DEPREDATION OF SEA TURTLE NESTS

- A NEED FOR FOX CONTROL

Jurabi Coastal Park, North West Cape, Western Australia

FINAL REPORT

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Prepared by Sharon McKinna-Jones

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Disclaimer

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Cover pictures: Fox predation of a hawksbill turtle nest and fox tracks on the beach at Five Mile, Jurabi Coastal Park.

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Terms & Abbreviations

CALM	Department of Conservation and Land Management
GPS	Geographical positioning system
JCP	Jurabi Coastal Park
JCU	James Cook University
NCTMP	Ningaloo Community Turtle Monitoring Program
NMP	Ningaloo Marine Park
NWC	North West Cape

Executive Summary

Over the past decade, predation of sea turtle nests by the European red fox *(Vulpes vulpes)* along beaches of the North West Cape (NCW) in Ningaloo Marine Park (NMP) has required that control measures be introduced. Historically, little known fox activity along beaches within Jurabi Coastal Park (JCP) on the NWC has not warranted control measures. However during early January 2004, observations of depredated turtle nests by foxes within this area prompted the initiation of a fox monitoring program.

The prime objectives of the fox monitoring program, were to record fox activity and to determine the current level of fox predation on green *(Chelonia mydas)*, loggerhead *(Caretta caretta)*, and hawksbill *(Eretmochelys imbricata)* turtle nests, which involved a detailed assessment of Five Mile beach within JCP. Following this, recommendations were made to CALM.

Over the 2003/2004 turtle season, it was estimated that fox predation reached 10.1 percent of nests laid along Five Mile beach for all three species combined, and 9.2 percent for green turtle nests. These nests incurred an average loss of eggs and/or hatchlings of 68.2 percent.

The deployment of wire cage traps at Five Mile and other beaches within JCP by CALM, proved ineffective in controlling fox predation activity in the 2003/2004 turtle season. In contrast, 1080 (sodium fluoroacetate) poison dry meat baits deployed at Bateman Bay in the southern region of Ningaloo Marine Park was reported by CALM to have successfully reduced predation of loggerhead turtle nests to just 2.3 percent (Parker *et al*., 2004).

It was concluded that the level of fox predation witnessed at Five Mile beach is cause for concern for the sustainability of turtle nesting populations, and that the use of a more effective fox control method may be necessary.

Recommendations to CALM were to seek an alternative method to wire cage traps in order to control the current fox predation problem, and that this be in place during the turtle season to include nesting and hatchling emergence periods, October to April. Also, fox monitoring should continue at Five Mile beach to assess the success of the fox control method introduced.

1.0 Introduction

Predation of sea turtle eggs and hatchlings by the European red fox *(Vulpes vulpes)* has been identified by the Department of Environment and Heritage (formerly Environment Australia), in their *Recovery Plan for Marine Turtles of Australia*, as being a key threat to the recovery of threatened turtle populations (Environment Australia, 2003). In this plan, the management criteria for the success of marine turtle nesting, prescribes that hatchlings must be produced from greater than 70 percent of nests laid where populations are affected by fox predation. For loggerhead *(Caretta caretta)* turtle nests however, the criteria aims for an almost zero level of fox predation on eggs and hatchlings (Environment Australia, 2003).

This project evaluates the magnitude of fox predation on sea turtle nests at Five Mile beach, Jurabi Coastal Park (JCP), on the North West Cape (NWC), Western Australia, against the recovery criteria. It is the first comprehensive account of fox predation pressures on sea turtle nests within this region. The report also draws upon data collected by the Ningaloo Community Turtle Monitoring Program (NCTMP), and outcomes of fox control measures employed by CALM during the 2003/2004 turtle nesting season.

1.1 Aims and objectives

The aim of the study was to establish the current level of fox predation along JCP for the 2003/04 turtle nesting season with a detailed assessment of Five Mile beach.

The specific objectives of this study were to:

- Monitor fox activity at Five Mile throughout the peak nesting and hatchling emergence times of the turtle season.
- Determine the level of fox predation of sea turtle nests within JCP.
- Establish, where possible, the stage of development at which nest depredation predominantly occurs.
- Review the effectiveness of fox control measures used by CALM on the NWC during the 2003/2004 turtle nesting season.
- Provide recommendations from research findings on whether or not there is a need for fox control within JCP.

2.0 Background

Foxes are a well known predator on sea turtle eggs and hatchlings. All sea turtle species within Australia are listed as either vulnerable or endangered under the *Environmental Protection and Biodiversity Conservation Act 1999,* and also the World Conservation Union *(IUCN) Red List of Threatened Animals* (Baillie & Groombridge, 1996). The Department of Environment and Heritage recognise the necessity for control programs of feral animals to increase nesting success where turtle populations have been identified as a priority (Environment Australia, 2003).

Three species of sea turtle, the green *(Chelonia mydas)*, loggerhead *(Caretta caretta)*, and hawksbill *(Eretmochelys imbricata),* nest annually along the coastal strip adjacent Ningaloo Reef, Western Australia. This includes beaches of JCP, NWC. All three species are potentially subjected to fox predation of nests during turtle season, as foxes have a confirmed presence within this area (Randall & Bradley, 2003). On some beaches south of JCP, the European red fox has been responsible for up to 75 percent annual loss of turtle nests in the past decade (Mack, 1995-2001; Reinhold & Mau, 2003).

CALM monitors fox predation activity on the NWC and annually engages in fox control programs. Control efforts have primarily focused on 1080 (sodium fluoroacetate) baiting. Baiting is conducted seasonally between October and April in selected areas from Cape Range National Park to Coral Bay (Dean, 2003). In 2003, CALM in collaboration with the Department of Defence, also initiated the Ningaloo Fox Control Project.

Historically, no fox control measures have been warranted along the coastal strip of JCP, as limited problems of fox predation have been reported (Dean, 2003; Reinhold & Mau, 2003). However recent observations at Five Mile beach within JCP during the 2003/2004 turtle nesting season suggested otherwise. Until now, no comprehensive monitoring of fox predation had been conducted within this area which is considered to be a significant green turtle rookery (Prince, 1994; Waayers & Newsome, 2003).

3.0 Methods

3.1 Study area

Fox predation of sea turtle nests was intensively monitored from Five Mile North to Five Mile carpark within Jurabi Coastal Park on the North West Cape, Western Australia (Figure 1). Situated around latitude 21°S and longitude 114°E, this beach extends along 800 metres adjacent Ningaloo Reef (Figure 2) and is encompassed within the Marine Park. Green turtles *(C. mydas)* predominantly nest along this beach with some nesting activity by loggerheads *(C. caretta)* and hawksbills *(E. imbricata)*.

3.2 Monitoring fox activity at Five Mile

Presence of foxes on the beach and predation of sea turtle nests was monitored daily at Five Mile beach between January and April 2004, excluding one week at the end of March. This time frame incorporated both the peak nesting (January) and hatchling emergence (March) times of the turtle season. This study was run concurrently with a green turtle clutch survivorship study being conducted at Five Mile, thus those study nests were utilized as well as additional nests to include all green, loggerhead and hawksbill turtle nests which had been predated. Both newly laid nests and older nests were monitored for predation by foxes.

3.3 Fox predation of sea turtle nests

To determine the level of fox predation on sea turtle nests, and on each turtle species at Five Mile, all nests disturbed by foxes were recorded and GPS positioned. Those nests forming part of the clutch survivorship study were additionally positioned by triangulation from markers on the beach. Depredated nests were categorised as either:

- Incubating (eggs unhatched with developing embryos)
- Emergent (hatchlings having just hatched from eggs and in the process of emerging to, or having just emerged at the sand surface)
- Post-emergent (predation after the main run of hatchlings with possible predation of late emerging hatchlings)
- Revisit (fox has returned on subsequent nights following the main predation event with further predation having possibly occurred)

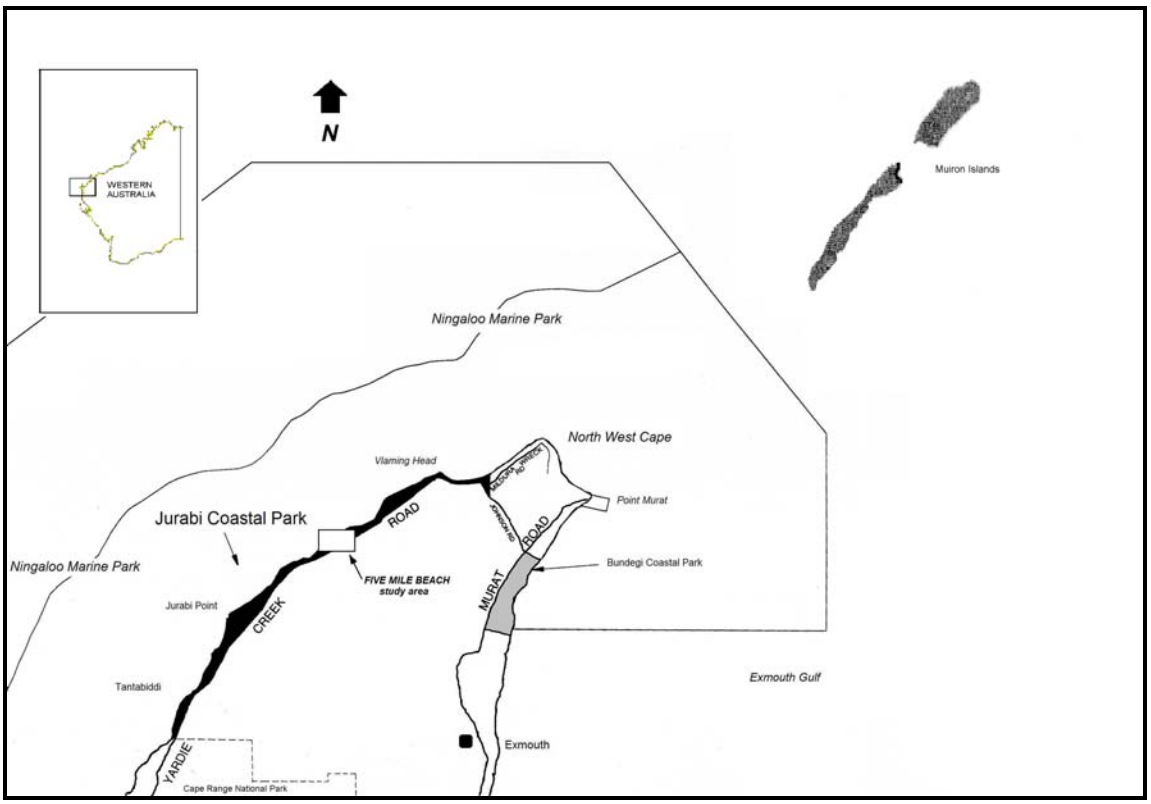

Figure 1: *Map of Jurabi Coastal Park adjacent Ningaloo Reef on the North West Cape, WA.*

Figure 2: *Aerial photograph of the fox predation study area extending 800 metres from Five Mile carpark to Five Mile North. Photograph courtesy of the Department of Primary Industries, WA.*

Species identity for each nest was confirmed either through cross-referencing to clutch survivorship study nests, track identification of nesting turtles or embryos and hatchlings found at depredated nest sites or during post-emergent nest excavations. Generally, only those nests which formed part of the clutch survivorship study were followed through to emergence of hatchlings and later excavated after predation events.

Actual percentage loss of eggs and hatchlings from individual nests has been report where this could be determined. In those cases either, clutch size was known, shells and broken eggs at the sand surface of depredated nests could be enumerated, or the number of hatchlings or tracks to sea and intercepted by foxes could be counted and compared with clutch size at nest excavations. When incubating nests had been partially depredated and eggs exposed and/or shells scattered at the sand surface, the number of shells and broken eggs were recorded and removed from the nest site and the nest re-covered to continue incubation.

Fox predation on other beaches within JCP is summarised from data collected by the NCTMP between 1 December 2003 and 29 February 2004.

3.4 Nest development at depredation

Depredated nests were recorded as either incubating, emergent, post-emergent, or revisit as previously mentioned. For incubating nests however, the level of embryo development at depredation is reported as a percentage of the nest incubation period. This incubation period was determined from known nest deposition dates to the first emergence of hatchlings, less 4 days over which hatchlings make their way to the sand surface (Godfrey & Mrosovsky, 1997).

It had been hoped that deceased hatchlings may be obtained from depredation events to determine development in accordance with Miller's turtle embryo staging criteria (Miller, 1985). However no deceased embryos were able to be obtained.

3.5 Review of fox control measures

In an attempt to control fox predation of nests at Five Mile, a wire cage trap was deployed by CALM on two separate occasions and different sites. This consisted of 16 days in January and 13 days in March 2004, during periods of fox predation activity along this beach.

The effectiveness of fox control measures employed by the CALM during the 2003/2004 turtle nesting season, including the wire cage trap located at Five Mile, are reviewed.

3.6 Recommendations

Recommendations on fox control within JCP are provided, and are based upon all data collected and analysed on fox predation levels within the park with particular reference to Five Mile.

3.7 Statistical analyses

Data of fox activity on Five Mile beach was analysed using a chi-squared contingency table. Statistical analyses could not be validly applied to any other data.

4.0 Results

4.1 Monitoring fox activity at Five Mile

Between January and April 2004, a total of 111 days of monitoring were conducted. Of these 111 days, foxes were present on the beach on 87 occasions (nights) over which 45 of these nights present resulted in predation activity (Table 1). This equates to 52 percent of the total nights foxes were present at Five Mile beach, that turtle nests were subjected to predation. Fox predation of sea turtle nests continued throughout the monitoring period from the first observed digging of a nest in early January 2004 through to the end of April 2004 when monitoring was concluded.

The greatest predation activity on turtle nests occurred in March 2004. A chi-squared contingency table revealed a highly significant association between predation activity and the months in which predation occurred ($X^2 = 11.82$, n = 45, df = 3, $P < 0.01$). However, Cramer's phi test detected that only 51% of the variation could be explained by this relationship (Appendix A). There was also evidence that fox predation activity had continued through the last week in March when monitoring was not conducted.

***Table 1**: Fox monitoring effort in days, fox presence on the beach, and predation activity by month from 1 January to 30 April 2004 (excluding one week in March) at Five Mile beach, Jurabi Coastal Park. Fox predation activity includes predation of incubating, emergent, and post-emergent phase nests, and nests revisited which were subjected to possible further predation. Predation activity refers to the number of nights when predation of a turtle nest occurred, although this may have resulted in multiple predation events (i.e.. several nests predated over a single night) which have not been listed separately in this table.*

Month (2004)	Monitoring effort (no. days)	Fox present on beach (no. nights) & as % of days monitored	Fox predation activity (no. nights) & as % of nights fox present on beach
January	30	24 (80%)	7 (29%)
February	29	19 (66%)	8 (42%)
March	24	22 (92%)	17 (77%)
April	28	22 (79%)	13 (59%)
Totals	111	87 (78%)	45 (52%)

4.2 Fox predation of sea turtle nests

Five Mile Beach

All three species of sea turtles nesting along JCP were subjected to depredation by foxes. In total, 33 incubating and emergent phase nests (10.1% of total nests laid) at Five Mile

beach during the nesting season between 17 November 2003 and 30 April 2004, were predated to some degree. By species, this consisted of 27 green (9.2% of total green nests laid), 3 loggerhead (12.5%), 2 hawksbill (66.7%), and 1 nest of undetermined species (25%) (Table 2). Of the 33 nests predated during the study, predation occurred to 14 of these nests during peak fox activity in March 2004 (Table 2).

Actual loss of eggs and/or hatchlings to fox predation could only be determined for seven nests. These nests experienced an average loss of 68.2 percent (range = 15.7 to 100 percent) of eggs and/or hatchlings from the total clutch (Table 3). Most of this loss was incurred when hatchlings were in the emergent phase from the nest.

Table 2: *Total nests laid at Five Mile and predation of nests of all three turtle species during various phases of nest development. Excludes 12 days throughout the nesting season from when monitoring commenced in November 2003, where data was either not available or beach was not monitored. An individual nest may have been predated during more than one phase of development, thus some nests have been recorded in more than one category. Total nests predated is the number of individual nests regardless of whether they fall in to one or more categories of development when predation events occurred. This total also excludes post-emergent (PE) nests as minimal loss is expected due to the main run of hatchlings having occurred prior to fox predation activity. G=green, L=loggerhead, H=hawksbill, U=undetermined species. Figures on the total nests laid provided courtesy of the NCTMP.*

Month	Nest Laid	Incubating (I)	Emergent (E)	Post Emergent (PE)	Total Nests Predated	Nest Revisit Predation
November 2003	**29** 24G/4L/1U	Predation not monitored but no activity apparent				
December 2003	**42** 39G/2L/1H	Predation not monitored but no activity apparent				
January 2004	**137** 126G/10L/1H	**1** 1G	**4** 3G/1H	**0**	**5** 4G/1H	**2** 2G
February 2004	**97** 86G/7L/1H/3U	**2** 2L	**5** 4G/1L	**2** 1G/1U	**6** 4G/2L	**4** 2G/2L
March 2004	**18** 17G/1L	**2** 1G/1H	**14** 11G/1L/1H/1U	**1** 1G	**14** 11G/1L/1H/1U	**4** 2G/1H/1U
April 2004	**3** 3G	**0**	**8** 8G	**4** 4G	**8** 8G	**3** 3G
Totals	**326** 295G 24L 3H 4U	**5** 2G 2L 1H	**31** 26G 2L 2H 1U	**7** 6G 1U	**33 (10.1% of total nests laid)** 27G (9.2%) 3L (12.5%) 2H (66.7%) 1U (25%)	**13** 9G 2L 1H 1U

Table 3: *Estimated loss of eggs and hatchlings to foxes from 7 nests of the 33 nests predated at Five Mile. Percentage loss from nests (total clutch) estimates the total loss of eggs and/or hatchlings in relation to the total clutch size. Percentage loss from nests (viable eggs) excluded those eggs which were undeveloped, unhatched or depredated in the nests by other sources.*

Nest ID	Species	Eggs	Hatchlings	Total Clutch size	% Loss from nests (total clutch)	% Loss from nests (viable eggs)
N005	Green		72	85	**84.7**	88.9
N007	Green	≥ 41		≥ 47	**≥ 87.2**	≥ 87.2
N052	Green		88	95	**92.6**	96.7
H009	Green		12	89	**13.5**	19.4
H032	Loggerhead	Unknown		Unknown	**100**	100
H033	Hawksbill	≥ 13	33	≥ 55	**≥ 83.6**	≥ 85.2
H038	Loggerhead		17	108	**15.7**	17.3

Jurabi Coastal Park

Very little fox predation activity was recorded on other beaches within JCP during daily monitoring of turtle nesting by the NCTMP between 1 December 2003 and 29 February 2004 (NCTMP, unpublished data). In total, 12 nests were predated by foxes. This consisted of five newly laid green turtle nests, and seven older nests, primarily incubating, of which there was one green, one loggerhead, and five nests of undetermined species.

4.3 Nest development at depredation

Primarily, foxes dug into emergent phase green turtle nests at Five Mile (Figure 3). Of the total nests laid for all three turtle species combined, 31 were depredated whilst in the emergent phase and five during incubation (Table 2). It was not uncommon for repeat digging by a fox into individual nests on days following the initial predation event. Thus an individual nest may have been depredated during both the incubating and emergent phases of nest development (see Appendix B for photographs of predation at various phases of nest development). No freshly laid nests were predated, however fox prints were regularly observed over the top of or within a five metre radius of new nests.

Of the five nests predated during incubation, embryo development in terms of the percentage of nest incubation period could be determined for only four nests. Although nest deposition date was known for a depredated loggerhead turtle nest (nest H032), foxes had taken the entire contents of the nest. Thus no eggs remained to produce hatchlings to emerge from the nest so total incubation period could not be known. Percentage of nest incubation for this nest has been estimated however, by using a similar incubation period known for other loggerhead nests deposited around the same time (Table 4).

Of the five nests predated during incubation, nest incubation period averaged 83.2 percent (range = 78.6 to 92.0%). All nests depredated during incubation where further subjected to loss of eggs and/or hatchlings during repeat predation visits by foxes (Table 4).

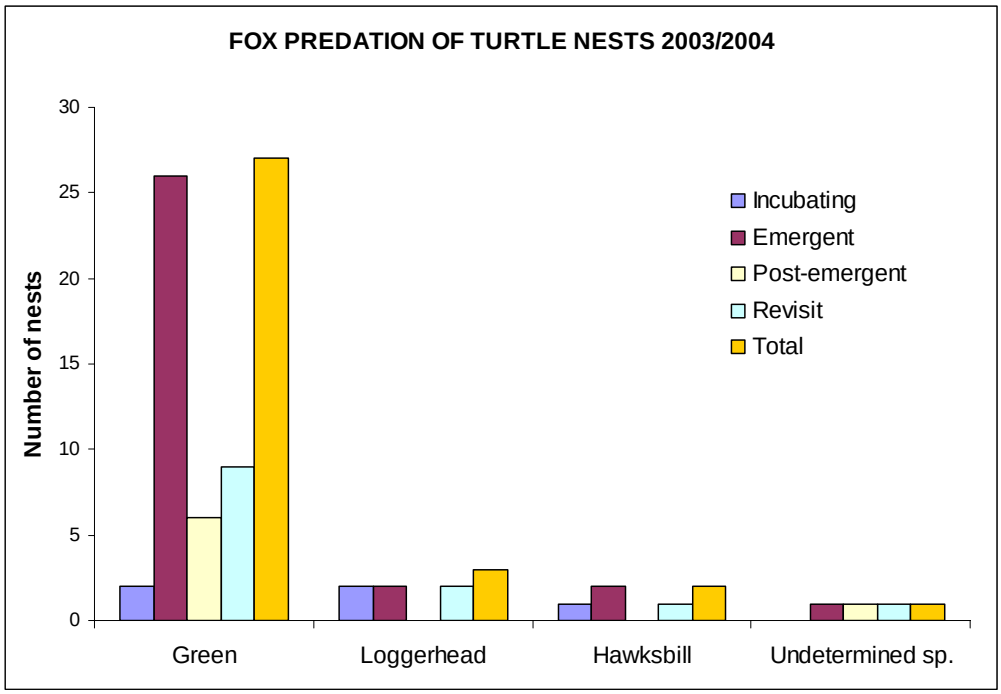

Figure 3: *Fox predation of nests of each of the three turtle species nesting at Five Mile beach showing the various phases of nest development when predation occurred. Emergent phase nests were predominantly predated by foxes.*

Table 4: *Development of embryos at depredation reported as a percentage of nest incubation period. Percentages estimated from known deposition and hatchling emergence dates (less four days from hatching to emergence of hatchlings at the sand surface). *Where emergence was absent due to total depredation, emergence date was estimated using data collected from same species nests deposited around the same time. All of these nests were revisited by foxes and further predated throughout development.*

Nest ID	Species	% of nest incubation period	Repeated depredation of nest
N007	Green	80.3	Yes - incubating
H027	Loggerhead	78.6	Yes - incubating & emergent
*H032	Loggerhead	82.1	Yes - incubating
H033	Hawksbill	83.0	Yes - incubating & emergent
H035	Green	92.0	Yes - emergent

4.4 Review of fox control measures

During the 2003/2004 turtle nesting season, only two fox control methods were employed by CALM. These methods were wire cage traps and 1080 (sodium fluoroacetate) baiting. Within JCP only wire cage traps were used, with the later method undertaken farther south along the coastal strip of NMP and also within Cape Range National Park.

Wire Cage Traps

The wire cage trap deployed at Five Mile failed to capture a fox. To a large extent the trap failed to even attract the attention of foxes with no activity observed around the trap during 45 percent of the trap deployment time. Fox tracks were observed nearby (within a five metre radius of, but not leading to the trap) during 35 percent of the time in which the trap was deployed (Table 5). There was however, an apparent failure of the trap to retain a fox on one occasion when the door of the trap was found closed and fresh fox tracks all around the cage. It appeared that surrounding vegetation had prevented the sliding bar from correctly engaging, thus enabling the animal to escape.

At Five Mile beach, there was one incidental capture of a non-target species, a perentie *(Varanus giganteus)*, which was subsequently release unharmed.

Table 5: *Recorded fox activity in relation to a single wire cage trap deployed at Five Mile over two separate periods consisting of a total of 29 days. On one occasion the cage was believed to have gone unchecked and therefore recorded as undetermined fox response.*

Fox response to trap	Number of days	% of response to trap deployment time
No prints nearby	13	45
Prints nearby	10	35
Prints around cage	5	17
Undetermined	1	3

CALM also deployed wire cage traps at Trisel and Baudin beaches within JCP during the 2003/2004 turtle nesting season. During 18 days of deployment, which included more than one cage per day on occasions for the two beaches combined, only one fox was caught. Ten days resulted in fox activity being observed around the cages (Oades, 2004).

Combined, of the 47 days in which wire cage traps were deployed on all three beaches by CALM, fox activity around these cages was observed during only 32 percent of their time in place.

1080 Baiting

At Bateman Bay, along the southern section of Ningaloo Marine Park near Coral Bay, a continued 1080 (sodium fluoroacetate) fox baiting program resulted in the reduction of sea turtle nest predation from 6.8 percent of confirmed nests laid in the 2002/2003 nesting season (Reinhold & Mau, 2003), to 2.3 percent in the 2003/2004 season (Parker *et al*., 2004). This was in contrast to a staggering 88 percent predation experienced on the neighbouring Whaleback Beach, adjacent Ningaloo Station, where baiting did not occur (Parker, 2004). Turtles nesting in this region are predominantly loggerhead species.

5.0 Discussion

The level of fox predation on sea turtle nests for all three species nesting at Five Mile beach, JCP, has been estimated in this study to be 10.1 percent of all nests laid during the 2003/2004 nesting season. For green turtles which predominantly nest along the coastal strip of JCP, the level of predation recorded was 9.2 percent. This satisfies the criterion of the *Recovery Plan for Marine Turtles of Australia* (Environment Australia, 2003), whereby greater than 70 percent of green turtle nests at Five Mile beach produced hatchlings. However, Flakus (2002) previously reported that continuing loss from sea turtle nests to foxes which exceeds five percent above natural annual mortality, is likely to significantly reduce turtle populations.

The level of predation experienced by loggerhead and hawksbill turtle nests was greater at 12.5 and 66.7 percent respectively. For loggerheads, the *Recovery Plan for Marine Turtle in Australia* aims to reduce fox predation of eggs and hatchlings to almost zero (Environment Australia, 2003). The level of predation on both loggerhead and hawksbill nests therefore far exceeds the recovery plan criteria. However, it must be emphasized that this study worked with very small sample sizes for both species.

When estimating predation in terms of actual loss of eggs and/or hatchlings rather than as the number of nests depredated during the season, an average loss of 68.2 percent (range = 15.7 to 100 percent) per depredated clutch, as estimated in this study, would need to be assumed. Thus, the expected average loss of eggs and/or hatchlings to fox predation would more likely be 6.9 percent (range = 1.6 to 10.1 percent) for all three species combined, and 6.2 percent for green turtles (range = 1.4 to 9.2 percent) from the total nesting effort during the study period.

JCP has been identified as a major green turtle rookery with some nesting by loggerhead and hawksbill turtles (Prince, 1994; Waayers & Newman, 2003). Loggerheads have been recorded to predominantly nest on the Murion Islands, 16 kilometres north east of Point Murat on the NWC (Prince, 1993), and farther south of JCP including Coral Bay (Reinhold & Mau, 2003). Given this, the level of predation on loggerhead turtles in JCP may be of little consequence. For hawksbill turtles however, relatively low levels of nesting within the region of the NWC peninsula (Mack, 1995-2001; Prince, 1994; Reinhold & Mau, 2003; Waayers & Newman, 2003), may suggest that any level of predation could be critical to the survival of the local population of this species.

Monitoring of beaches other than Five Mile within JCP by the NCTMP, revealed that only 12 nests had been predated by foxes during the 2003/2004 turtle season (NCTMP, unpublished data). However, as monitoring is concentrated on turtle nesting success rather than fox predation, it is possible that much of the predation activity may have gone unnoticed and therefore unrecorded.

The first sign of fox predation of turtle nests at Five Mile beach was observed in early January 2004. Foxes were most active and predation increased during March 2004, which

coincided with the peak of hatchling emergence from nests. The statistically significant relationship between predation activity and the time of the turtle season, which only explained 51 percent of the variation, may possibly be further explained by the difference in hatchling activity given that predation occurred most frequently on emergent phase nests.

As the peak of fox activity and predation at Five Mile occurred in March, it is reasonable to expect that predation would have also continued on other beaches along Jurabi Coastal Park during this time. However, this would have gone unrecorded due to the NCTMP having completed monitoring of nesting activity in this area at the end of February 2004.

At Five Mile, predation of turtle nests appeared to primarily be the result of a single fox on the beach on any given night. Seldom was there more than a single set of fox tracks, and on those few occasions when there were more than one fox, it appeared to be one adult and a juvenile. Thus, the number of foxes accessing beaches of JCP may in fact be no more than a few individuals (Oades, 2004).

Predation of green turtle nests predominantly occurred during the period when hatchlings were in the emergent phase from nests. Intercept predation by foxes on hatchlings along the beach prior to reaching the sea, although generally not enumerated in the current study, is also a regular occurrence (Randall & Bradley, 2003). From track observations, Randall & Bradley (2003) reported a 12.7 percent loss of hatchlings to foxes prior to reaching the sea.

Although predation of emergent phase nests dominated at Five Mile, incubating nests of all three turtle species were also partially or totally destroyed by foxes. Two green turtle nests depredated during incubation both appeared to have been made shallower due to body pits from other nesting turtles. Shallower nest depths of both the hawksbill (mean = 62 cm) and loggerhead turtles (mean = 70 cm) nesting at Five Mile, as opposed to the average depth of green nests (mean = 77 cm) (pers obs), may have also had some bearing upon the higher level of fox predation encountered by these two species.

All turtle nests at Five Mile predated by foxes during incubation were in later development averaging 83.2 percent of their incubation period. However studies have shown that foxes will dig up nests at any stage of development from the night in which they are laid or within a few days following, to late in incubation and upon hatching (Mack, 1995-2001; Reinhold & Mau, 2003).

Predation of nests sometimes occurred both during incubation and again during the hatchling emergence phase. It is also not uncommon for a nest to be revisited by foxes with a further attempt at predation of straggling hatchlings on days following the main run from the nest (Mack, 1995; Randall & Bradley, 2003) as was observed during this study.

Unlike some beaches within JCP during the 2003/2004 nesting season (NCTMP, unpublished data), and beaches at Coral Bay (Mack, 1995-2001; Reinhold & Mau, 2003),

no freshly deposited nests were depredated by foxes at Five Mile. However on one occasion it was observed that a fox had repeatedly dug into fresh turtle body pits presumably trying to locate a new nest.

At Five Mile, all but one of the disturbed nests were only partially predated, although there were repeated attempts on consecutive nights on many of these nests to take the remaining contents. Apart from the obvious loss of eggs and hatchlings to direct predation, there is also the potential to negatively impact upon the remaining nest contents. Eggs or hatchlings that remain in the nest may be exposed to the elements, such as direct sunlight and temperature fluctuations, which is likely to increase the rate of mortality above predation (Reinhold & Mau, 2003). It is also expected that the level of natural predation under these circumstances is likely to increase as seagulls and crabs may easily access remaining exposed nest contents (pers obs). It was observed at Five Mile that hatchlings not quite ready to emerge were often left exposed in partially predated nests dug by foxes. Also, torn eggs and spilt contents were regularly removed from partially predated incubating nests, which, if left, may have caused decay of remaining viable eggs (Phillot & Parmenter, 2001).

The practice of removing broken or split eggs and shells, and re-covering of partially predated nests, is expected to have influenced the true level of fox predation and loss to turtle nests in this study. Natural revisit behaviour by foxes to these nests may have been altered by researcher interference. Predation by other sources following initial fox predation may have also been disrupted. However the practice of removing broken eggs and re-covering nests has proven successful in the continued incubation and emergence of hatchlings from partially predated nests (Mack, 2000; pers obs).

Historically, until the 2002/2003 turtle nesting season no fox control measures had been employed by CALM along Jurabi coastal strip. However, given the observed level of predation at Five Mile during the 2003/2004 turtle season it may be necessary that more effective control measures be put in place, or that the situation be monitored annually to assess if the current level of depredation increases.

Wire cage traps deployed by CALM at Five Mile, Trisel and Baudin beaches during the 2003/2004 turtle season proved relatively unsuccessful except for the capture of one fox at Trisel (Oades, 2004). The capture of this fox early in the turtle season appeared not to reduced fox activity on the adjacent Five Mile beach during the remainder of the season (pers obs). The failure of a trap to secure a fox on one occasion at Five Mile may have resulted in this fox becoming trap shy. CALM has highlighted that mechanical or human error may disrupt the chances of catching a fox and invoke trap shyness (Oades, 2003). The limited success of these traps therefore highlights the need to review current fox control methods used in JCP. Oades (2004) recommended that a 1080 (sodium fluoroacetate) baiting program be implemented between Five Mile and Trisel annually between October and March.

In response to unacceptably high levels of fox predation of sea turtle nests along southern beaches of Ningaloo Marine Park, CALM implemented a 1080 fox baiting program in the

2002/2003 turtle nesting season. The success of this fox abatement strategy in reducing predation of turtle nests at Batemen Bay to below the target objective of 5 percent (Parker *et el*., 2004), indicates that 1080 poisoning is an effective method for reducing fox predation. This success is further realised when comparing the high level of predation, 88 percent, experienced at the neighbouring Whaleback Beach where no fox control measures were taken (Parker, 2004).

Although 1080 is a naturally occurring toxin in numerous Australian plants, from which many native fauna are reasonably resilient (Dep. Agriculture *et al.*, 2002; Twigg & King, 1991), there has been some apprehension in relation to non-target species uptake of baits (Flakus, 2002; Dean, 2003). Of particular concern is the potential for uptake by domestic dogs (Dean, 2003). Domestic dogs were observed on occasions at Five Mile beach during the turtle season, and, as a rule they were unleashed and at times unattended whilst owners snorkeled or swam in the sea (pers obs).

Should 1080 baiting be introduced into JCP, and following the appropriate risk assessment by CALM, it would also be appropriate to include some form of monitoring to determine bait uptake by the target species (Flakus, 2002) and also to gauge the success of baiting in reducing predation levels on turtle nests.

Regardless of the method employed to control fox predation of sea turtle nests, the Department of Environment and Heritage through their national *Recovery Plan for Marine Turtles in Australia*, recognise the necessity for control programs of feral animals to increase nesting success where turtle population have been identified as a priority (Environment Australia, 2003). JCP has been identified as being a significant green turtle rookery (Prince, 1994; Waayers & Newman, 2003), and is now confirmed to have a fox control problem (this report). If not monitored or if left uncontrolled, fox predation of sea turtle nests in JCP may continue to escalate unnoticed to an unsustainable level.

6.0 Conclusions

Results from recent observations and monitoring of fox predation activity at Five Mile beach, JCP during the 2003/2004 turtle nesting season indicate that there is cause for concern. Depredation of sea turtle nests has reached an estimated 10.1 percent of total nests laid, all species combined, with an average loss of 68.2 percent of eggs and/or hatchlings per nest. This level of predation satisfies the Department of Environment and Heritage's management criterion of the *Recover Plan for Marine Turtles of Australia*, whereby greater than 70 percent of nests produce hatchlings. However, there is the potential that this level may escalate if left uncontrolled.

Also, predation of loggerhead turtles on this beach far exceeds the recovery plan's specified near zero fox predation level, being at 12.5 percent. However caution must be exercised in reviewing the result of loggerhead and hawksbill turtle nest predation, as these were derived from very small sample sizes.

Predation levels on other beaches within JCP are expected to have been higher than reported as much of the predation may have occurred relatively unnoticed.

Fox predation continued throughout the turtle season extending into April when nesting activity had ceased but hatchlings were still emerging from nests. Most predation experienced was to emergent phase nests, although incubating nests in the later stages of development were also totally or partially destroyed.

The use of wire cage traps employed by CALM to control fox predation of turtle nests during the 2003/2004 turtle nesting season has proven to be ineffective. Given this, it may be appropriate that more effective measures by taken by CALM to control fox predation of sea turtle nests in future seasons to ensure predation at Five Mile does not exceed the current level being experienced. In order to assess the future effectiveness of fox control measures, some form of monitoring will be necessary.

7.0 Recommendations

1. Given the level of fox predation recorded at Five Mile, JCP, during the 2003/2004 turtle nesting season, consideration should be given to implementing appropriate and effective fox control measures annually from October to April. This extends beyond the turtle nesting period and proposed baiting program by CALM from October to March to incorporate most of the hatchling emergence period as predation continues during this time.

2. Clearly, wire cage traps do not appear to warrant further use due to the lack of success in controlling fox predation during the 2003/2004 turtle season. Therefore, an alternate and preferred method/s should be employed by CALM following the appropriate risk assessment/s.

3. Should 1080 baiting be conducted as proposed by CALM within JCP, attempts should be made to regularly check baits to asses bait uptake and determine if this is by the target species or other fauna.

4. Monitoring of fox activity should be continued at Five Mile and extended to beaches further south to at least include Trisel which adjoins Five Mile, as fox predation appears to be most intense in these areas of JCP. The development of an appropriate datasheet to record fox activity and the loss incurred to nests, and possibly incorporating the uptake of baits should be considered. The inclusion of fox monitoring and completion of the datasheet could be incorporated into the NCTMP, but would require careful negotiation with the programs Steering Committee.

5. Procedures should be development by CALM for the NCTMP on dealing with partially predated nests by foxes to increase the likelihood of successful incubation or natural emergence of remaining eggs or hatchlings.

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Appendices

Appendix A

Chi-Squared Contingency Table Fox Activity and Nest Predation									
	January		February		March		April		Total
	Obs	Exp	Obs	Exp	Obs	Exp	Obs	Exp	
Predation Activity – Nights (of total nights fox present on beach)	7	(45 x 24) / 87 = 12.4137	8	(45 x 19) / 87 = 9.8275	17	(45 x 22) / 87 = 11.3793	13	(45 x 22) / 87 = 11.3793	45
$(O-E)^2/E$	= 2.3610		= 0.3398		= 2.7762		= 0.2308		
No Predation – Nights (of total nights fox present on beach)	17	(42 x 24) / 87 = 11.5862	11	(42 x 19) / 87 = 9.1724	5	(42 x 22) / 87 = 10.6206	9	(42 x 22) / 87 = 10.6206	42
Total	24		19		22		22		87
$(O-E)^2/E$	= 2.5296		= 0.3641		= 2.9745		= 0.2473		

X^2 = 2.3610 + 0.3398 + 2.7762 + 0.2308 + 2.5296 + 0.3641 + 2.9745 + 0.2473 = 11.8236

Degrees of freedom (df) = (rows - 1) x (columns - 1)
df = (2-1) x (4-1) = 3

Sig levels: 0.20 0.10 **0.05** 0.025 **0.01** 0.001
Crit vals: 4.64 6.25 **7.82** 9.35 **11.34** 16.27

Sig. 0.01: chi is greater than or equal to 11.34

Degrees of freedom: 3
Chi-square = 11.8236889572416
p is less than or equal to 0.01.
The distribution is significant.

CRAMER'S PHI – (the product interpreted as a Pearson's r)
Square root of (chi-square/(n*(k-1))) = Square root (11.824/45(2-1)) = 0.513
r_2 = 0.513
0.513/1 * 100 = 51.3%

Appendix B

Photographs of nests predated by foxes during various phases of nest development, and revisit predation activity at Five Mile beach, JCP.

Nest ID: H027. 22Feb04. Loggerhead nest with incubating eggs exposed.

Nest ID: H027. 5Mar04. Loggerhead hatchling from emergent phase nest with head bitten off.

Nest ID: H033. 4Mar04. Predated incubating hawksbill nest. 84% predation of eggs and hatchlings combined over revisit fox activity.

Nest ID: H033. 4Mar04. Hawksbill nest with split egg and live embryo still inside

Nest ID: H038. 21Mar04. Loggerhead hatchling heads slightly exposed after partial predation of emergent phase nest.

Nest ID: N005. 24Jan04. Green nest, 85% predation of emerging hatchlings.