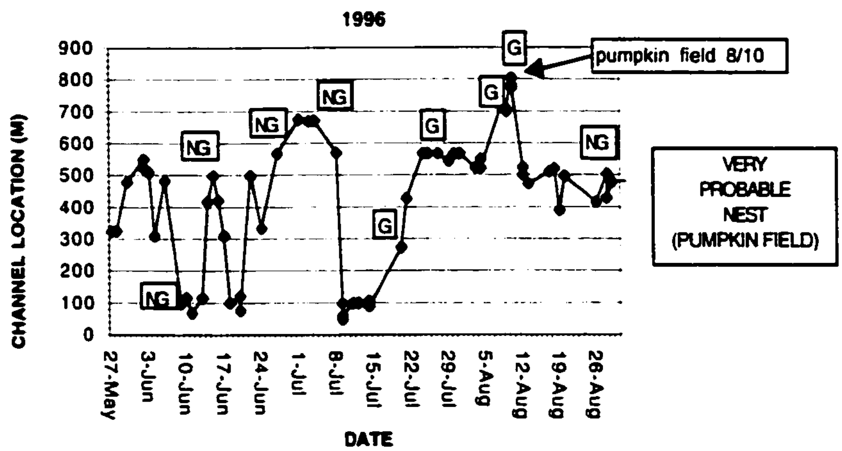

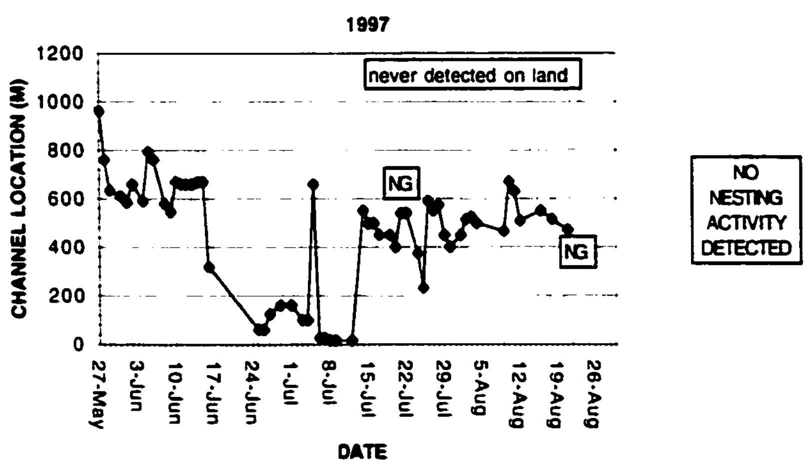

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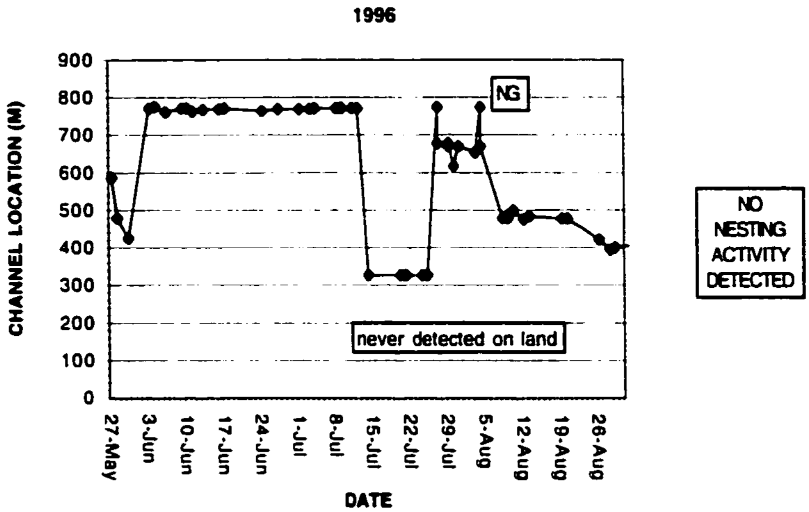

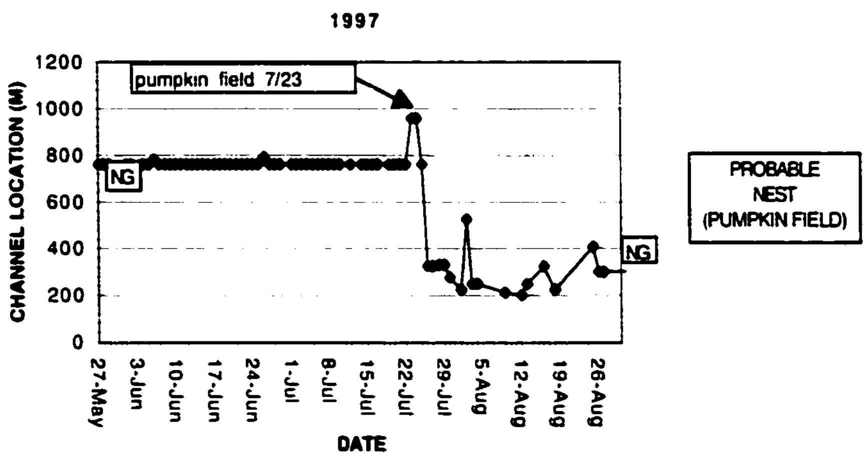

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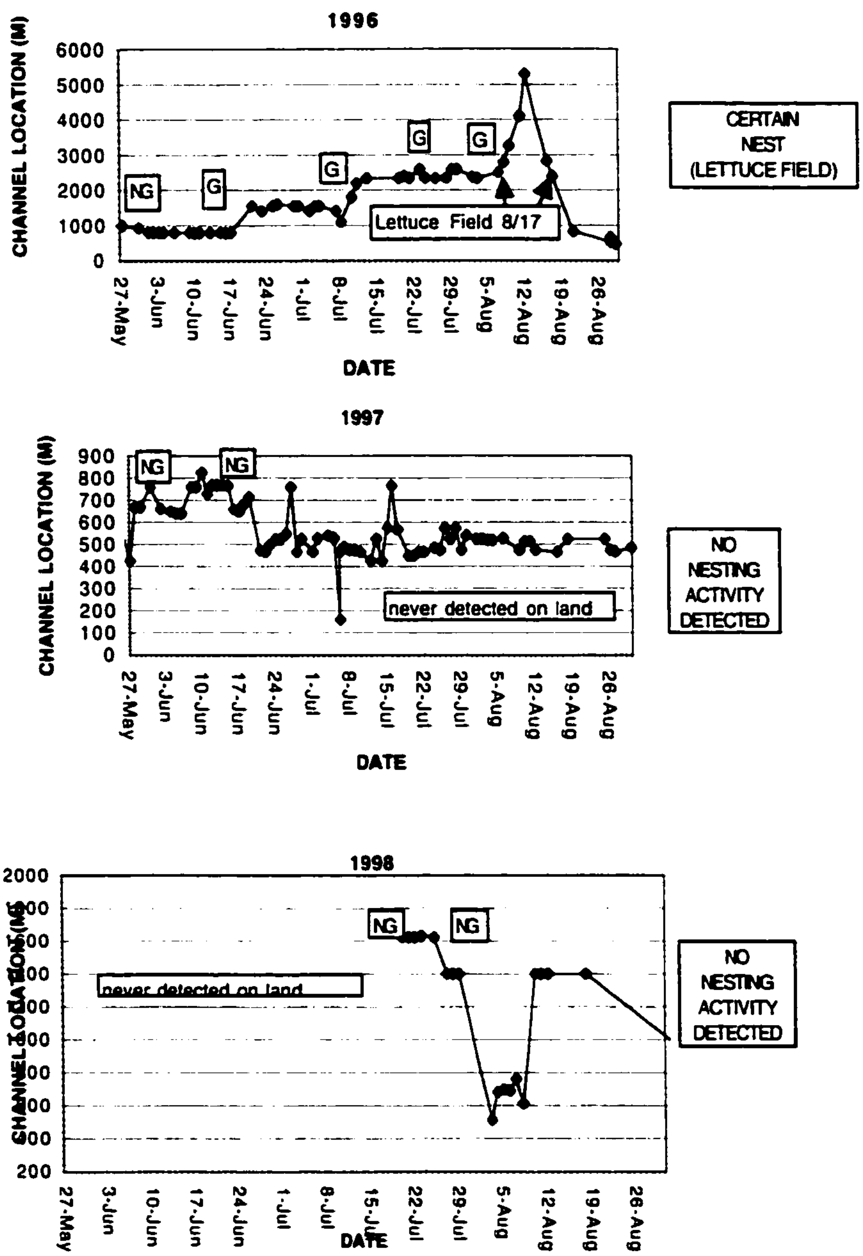

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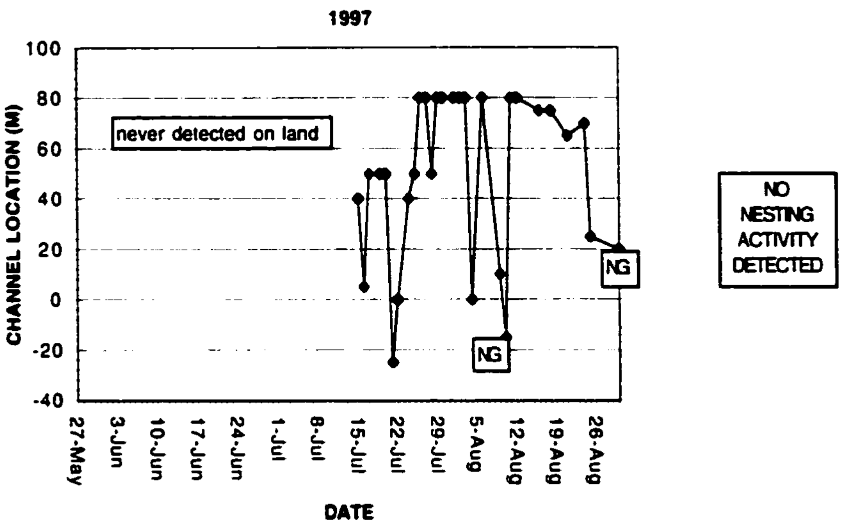

Turtle 30 stream movements.
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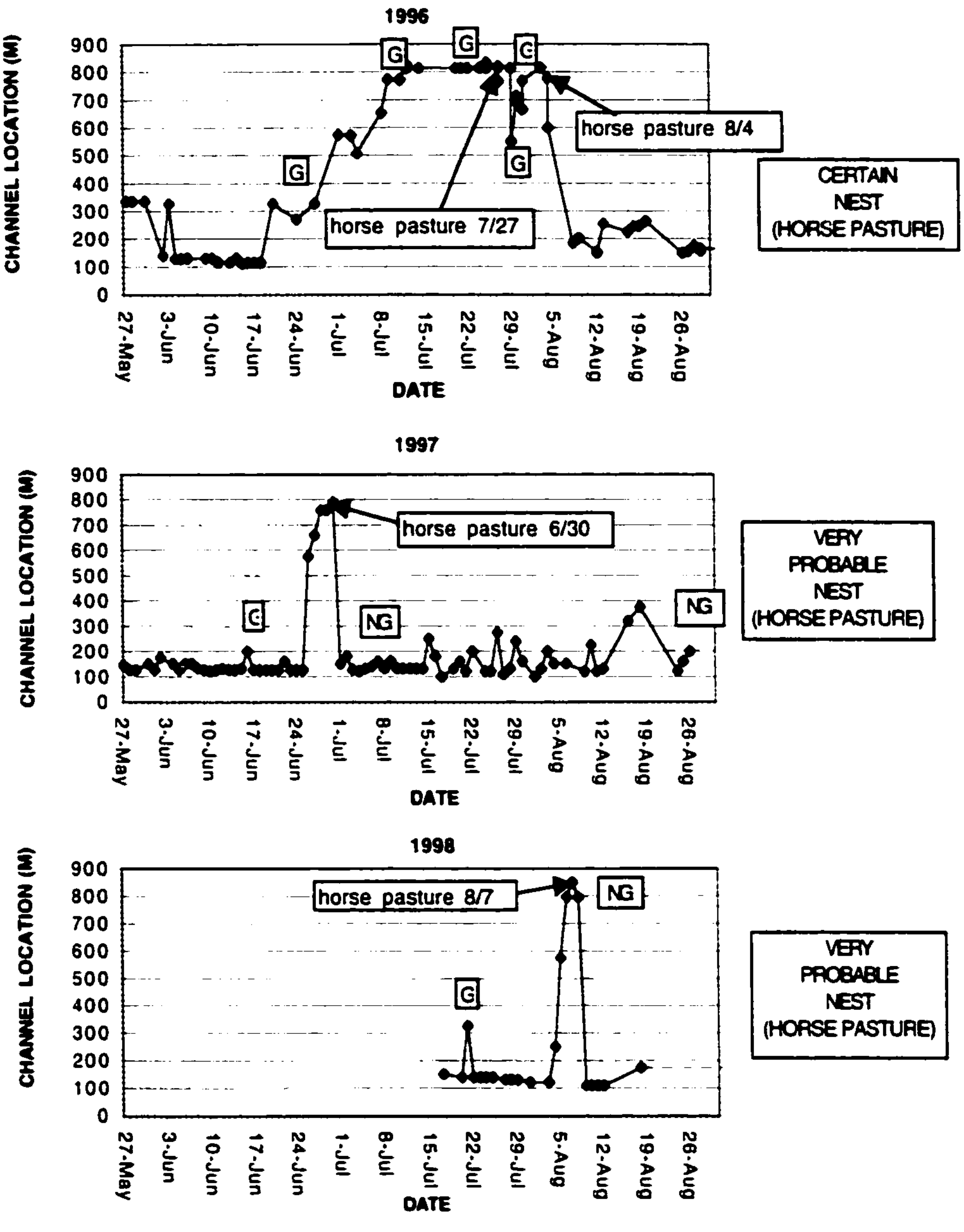

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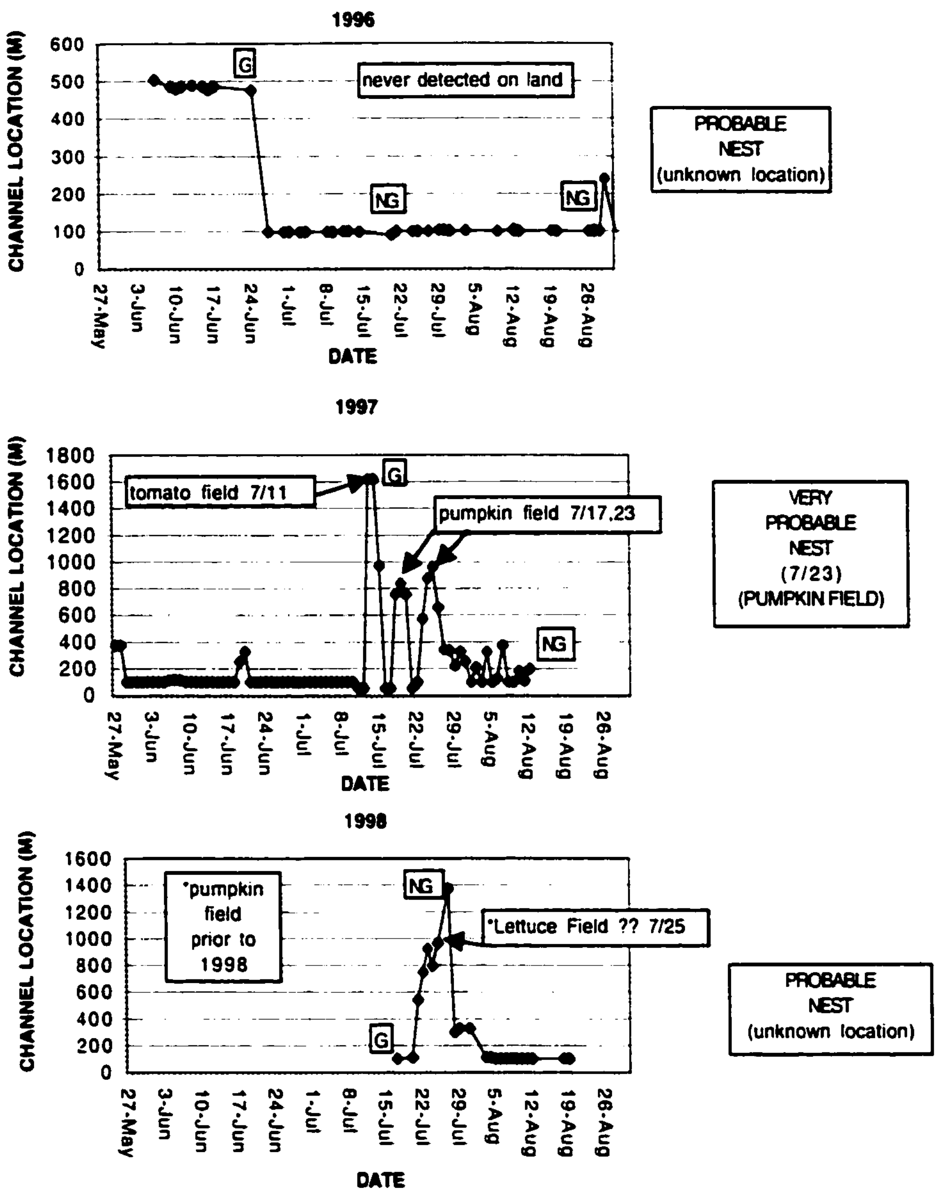

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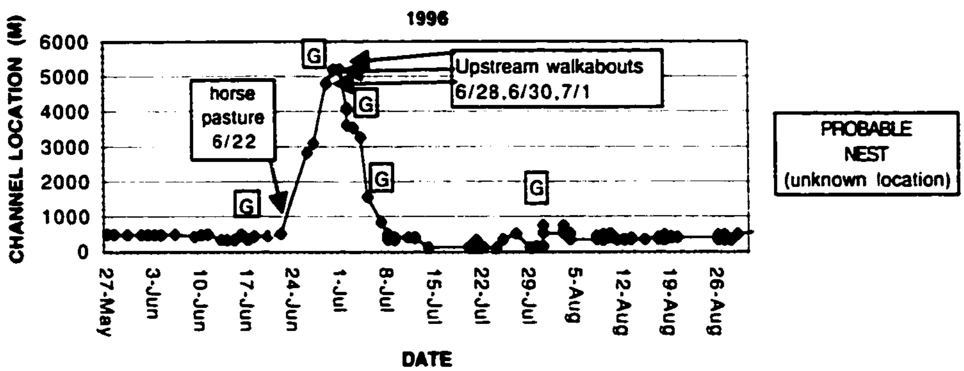

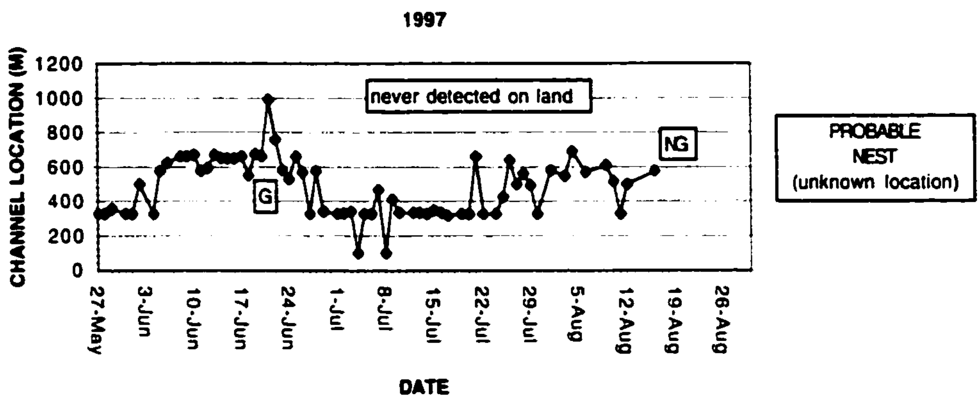

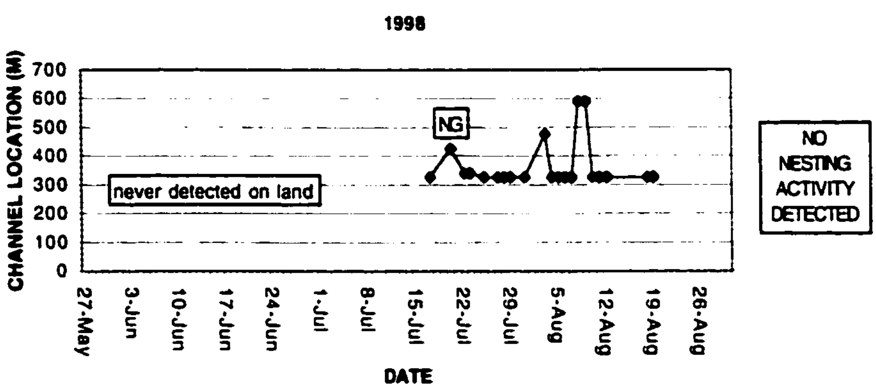

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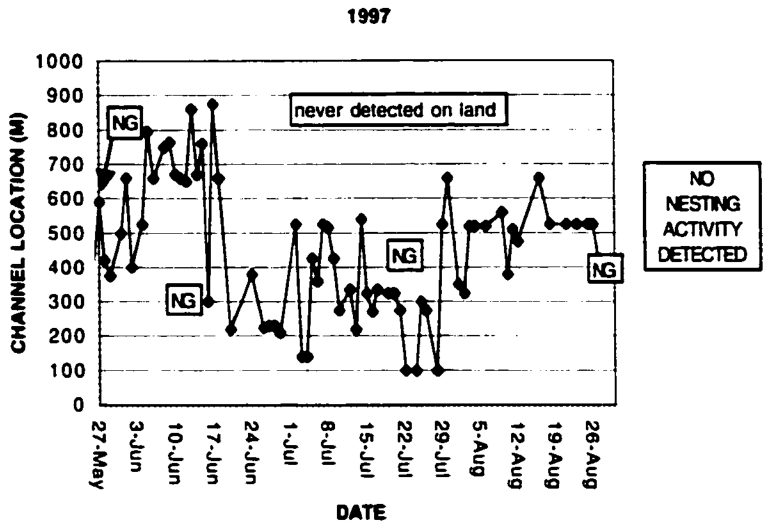

Turtle 122 stream movements.
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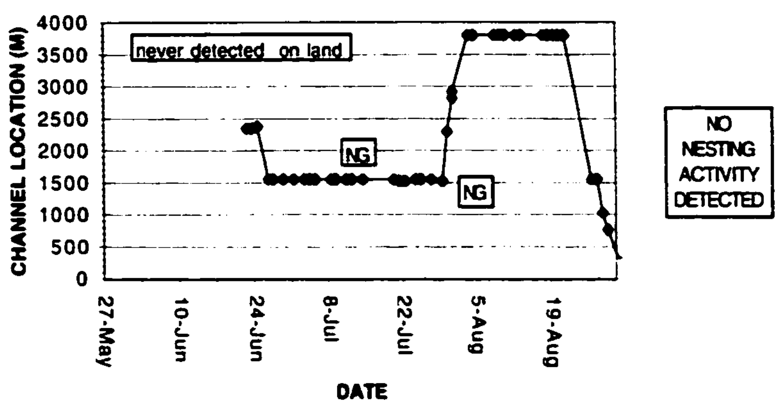
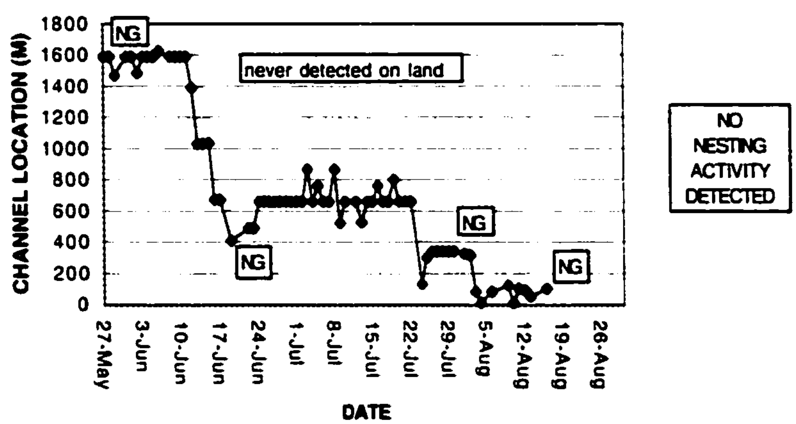
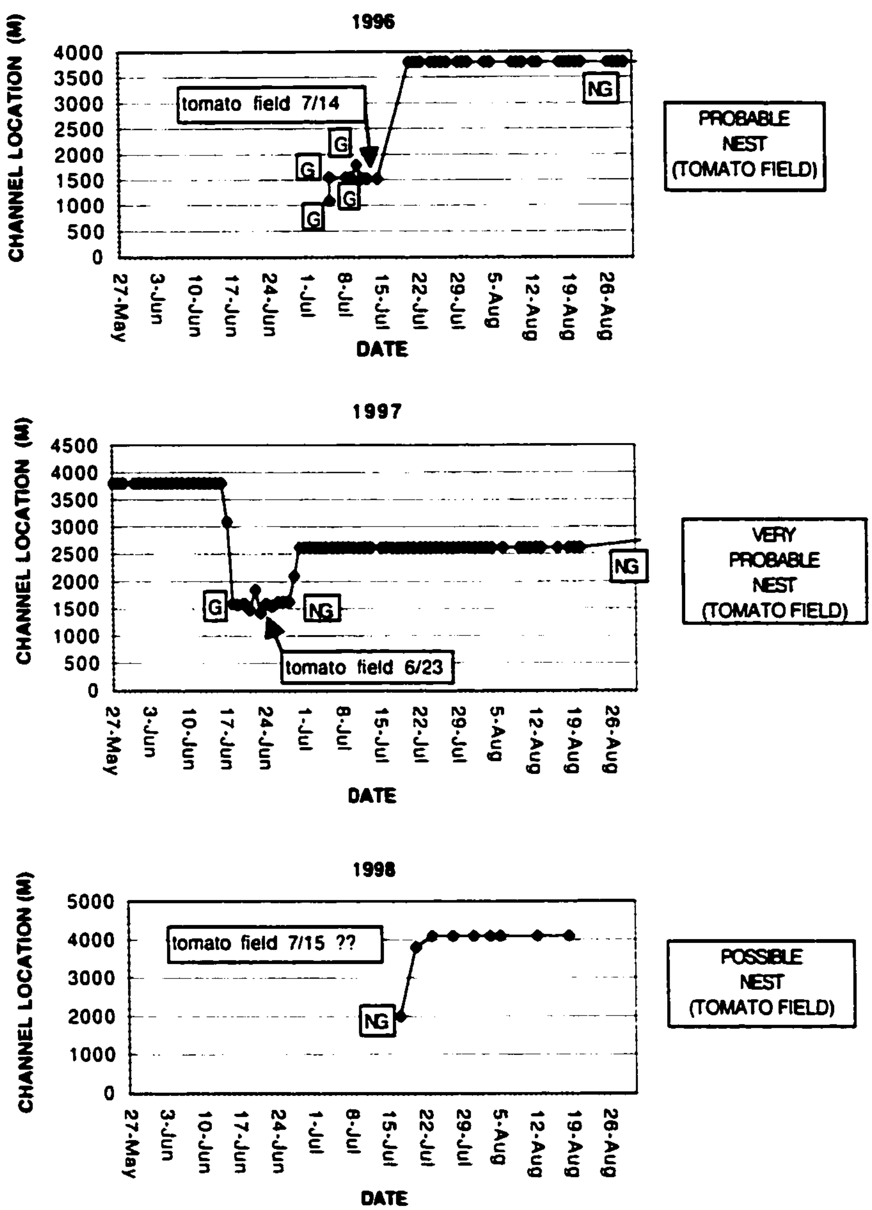
1996



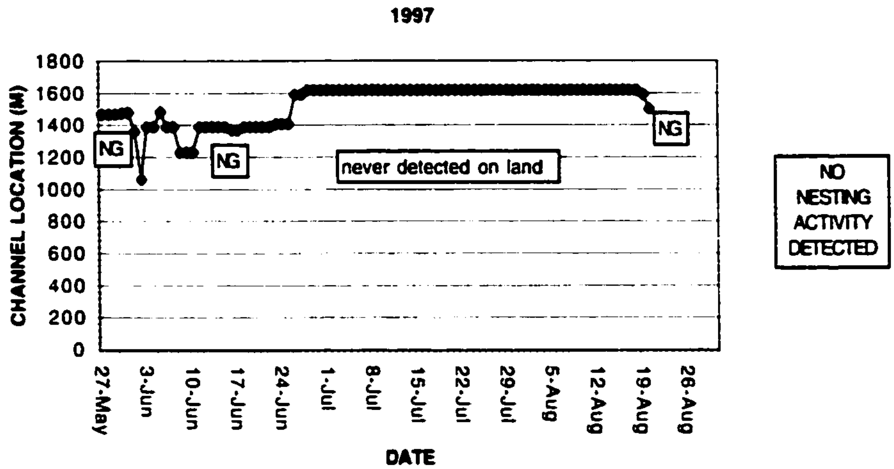
1997



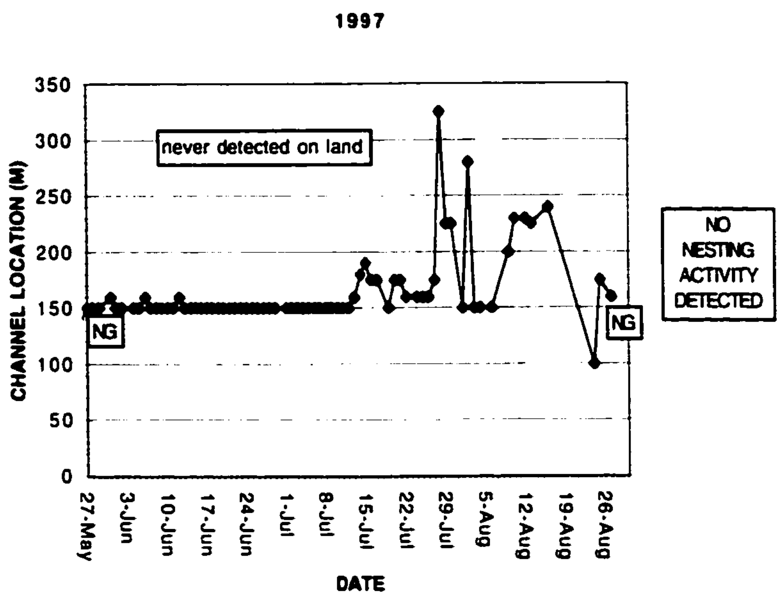
Turtle 173 stream movements.
(G=GRAVID, NG=NOT GRAVID)



Turtle 177 stream movements and nesting activity.
(G=GRAVID, NG=NOT GRAVID)



Turtle 183 stream movements.
(G=GRAVID, NG=NOT GRAVID)



Turtle 200 stream movements.
(G=GRAVID, NG=NOT GRAVID)