An evaluative and evidence based report

of the project

Studying the incubation temperature of a nesting population of olive ridley turtles (*Lepidochelys olivacea*) in the coast of Maharashtra with advance data logging system (Phase II).

Principal Investigator
Sumedha Korgaonkar
PhD scholar
Wildlife Institute of India, Dehradun.

Project Supervisor
Dr K Sivakumar
Scientist F & Head of department of endangered species management
Wildlife Institute of India, Dehradun.

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Executive Summary

The Indian Ocean west is considered as the 8th regional managing unit (RMU) for the conservation of olive ridley turtles. Maharashtra coast of west India is the significant solitary nesting site for this species and leads the conservation program in this RMU, effectively. Indian Ocean west is a putative RMU for this species due to lack of knowledge especially of terrestrial life cycle. In the climate change scenario where high temperature is shifting the peak nesting season, as a research priority, there is a need for identifying preferred nesting site and factors that maximize hatching success. The shift in the nesting season in prominently observed in Maharashtra from December- January in 2002 (winter nesting season) to February- March in 2020 (summer nesting season). Nest temperature plays a pivotal role in embryonic development, the sex ratio of population, hatching and emergence success rate. Increased temperatures as a result of late nesting extending to summers would not only alter sex ratios of the population but also decrease hatching and emergence success. Lethal nest temperatures during the pre-emergent period could compromise the successful emergence of hatchlings by inhibiting coordinated movement and in extreme cases can cause muscle spasms. The highly skewed female-biased sex ratio of hatchlings is observed at all sea turtle nesting sites in the world and is currently the focus of sea turtle research.

Being small in size than other sea turtles the olive ridley nest are shallow. Due to this, the developing embryos are subjected to fluctuations in the temperature. Studies have reported the terrestrial life cycle of olive ridley to be more vulnerable to high mortality rate than other endangered sea turtles. This species has shown low tolerance to high temperature.

The temperature provided to the developing embryos inside the nest depends on factors such as ambient air temperature, sand colour, sand grain size, sand thermal conductivity, depth of the nest, vegetation cover on the beach, biological heat developed during growth. The various factors result in different outcomes on the nesting sites in terms of hatching and emergence success rate. The nesting site in Maharashtra coast showing variations in sand type due to the presence of estuaries and extent of vegetation cover on the beach. It is expected to show varying nest temperature within and between the sites though the ambient air temperature is more or less constant.

The ‘Temperature data logger’ project was designed to continuously monitor and assess the effect of temperature on hatching success and effectively implement a mitigation method. An advance temperature data logging system has been developed and customized in this project to be used for sea turtle conservation. The data logger instrument is found to be technically robust in its functioning on

turtle nesting beaches in extreme weather conditions. A total of 49 nests were monitored with the temperature data logger in 2019-20 nesting season.

The phase II of this project has managed to fill in the knowledge gap of the incubation temperature, threshold temperature and its effect on hatching and emergence success on each nesting sites with a preliminary observation on mitigation. New methods were applied during the project and protocol standardised for the same. The reason for low hatching success is based on many factors and prominent being temperature and relocation skills. A direct method of nest excavation post successful emergence or failed emergence was done to evaluate the exact reason of mortality. In case of failed emergence, the nest excavation after the avg incubation period of 50 days has shown, dead or highly dehydrated live hatchlings stuck inside the nest. Rescue of these hatchlings adhering to the standard protocol is a must and needs to be implemented. The excavation of the nest and thorough examination of the unhatched eggs also gives a clear picture of the reason for mortality.

The overall sex ratio of hatchlings from Maharashtra is female-biased but a sizable number of male hatchlings are also released. The female-biased sex ratio is not a concern now for the nesting population in Maharashtra so any attempt to alter the sex ratio should not be encouraged on the nesting sites. Instead, the early nest found from Nov to Jan end should be highly protected at all sites as this will ensure the male-biased sex ratio and successful release of male hatchlings. More focus should be given to the mitigation of the nest temperature and maintaining it below the threshold temperature of 33^0C. The partial and complete application of the use of green shade net did not show any promising result. Use of cane basket and wet jute gunny bag kept over the nest has reduced the nest temperature by 1.5 ^{0}C and has worked on white and coarse sand of Vayangani -Vengurla. The use of the type of shade most suitable for the specific sand type needs further examination.

The project was successful due to the active participation of hatchery managers and volunteers during this pandemic and national lockdown. Excavation of nest, examining the eggs, experimental set up to test the efficiency of the shade was done by these hatchery managers in coordination with the PI. The local hatchery managers are the only unchangeable stakeholders in turtle conservation who witness the change on their site. They should be developed further as **Parabiologist** to achieve the long term conservation goal of the project.

This project is a first of its kind globally where temperature data logger is deployed on large scale at major nesting sites with a goal of long term conservation and monitoring. The information procured from the project would help in adapting a mitigation strategy specific for the nesting beach. Maharashtra being a major nesting site for olive ridley sea turtle has come a long way in pragmatically conserving this species. Maharashtra Forest department can take lead actions in introducing the scientific evidence, an outcome of this project to strategize and adapt the hatchery management practice. It will ensure not just the increase in hatching success but also ensuring a healthy stock of olive ridley population of the Indian Ocean west.

Acknowledgement

I will always be grateful to my PhD supervisor and mentor Dr K Sivakumar in giving me an opportunity to work on sea turtles on such a larger scale. We both are thankful to Shri N Vasudevan ex-Director Mangrove and Marine Biodiversity Conservation Foundation of Maharashtra for selecting this project for funding. We also thank Shri Virendra Tiwari APCCF and Director of Mangrove and Marine Biodiversity Conservation Foundation of Maharashtra and wish for his support and cooperation in future projects. I'm grateful to Dr Manas Manjarekar for aptly believing in the scale and outcome of this project with a long term conservation goal.

The execution of the project was in dilemma due to pandemic and national lockdown. I must appreciate the efforts of all the hatchery managers who has gone out of their way to collect information and overcome technical issues in order to run the project successfully. Iam thankful and indebted to Dhopavkar mama and Rakesh Dhopavkar of Kelshi, Ajinkya Keluskar of Anjarla, Kedar and Pravin Todankar of Kolthare, Dattaram Vanarkar of Dabhol, Pradeep Dingankar and Rakesh Patil of Gaokhadi, Shyamsunder Gavankar of Madban and Suhas Toraskar of Vayangani for making phase II of this project a success.

Some people needs special mention for their pro-active role in collecting scientific evidence, disseminating information to beach managers and participating voluntarily in this project. Yogesh Anavkar from Kelshi, Nandu Gavankar of Madban, Prakash Khobrekar and Digambar Toraskar of Vayangani. Their participation has helped me in coordination and collect information during lockdown. Due to their involvement some important fact filled information was gathered. Pradeep Dingankar and Ajinkya Keluskar needs special mention for applying the techniques they have learned in phase I helping the project to its logical outcome. I am thankful to all these dedicated people.

This year was different due to pandemic and lockdown making the implementation of the project difficult. I sincerely thank DFO Ratnagiri Shri Ramakant Bhawar Sir and RFO Dapoli Shri Vaibhav Borate sir for their kind cooperation and patience. Borate sir needs special mention for sharing a detailed and accurate nesting data of Dapoli region which has helped in an important scientific observation. I am also thankful to other officials of Maharashtra Forest department. Lastly, I would like to thank PCCF (WL) of the Maharashtra State Forest Department for granting me permission to work on Schedule I species

Ms Sumedha Korgaonkar
18 th Nov 2020

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Introduction:

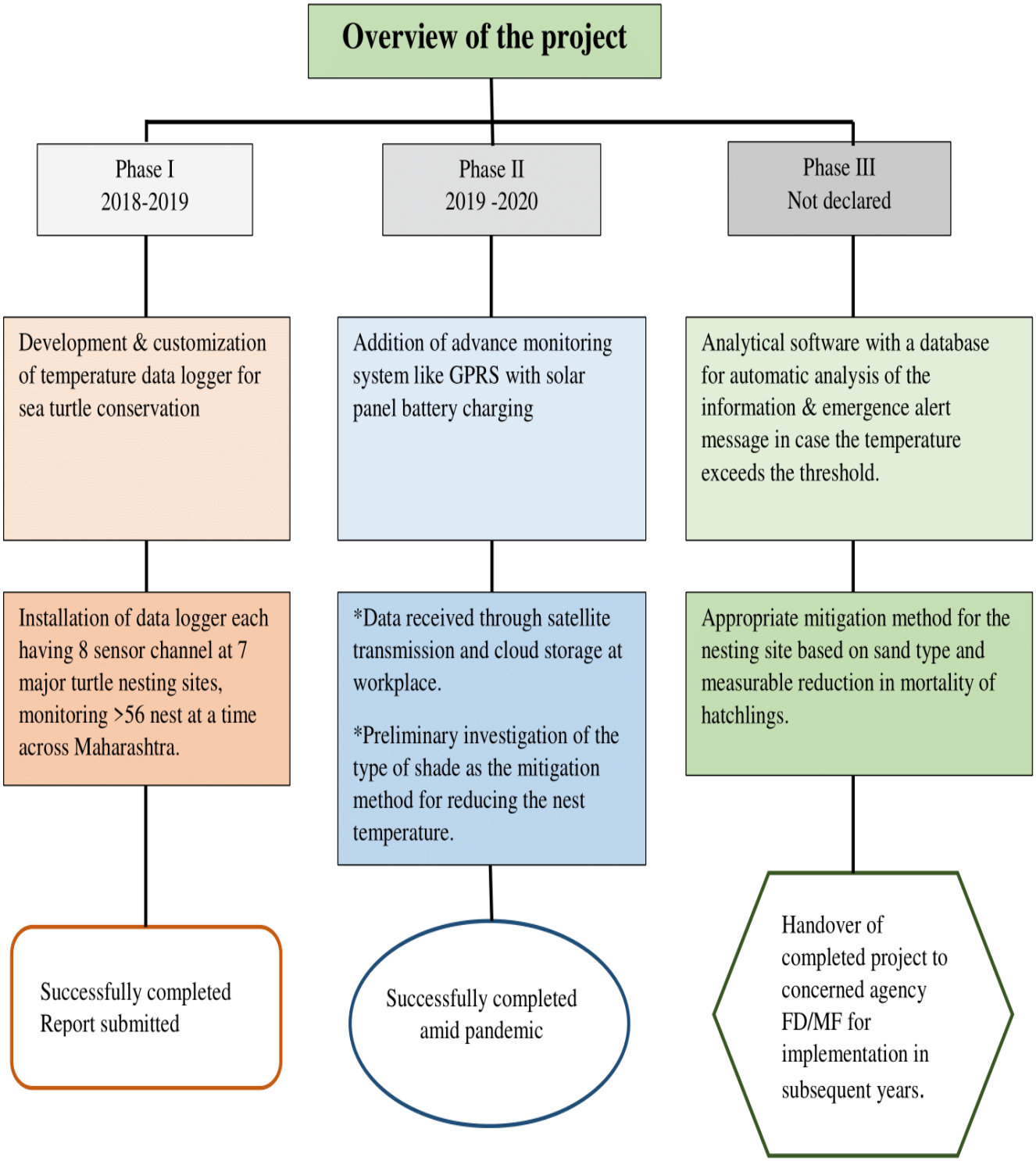
Globally, Indian Ocean west is considered a putative Regional Managing Unit (RMU) for the conservation of olive ridley turtle and necessitates research (Wallace et al., 2010). The regional population of circum-tropically distributed olive ridley turtles occupies distinct ecological roles in defined RMU attracting conservation efforts. Maharashtra in the west coast of India, a part of this unit harbors important nesting site for this distinct population of solitary nesters.

As a research priority, there is a need for identifying the preferred nesting site and factors that maximize hatching success. Nest's environmental conditions affecting sea turtle embryonic development can vary between inter and intra nesting beaches. This difference is due to geographic location, weather, human interactions, and sand characteristics. Like other reptiles, **the sex of the hatchling is temperature-dependent. Generally, lower incubation temperatures (25°C -28°C) produce males while higher temperatures (30°C -32°C) produce females** but could vary among populations. Nest temperature plays a pivotal role in embryonic development, the sex ratio of population, hatching and emergence success rate. Increased temperatures as a result of climate change or late nesting extending to summers would not only alter sex ratios of the population but also decrease hatching and emergence success (Laloë et al., 2017) Lethal nest temperatures during the pre-emergent period could compromise successful emergence of hatchlings by inhibiting coordinated movement and in extreme cases can cause spasms (Rings et al., 2015).

Sea turtle beach hatcheries existing as an ex-situ conservation management is a common practice in Maharashtra. The average four years nesting data of forest department from various nesting sites suggest >50% hatching success rate. To assess the effect of temperature on hatching success and effectively implement a mitigation method with a continuous temperature monitoring system has been developed and customized.

The objective of the phase II project is as follows:

1. To install the temperature data logger with advance GSM hardware and solar panels.
2. To evaluate the effect of the temperature on the hatching and emergence success rate for the complete nesting season on all sites.
3. To suggest and implement field methods mitigating the effect of high temperature on the nest.



Studying the incubation temperature of a nesting population of olive ridley turtles (*Lepidochelys olivacea*) in the coast of Maharashtra with advance data logging system (Phase II) – Submitted by Sumedha Korgaonkar (Nov 2020).

Key stakeholder:

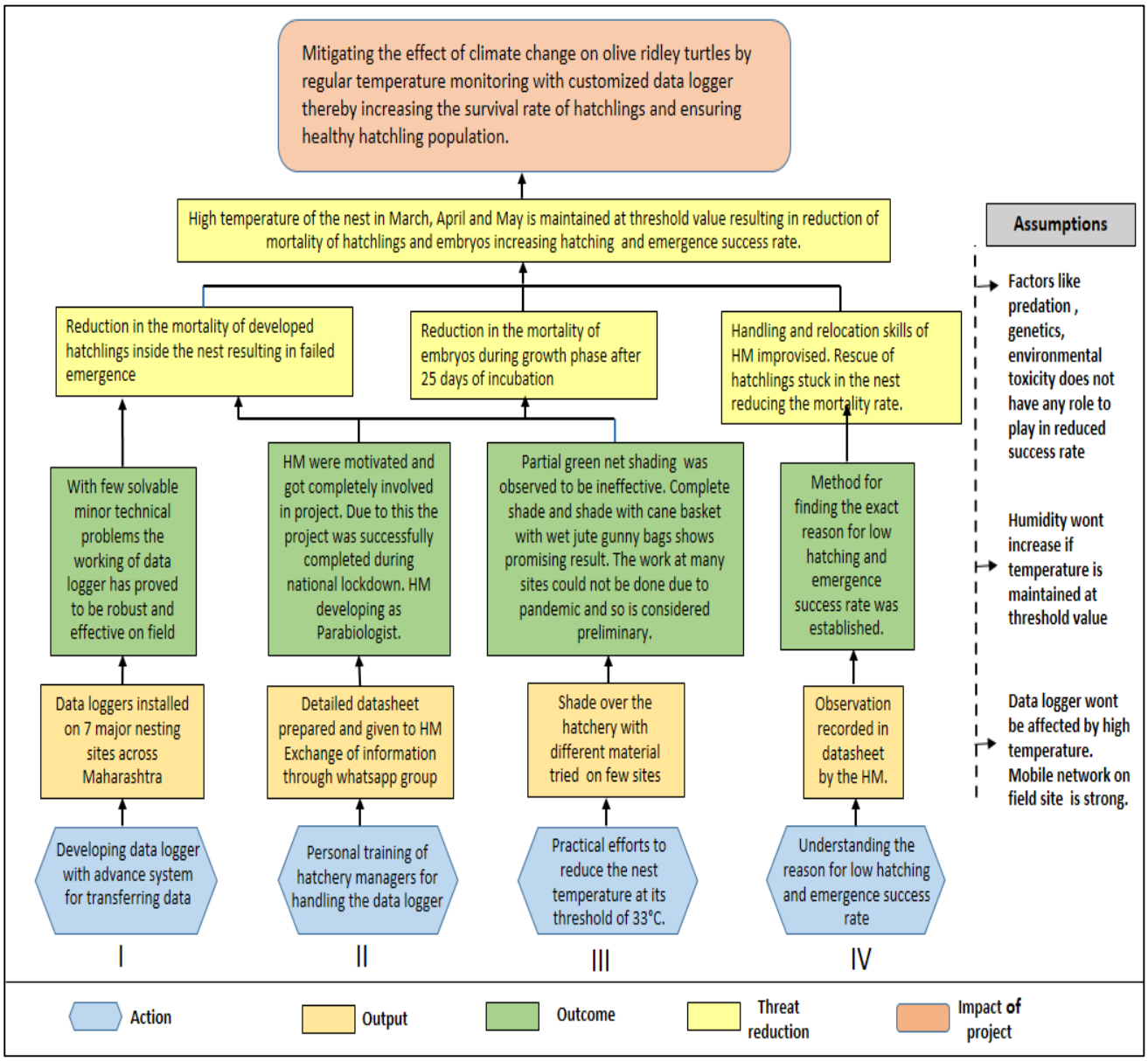
The following key evaluation stakeholders have been identified and documented in the table below along with their interest in the evaluation.

Sr no	Key stakeholders	Interest
1	**Mangrove and Marine. Biodiversity Conservation Foundation of Maharashtra.** (hereafter mentioned as MF)	As a funding agency, their interest is in the utilization of funds in the project and outcome of the project having long term conservation impact.
2	**Maharashtra State Forest Department** (hereafter mentioned as FD)	Their interest would be in recommendations and SOP for effective hatchery management practice based on the outcome of this project.
3	**Local hatchery managers** (hereafter mentioned as HM)	The actual on-field implementation of hatchery management is done by locals who are temporarily appointed as hatchery managers during nesting season. The project will inform them of the scientific evidence, general practice & corrective measures that are needed for maximizing the hatching success rate.

Activity Timeline:

Sr.no	Activity	Time period	
		Planned	Actual
1.	Temperature data logger with advance GPRS system and solar panel with extra battery- Vendor purchase order and installation on field	Jan 2020	Placing order – Dec 2019 Procurement of Data logger – 1st week of Feb 2020. Installation of Data logger – 1st & 2nd week of Feb 2020.
2.	Data collection and conservation efforts	From installation till end of season ie: May 2020	From installation till end of season ie: May 2020
3.	Data analysis and final report submission	May 2020 - October 2020	May 2020 - October 2020

Intervention logic: Phase II of the project.



Part A - Evaluation framework of Project

Evaluation source:

PRISM is a toolkit developed by a collaboration of international conservation organizations to help support conservationists to evaluate the outcomes and impacts of their work. The toolkit is specially designed for low to medium budget project (5000$ - 100000$) and having short duration of <5 years. Short term conservation projects often has the measurable impact visible many years after the project ends. This toolkit with its evaluation of outcome and impacts helps to overcome this challenge.

Source: www.conservationevaluation.org

Purpose of the evaluation: The short term project aims to achieve a long term conservation impact in mitigating the effect of high nest temperature due to gradual shift of nesting season from winter season to the summer season (see part B).

The evaluation of the outcome and impact of this project will help in identifying if any modification required for improved delivery in case the project gets approved for phase III. Detailed scrutiny thorough evaluation would give insight into what works and what won't on the field to decide on the actions and effective implementation for long term conservation impact.

Evaluation method:

As per the intended outcome and key questions different evaluation method is selected. Direct measure on the field, survey, questionnaire for focus group (HM), before and after measure (see M&E plan in annexure).

Limitations of Evaluation:

Limitations if any is assessed and highlighted in terms of their impact on lessons and recommendations for improvement (see M&E plan in annexure).

Key evaluation questions: Based on outcomes of phase I of this project concluded in 2019 nesting season and available literature, key questions were framed in phase II of this project (see M&E plan in annexure).

The following are the key questions addressed in evaluation:

Q1) Is climate change the driving force behind the shift in nesting pattern to hot summer months reducing the hatching success rate?

Q2) Are the deployed data loggers robust in their application on the field?

2a) Is the data logger and its accessories in any way harmful to the incubating nest or emerging hatchlings?

2b) Has the data from data logger helped in collecting information filling up the knowledge gap for the conservation of this species in Maharashtra?

Q3) Developing hatchery manager from the local community as Parabiologist by imparting advance training. Will it help to achieve the long term conservation goal of the project?

Q4) Are there completely developed hatched but dead hatchlings seen in the nest post-incubation period?

4a) Is it correct to open the nest as a general hatchery management practice at the time of emergence to rescue the hatchlings in case the hatchlings fail to emerge?

4b) What method should be implemented for the mitigation of temperature?

Q5) Will the evaluation of eggs to check the stages of development at mortality give a clear picture of the reason of mortality?

Evaluation findings of the project

Q1) Is climate change the driving force behind the shift in nesting pattern to hot summer months reducing the hatching success rate?

Score card

To evaluate the Climate change as the driving force behind shift in nesting pattern resulting in high nest temperature reducing hatching success rate.			
Aspect of Knowledge	**Before the project**	**After the project**	**Estimate without the project**
Threats	**Score 1** - threat unknown to study site.	**Score 5**- Data analysis has identified key threats with high confidence.	**Score 2**- Some ad hoc data or expert judgment about the importance of potential threat(s) is available
Justification	In recent years the effect of climate change and global warming on turtle breeding and nesting has been published in international journals. The shift in nesting pattern was first reported in phase I report of this project from the study site. Informally the HM were aware of the shift and had a fair idea about the threat. The nesting data documented by FD strongly indicate this shift from 2014 onwards. Literature review of past 5 years on sea pinpoints the effect of climate change on breeding and nesting turtle happening globally. Analysis of secondary data in the project has identified the key threats.		

Score

Threats	**1**- Threats unknown to the study site
	2- Some ad hoc data or expert judgment about the importance of potential threat(s) is available
	3- limited analysis of single threat is available, but from a limited sample or small proportion of the project area (ie : may not be representative)
	4- Robust analysis of threats undertaken but key threats still not identified.
	5- Data analysis has identified key threats with high confidence.

Q2) Are the deployed data loggers robust in their application on the field?

Score card

To evaluate the application of customized developed temperature data logger used for identifying high temperature as key threat at major nesting sites of Maharashtra.			
Aspect of Knowledge	**Before the project**	**After the project**	**Estimate without the project**
Actions/ Interventions - C	**Score 1-** Solutions untested in study area.	**Score 5-** Analysis of the impact of intervention and mitigation of the threat at multiple locations (7 major nesting sites) which can be synthesized using meta analysis.	***Score 1-*** Solutions untested at study sites.
Justification	The temperature monitoring and mitigation was not studied previously at study sites. Although Dakshin foundation had given pendant data logger at one site to be used in few nest before this project. No data is available from this intervention in publication or report. The data logger developed through this project is robust in its application. It is customized for use in study area having high temperature and humidity. Data is collected from 5 sites from 5x8= 40 nest giving a complete spectrum of information. The metadata analysis of which can give an in-dept information of the threat which could be used accurately for mitigation hence the score of 5. In absence of this project hypothetically it would have been difficult to initiate such intervention at a large scale.		

Score

Actions/ Interventions	**1**- Solutions untested in the study area
	2- Some anecdotal information about responses to interventions at one or a small number of locations.
	3- Some quantitative information or expert based assessment on the effectiveness of action.
	4- Some formal analytical tests undertaken on the success of intervention from at least one location.
	5- Analysis of the impact of intervention and mitigation of the threat at multiple locations which may be synthesized using meta analysis.

2b) Has the data from data logger helped in collecting information filling up the knowledge gap for the conservation of this species in Maharashtra?

Score card

To evaluate the intervention for low emerging rate of hatchlings during the month of April and May at major nesting sites of Maharashtra.			
Aspect of Knowledge	**Before the project**	**After the project**	**Estimate without the project**
Actions/ Interventions - A	**Score 1**- Solutions untested in study area	**Score 4** - some formal analytical tests undertaken on the success of intervention from at least one location	**Score 2**- some anecdotal information about responses to interventions at one or small number of locations.
Justification	In absence of the knowledge of the threat no solutions were implemented officially before this project. Though at some sites, hatchery managers unofficially had rescued the hatchlings by opening the nest after the first natural emergence of the hatchlings. This was done during the summer months of April and May. The project has analyzed the intervention method on some site with huge success. Timely rescuing of the hatchlings and releasing them in water achieved the score of 4. In absence of this project hypothetically the hatchery managers at some sites would have continued rescuing the hatchlings.		

Score

Actions/ Interventions	**1**- Solutions untested in the study area
	2- Some anecdotal information about responses to interventions at one or a small number of locations.
	3- Some quantitative information or expert based assessment on the effectiveness of action.
	4- Some formal analytical tests undertaken on the success of intervention from at least one location.
	5- Analysis of the impact of intervention and mitigation of the threat at multiple locations which may be synthesized using meta analysis.

Score card

To evaluate the knowledge of effect of high temperature on hatching and emergence success rate as the key threat due to shift in nesting season at major nesting sites of Maharashtra.			
Aspect of Knowledge	**Before the project**	**After the project**	**Estimate without the project**
Threats	**Score 1-** Shifting of the nesting season to summer season and the effect of high temperature on reducing the hatching success rate was not known as a emerging key threat in recent years.	**Score 5-** The project has scientifically evident the effect of high temperature on hatching success as the key threat. Preliminary studies has identified the mitigation of this effect.	**Score 2-** Some observations by hatchery managers or local NGO would have given during training (if any)or reported to forest department.
Justification	The reduction in hatching success rate was persistently blamed on hatchery managers for their improper handling and relocation skills by the forest department. This has resulted in direct conflict between forest department and hatchery managers in some region and increase in dissent among the hatchery managers. Ironically, basic training regarding relocation of nest were regularly conducted at Dapoli and Ratnagiri range office for experienced hatchery managers. The research to fill in this knowledge gap of threat was successfully given by the project through data analysis, photographs and video recordings thus achieving the score of 5. In absence of this project some hatchery managers might have reported it to the forest department or during training sessions so a score of 2 is given.		

Score

Threats	**1**- Threats unknown to the study site
	2- Some ad hoc data or expert judgment about the importance of potential threat(s) is available
	3- limited analysis of single threat is available, but from a limited sample or small proportion of the project area (ie : may not be representative)
	4- Robust analysis of threats undertaken but key threats still not identified.
	5- Data analysis has identified key threats with high confidence.

Q3) Developing hatchery manager from the local community as Parabiologist by imparting advance training. Will it help to achieve the long term conservation goal of the project?

Score card

To evaluate the scope of involving local hatchery managers to train them as Parabiologist during nesting season in order to ensure long term conservation impact.			
Aspect of Knowledge	**Before the project**	**After the project**	**Estimate without the project**
Actions/ Interventions - D	**Score 1-** Solutions untested in study area	**Score 5-** Analysis of the impact of action in involving local hatchery managers will help mitigation of the threat at multiple locations (7 major nesting sites) which may be synthesized using meta analysis.	**Score 2-** Some anecdotal information about responses to actions at one or a small number of locations.
Justification	Hatchery managers are appointed by forest department on temporary basis during the nesting season. Some of them have experience of more than 15 years and have self developed special egg relocation skills ensuring high success rate. Amid pandemic and national lockdown the phase II project was successful due to active participation of these hatchery managers. If given appropriate training and disseminate the information collected during this project they would get clear insights about the threat. This will not only motivate them but also ensure high hatching success rate and effective hatchery management. The study sites are one of the major nesting sites of Maharashtra so on long term the hatchery managers with acquired knowledge will ensure a successful conservation goals.		

Score

Actions/ Interventions	**1**- Solutions untested in the study area
	2- Some anecdotal information about responses to interventions at one or a small number of locations.
	3- Some quantitative information or expert based assessment on the effectiveness of action.
	4- Some formal analytical tests undertaken on the success of intervention from at least one location.
	5- Analysis of the impact of intervention and mitigation of the threat at multiple locations which may be synthesized using meta analysis.

Q4) Are there completely developed hatched but dead hatchlings seen in the nest post-incubation period?

4a) Is it correct to open the nest as a general hatchery management practice at the time of emergence to rescue the hatchlings in case the hatchlings fail to emerge?

Score card

To evaluate the knowledge of dead but developed hatchlings which failed to emerge and live hatchlings stuck inside the nest due to high temperature.			
Aspect of Knowledge	**Before the project**	**After the phase II of project**	**Estimate without the project**
Threats	**Score 1-** The threat was unknown in the study area.	**Score 3-** Limited analysis of this threat is available from 4 study area.	**Score 1-** Threat unknown.
Justification	The number of hatchlings that emerged naturally from the nest were seen to reduce as the incubation period move to summer months of April and May. Though the threat was not reported by local NGOs or acknowledged by forest department, some experienced hatchery managers were aware of the threats. Phase I of the project in 2019 after opening the nest post incubation period this threat was identified. As the data available is restricted to just 4 sites in two years, the score given was 3. In absence of this project hypothetically this threat would have not been identified in any sites across Maharashtra. The reason for this is during the training session arranged at Anjarla in 2019 and even in previous years as a standard practice the beach managers were forbidden to open the nest even after the post hatching period of 50 days. This threat would have remained unknown.		

Threats	**1**- Threats unknown to the study site
	2- Some ad hoc data or expert judgment about the importance of potential threat(s) is available
	3- limited analysis of single threat is available, but from a limited sample or small proportion of the project area (ie : may not be representative)
	4- Robust analysis of threats undertaken but key threats still not identified.
	5- Data analysis has identified key threats with high confidence.

4b) What method should be implemented for the mitigation of temperature?

Score card

To evaluate the intervention for low emerging rate of hatchlings during the month of April and May at major nesting sites of Maharashtra.			
Aspect of Knowledge	**Before the project**	**After the project**	**Estimate without the project**
Actions/ Interventions - A	**Score 1**- Solutions untested in study area	**Score 4** - some formal analytical tests undertaken on the success of intervention from at least one location	**Score 2**- some anecdotal information about responses to interventions at one or small number of locations.
Justification	In absence of the knowledge of the threat no solutions were implemented officially before this project. Though at some sites, hatchery managers unofficially had rescued the hatchlings by opening the nest after the first natural emergence of the hatchlings. This was done during the summer months of April and May. The project has analyzed the intervention method on some site with huge success. Timely rescuing of the hatchlings and releasing them in water achieved the score of 4. In absence of this project hypothetically the hatchery managers at some sites would have continued rescuing the hatchlings.		

Score

Actions/ Interventions	**1**- Solutions untested in the study area
	2- Some anecdotal information about responses to interventions at one or a small number of locations.
	3- Some quantitative information or expert based assessment on the effectiveness of action.
	4- Some formal analytical tests undertaken on the success of intervention from at least one location.
	5- Analysis of the impact of intervention and mitigation of the threat at multiple locations which may be synthesized using meta analysis.

Q5) Will the evaluation of eggs to check the stages of development at mortality give a clear picture of the reason of mortality?

Score card

To evaluate the practice of opening the nest to check the stages of development at mortality to get a clear picture of reason of mortality			
Aspect of Knowledge	**Before the project**	**After the project**	**Estimate without the project**
Actions/ Interventions - E	Score 1- Solutions untested in study area	Score 5- Analysis of the impact of intervention to understand the effect of high temperature on developing embryos at multiple locations(7 major nesting sites) which may be synthesized using meta analysis.	Score 1- Solutions untested at study sites.
Justification	Opening of nest after the hatching period of 50 days (post hatching intervention) was not known in the study sites. The stage of development inside the unhatched dead eggs gives us a clear understanding of reason for mortality. The protocol for opening the nest was developed and standardized for application on field. The method has shown promising results in terms of ensuring appropriate actions that needs to be taken by hatchery managers as per their sites. The method will help in improving the relocation skills of hatchery managers if more of pre embryonic eggs are seen. It will also ensure appropriate method of mitigation of high incubation temperature if less number of dead hatchlings or half developed but dead hatchlings are seen hence given a score of 5.		

Score

Actions/ Interventions	**1**- Solutions untested in the study area
	2- Some anecdotal information about responses to interventions at one or a small number of locations.
	3- Some quantitative information or expert based assessment on the effectiveness of action.
	4- Some formal analytical tests undertaken on the success of intervention from at least one location.
	5- Analysis of the impact of intervention and mitigation of the threat at multiple locations which may be synthesized using meta analysis.

Conclusion:

The objectives of phase II of the project was mostly completed amid pandemic and lockdown. The strong role played by hatchery managers in collecting appropriate data during lockdown has shown their significance for this project as Parabiologist.

The temperature data logger instrument customized for hatchery on the beach was found to be technically robust in its functioning. Few technical issues of data transfer, weak network though identified during the project could not be attended due to lockdown. These technical issue has been rectified by the developer. The toolkit has helped evaluation of the project with finer details. Temperature emerging as a key threat to the developing hatchlings. The use of continuous monitoring device (customized data logger) to bring appropriate change on the field in terms of mitigation has been very well established due to toolkit.

The method of evaluation of the nest post-incubation period needs implementation on-field by giving specific advance training to the hatchery managers. The mitigation of nest temperature by using appropriate methods is still preliminary and needs detail experimentation as per site before its implementation.

The project in its second year of implementation seems to be successful in achieving its long term goal with few modifications and implementations required.

The evaluation by tool kit can be concluded as

1) Temperature emerging as a key threat to the developing hatchlings at a nesting site in Maharashtra.
2) The temperature monitoring device deployed in the hatchery with a focus to mitigate temperature will certainly help in achieving long term conservation goals of the project with hatchery managers developed as Parabiologist.

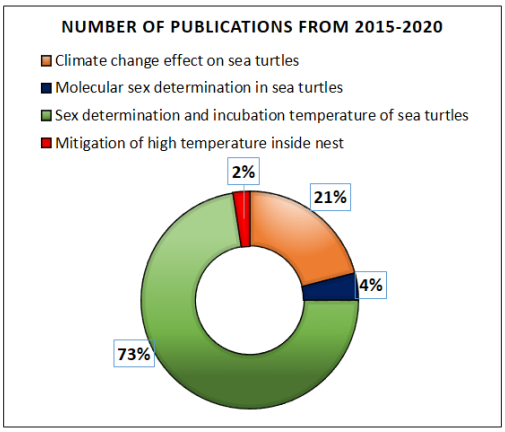
Part B - Scientific Evidence of Project

B1] Climate change as the driving force in the shift of nesting season:

Category of topics in published literature (2015-2020)	Year of publication					
	2015	2016	2017	2018	2019	2020
Climate change effect on sea turtles	5	4	3	6	6	2
Molecular sex determination in sea turtles	1	2	1	0	0	1
Sex determination and incubation temperature of sea turtles	12	10	13	22	19	14
Mitigation of high temperature inside nest	2	0	0	0	0	1
Total available literature	20	16	17	28	25	18

Table 1: number of research articles from 2015 -2020 on Google scholar.

The previous five-year articles till recent viz 2015 – Oct 2020 were searched using Google scholar search. A total of 124 publication consisting of thesis and research papers were reviewed and categorized in 4 sections. The articles based on climate change on the nesting cycle of sea turtles, sex determination of sea turtle hatchlings and incubation temperature of sea turtles were considered for review (Table 1).

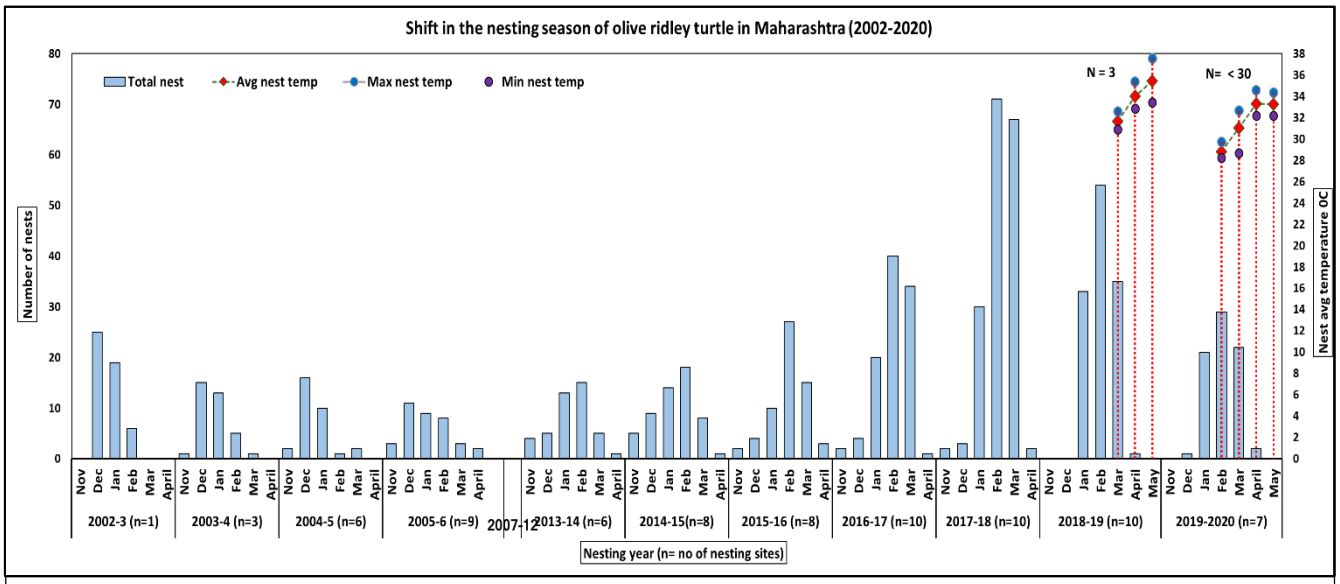


Graph 1: The proportion of publications dealing with different aspects of temperature effect on sea turtles terrestrial life cycle.

Out of the reviewed articles, 77% were addressing the female-biased sex ratio of hatchlings due to increase in the nest temperature as a result of climate change. **This phenomenon is observed at all nesting sites in the world and is currently the focus of sea turtle research.** 21 % of the articles were based on climate change phenomenon affecting the terrestrial life cycle of sea turtles (Graph 1).

Out of 124 articles, only 9 articles had studied olive ridley turtles (*Lepidochelys olivacea*) which were mostly related to the experimentation of molecular sex ratio**.** All the articles have targeted endangered sea turtle species like loggerhead, the green sea turtle. The effect of high temperature on developing embryos of olive ridley turtle is more profound than others**. The olive ridley is more vulnerable to the climate change effect than other endangered sea turtles** (Santidrián Tomillo et al., 2017)**.**

B2] Prominent shift in nesting season (2002 – 2020):



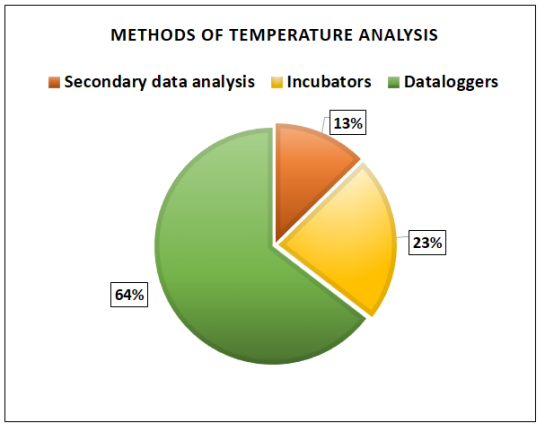
Graph 2: The month wise nesting data of olive ridley turtle in Maharashtra from year 2002 till 2020. N = no of nest, n = number of site
Source: Sahyadri Nisarga Mitra (SNM) Chiplun (2002-2006 data) and Maharashtra State Forest Department (2013-2020).

The above graph 2 shows a clear shift in the peak nesting season from December- January in 2002 (winter nesting season) to February- March in 2020 (summer nesting season). The nesting sites considered are spread across Maharashtra coast from Raigad to Sindhudurg district.

The data from temperature data logger installed in phase I and phase II of the project shows the avg nest temperature in April and May above the presumed avg threshold temperature of 33^0C.

In phase, I of the project hatchlings were seen stuck up in the nest which has hardened like a rock (Fig1). All the nesting sites are at the mouth of big and small estuaries depositing fine clay on the beach. This clay in the summer months of April and May with high incubation temperature and incubation moisture inside the nest results in the baking of the sand just like a brick kiln.

B3] Data logger a distinctive feature of this project:



Graph 3: The different methods of temperature analysis mentioned in research articles (n= 79) published from 2015-2020.

The methods and instruments used for temperature measurement given in the research articles were categorised in 3 sections

*__Secondary data analysis__ – climate change effect on the nesting life cycle of the sea turtle.

*__Incubators__ – Sex determination and lethal temperature for development

*__Data loggers__ – Sex determination and incubation temperature of the nest. (Graph 3).

The data loggers used in these research were listed from the articles. The data loggers used were commercial having 1-4 sensors channels for industrial and indoor application. Wildlife researchers in India use HOBO data logger (USA) available either through online or from a single official dealer in Gurgaon. The price is exorbitant with the additional cost of software and accessories. The after-sales services are not available in India for these imported data logger. Many of the HOBO models that were used for sea turtle research have a maximum shelf life of 5 years. Pendant loggers, i button data logger, mini logs are other types used on the field for nest temperature estimation in *insitu* nest. The shelf life for these mini loggers is a maximum of 3 years and temperature accuracy is min 0.5°C. These data loggers could aptly be used for research rather than long term monitoring (Fig2). The other UK based data logger like tiny tag having restricted use are not sold in India.

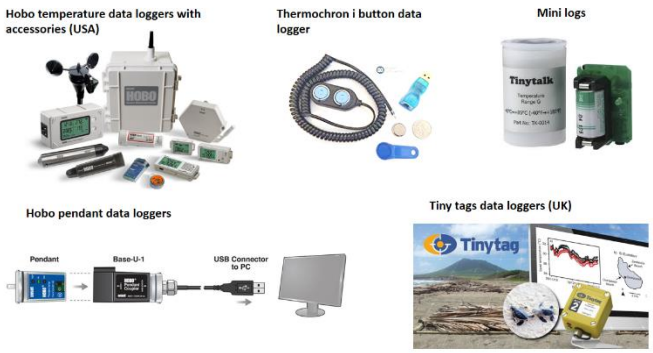


Fig 2: Different types of data loggers used in sea turtle research

Globally and in India concerning sea turtles conservation this project is one step ahead for its long term conservation goal in mitigating the effect of climate change on the terrestrial life cycle of a sea turtle. The information from the literature review reveals that conservation of sea turtle is at the research stage filling up the knowledge gap. Here in this project we are not just filling up the knowledge gap for this population but also implementing long term conservation efforts. Maharashtra coast is the prominent conservation unit for olive ridley sea turtle nesting on the west coast of India. This nesting population belongs to an Indian Ocean west population which is distinct than the Indian Ocean east population. The Indian Ocean west is considered a separate regional managing unit (RMU) for the conservation of this species.

Compared to other west coast states of India the Maharashtra state forest department along with local community participation has done commendable conservation work related to this species.

As against the commercially available units, the indigenously developed data logger unit is customised for use in sea turtle hatchery. It is comparatively cost-effective with a shelf life of more than 15 years, has an advance system like wireless mobile network data transfer through the cloud. The unit is easy to maintain and the hardware is replaceable locally. The unit works on solar panel and battery which is environmentally friendly.

This project is a first of its kind globally where temperature data logger is deployed on large scale at major nesting sites with a goal of long term conservation and monitoring, adapting a mitigation strategy specific for the nesting beach based on information procured.

B4a] Installation of Datalogger:

All seven data loggers have been installed with an advanced GSM system and batteries with a solar panel. The installation was done before the peak nesting season in Feb. Each data logger is equipped with a SIM card which sends data to paid cloud service once in a day. The data was retrieved off-field by the Ms Sumedha Korgaonkar. The data loggers are installed at Kelshi, Anjarla, Kolthare, Dabhol, Gaokhadi and Madban in Ratnagiri district and Vayangani in Sindhudurg district. Tambaldeg site was changed due to non-cooperation of the local hatchery manager and instead, Madban was selected as one of the study sites. Diveagar was changed due to inconvenience and Kelshi was selected this year as the study site. On all sites, the data logger unit was placed inside the hatchery. Solar panel and antennae were installed on the hatchery (annexe).

B4b] Working of data logger on the field:

Data loggers can be conveniently installed inside the hatchery without any threat of theft on these nesting sites. Except for Kolthare, the data logger was not damaged by any means. At Kolthare golden jackal predating on protected hatchery nest has cut the sensor wires of the data logger. The major technical difficulty observed was weak network service on these sites which can be overcome by installing network antennae at a higher place. The other technical issue (minor) observed was in software supporting the data transfer and was conveyed to the vendor. Damage to hardware due to the corrosive action of air was not observed even after 4 months of its use on nesting site. The humidity and water-resistant protective casing of IP 65 box embedding the data logger has proved to be effective (see annexe for detail).

The data logger instrument is found to be technically robust in its functioning on turtle nesting beaches having extreme weather conditions during peak summer

B4c] Data collection:

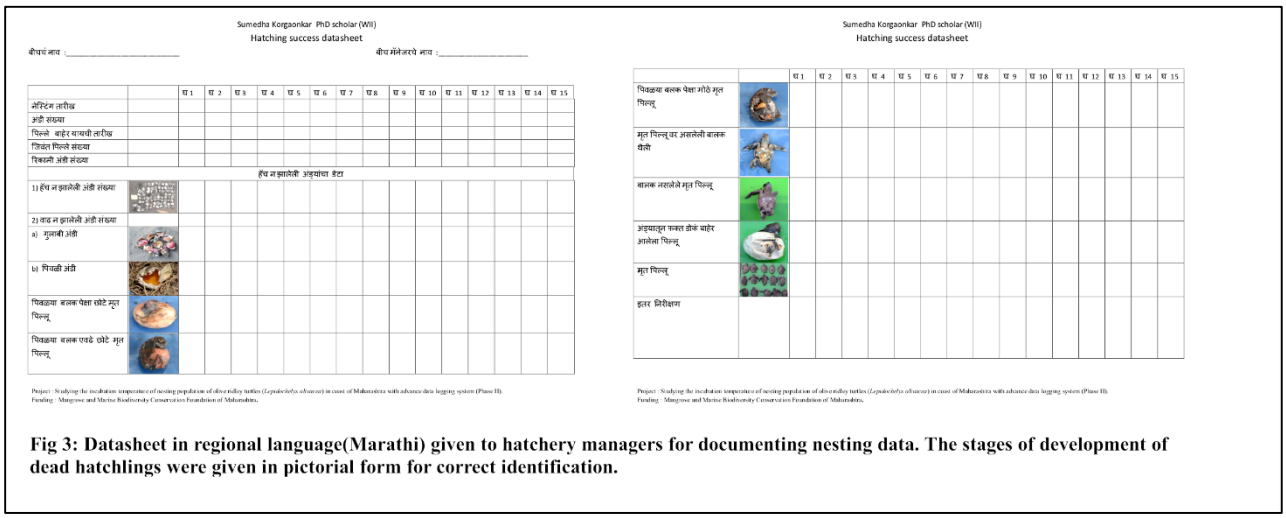
The beach managers were instructed about the installation and use of the data logger. Before installation, the beach managers were instructed to keep a stick similar to the diameter of the sensor (dia 2cm) in the middle of the nest at the time of relocation. Some of them did as instructed and under my supervision, the sticks were removed and very cautiously sensors were put in the nest. This has ensured the winter nesting data without any harm to the nest (annexe survey). No sensors were placed

in a relocated nest where sticks were not placed. All 8 sensors per data logger per site were used for monitoring the nest temperature.

A post-project online questionnaire survey was conducted for hatchery managers (N=10) to find the safe use of data logger (see annexe). 80% of the managers have positively reported that the wires of sensors and data logger do not cause any harm to emerging hatchling (see annexe). Emerging hatchlings entangling in the wire were not reported from any of the study sites. 10% of the hatchery manager still believe that it might harm the hatchlings. With no evidence in phase I and II, the anxiety is baseless.

Instead, this method has an advantage of using the sensors as and when it becomes free making it reusable till the end of the nesting season. The only caution that needs to follow is not letting the outer dry sand to fall in the nest while removing the stick and putting the sensor in its place. For that the upper dry sand of the nest should be removed and then with steady hands the stick should be replaced by the sensor. The experienced hatchery managers with their relocation skills do it properly.

At the start of the project data sheets prepared in Marathi were given to hatchery managers to fill in nesting data (Annex). The nest were opened after the post-incubation period of >50 days and /or after no emergence of hatchlings were observed.


Sumedha Korgaonkar PhD scholar (WII)
Hatching success datasheet

Sumedha Korgaonkar PhD scholar (WII)
Hatching success datasheet

Fig 3: Datasheet in regional language(Marathi) given to hatchery managers for documenting nesting data. The stages of development of dead hatchlings were given in pictorial form for correct identification.

Mr Yogesh Anavkar of Kelshi (voluntary participation), Mr Ajinkya Keluskar of Anjarle and Mr Pradeep Dingankar of Gaokhadi collected the necessary data in my absence (lockdown period). The method to observe the stage of development of the embryo at mortality was demonstrated to these people in 2019-20 Phase I of the project. DFO Shri Ramakant Bhawar Sir was regularly intimated before nest opening. This data collection by locals has proved to be important in the interpretation of data.

A total of 49 nests were monitored with temperature data logger on these sites in 2019-20 nesting season. This number would increase if the data logger is installed early on site.

Nesting site	Nest no	Nesting date	Emergence date	Sensor no	Total sensors used	Temperature data available
Kelshi	5	15/2/20	11-17/4/20	8	5	21/4/20
	6	26/2/20	18-21/4/20	7		
	7	13/3/20	2-3/5/20	1		
	8	13/3/20	3-4/5/20	6		
	9	17/3/20	6-7/5/20	4		
Anjarla	6	14/2/20	1/4/2020	2	8	15/5/20
	7	21/2/20	8/4/2020	3		
	8	25/2/20	14/4/20	4		
	10	28/2/20	13/4/20	5		
	11	2/3/2020	17/4/20	6		End of nesting season
	12	2/3/2020	19/4/20	7		
	13	12/3/2020	29/4/20	8		
	15	23/3/20	9/5/2020	1		
Dabhol	1	17/1/20	10-15/3/20	7	12	30/4/20
	2	24/1/20	15,24/3/20	8		
	3	26/1/20	17-24/3/20	5		
	4	15/2/20	4-6/4/20	6		
	5	16/2/20	2-4/4/20	1		
	6	16/2/20	2-6/4/20	2		
	7	17/2/20	7-10/4/2020	3		
	8	10/3/2020	25-28/4/20	4		
	9	12/3/2020	24/4/20	7		
	10	23/3/20	8-10/5/20	8		
	11	28/3/20	14,15/5/20	5		
	12	1/4/2020	Nil	6		
Gaokhadi	2	18/1	5/3/2020	1	10	29/2/20
	3	16/2	6/4/2020	2		
	4	18/2	8/4/2020	3		
	5	22/2	12/4/2020	4		
	6	3/3/2020	22/4/20	5		SD corrupted
	7	10/3/2020	29/4/20	6		
	8	12/3/2020	1/5/2020	7		
	9	13/3/20	2/5/2020	8		
	10	14/3/20	3/5/2020	1		
	14	2/4/2020	0	2		
Madban	3	13/2/20	31-5/4/20	1	8	15/5/20
	4	16/2/20	2-7/4/20	2		
	5	17/2/20	3-7/4/20	3		
	6	25/2/20	10-15/4/20	4		End of nesting season
	7	7/3/2020	19-26/4/20	5		
	8	7/3/2020	20-27/4/20	6		
	9	10/3/2020	22-3/5/20	7		
	10	28/3/20	14-19/5/20	8		
Vayangani	8	8/2/2020	29/3/20	5	6	9/4/2020
	9	16/2/20	3/4/2020	1		
	10	19/2/20	8/4/2020	2		
	11	22/2/20	8/4/2020	4		Flooded with high tide
	12	24/2/20	9/4/2020	3		Almost the end of the season
	13	24/2/20	12/4/2020	7		

Table 2: Details of the sensors used and the availability of data.

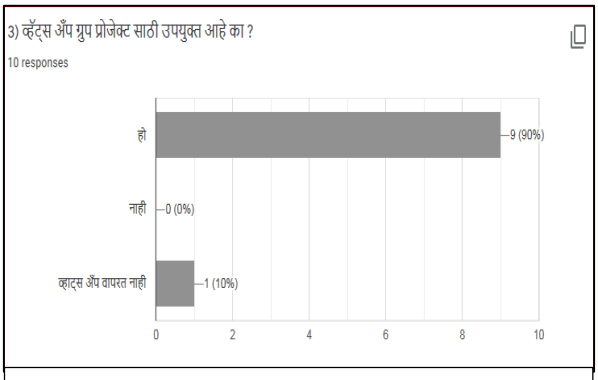


Fig 5: Questionnaire survey of hatchery managers regarding use of whats app group for the project

A Whatsapp group for this project was created to disseminate the information about nesting and hatching. Mr Harshal Karve of Mangrove Foundation was added as one of the members of the group to keep the funding agency in loop. The hatchery managers proactively shared the group information. 90% of the hatchery managers felt it was advantageous for the project.

B5] Filling the knowledge gap of solitary nesting olive ridley turtle in Maharashtra.

Temperature plays a key role in terrestrial nesting phase of sea turtles

1) **Temperature-dependent sex determination**
2) **Hatching and emergence output within the threshold (tolerance) limit.**

The temperature provided to the developing embryos inside the nest depends on factors such as ambient air temperature, sand colour, sand grain size, sand thermal conductivity, depth of the nest, vegetation cover on the beach, biological heat developed during growth (Speakman et al 1998, Broderick et al 2001). The various factors result in different outcomes on the nesting sites in terms of hatching and emergence success rate.

The nesting site in Maharashtra coast showing variations in sand type due to the presence of estuaries and extent of vegetation cover on the beach. It is expected to show varying nest temperature within and between the sites though the ambient air temperature is more or less constant.

Phase II of this project has managed to fill in the knowledge gap related to incubation temperature of an olive ridley nesting population of the west coast of India.

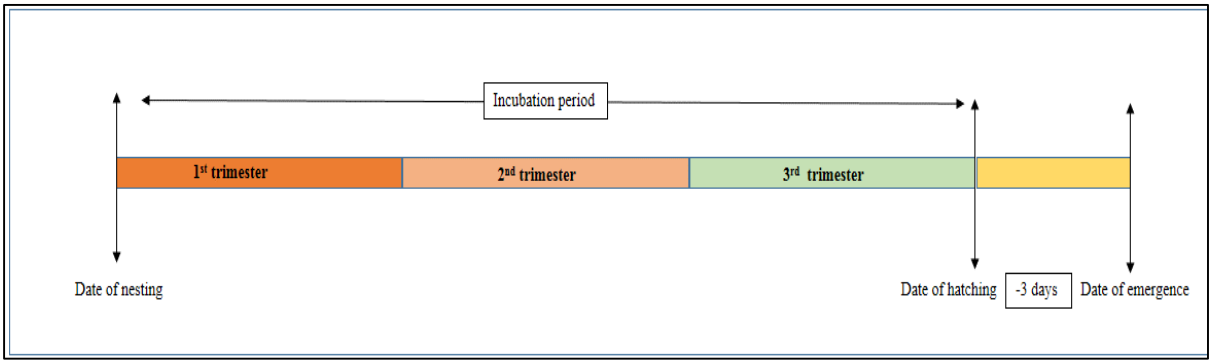
Temperature-dependent sex (TSD) determination

Temperature-sensitive period of sex determination in sea turtles is within the second trimester of the whole incubation period (Wibbels 2007). The estimation of sex determination is complicated and indirect due to lack of external sexual differentiation of hatchlings. There are various methods suggested for sex determination. An invasive technique like histological staining is the most reliable method but cannot be used as it needs the sacrifice of hatchlings. **The most common method in use is considering the average nest temperature during the second trimester of the incubation period.** It can be easily used to get an approximation of sex ratio of the hatchlings from the nesting sites. Phase II of the project present the appropriate and logistically convenient method to estimate approximate sex ratio of the released hatchlings from the sites. The incubation period is calculated from the day the nest is relocated to hatchery till hatching. In Maharashtra, the beach managers patrol the beach at least twice a day and the nests are relocated to hatchery within 6 hours. The date of relocation is considered as the date of nesting. Hatchlings that piped from the eggs are inside the nest for at least 3 days before emerging. Though the studies show a varying number of days between hatching and emergence for calculation of sex ratio we have considered 3 days period.

The incubation period calculated is as follows:

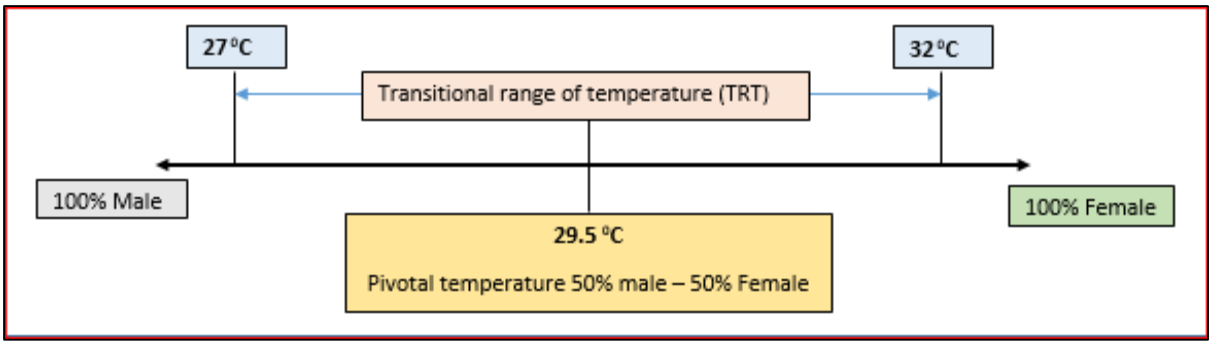
Incubation period = days interval (nesting date to date of first hatchling emergence) – 3

Trimester is calculated by dividing the incubation period by 3.



For sex ratio estimation average daily temperature of middle 2nd trimester for each nest on all sites is considered with maximum and minimum values.

Pivotal temperature is the temperature where 1:1 sex ratio of female: the male is observed. Though the pivotal temperature for Indian Ocean west population is not known, the pivotal temperature of closely related Arribada population from Orissa coast is considered. **The pivotal temperature of 29.5º C (Hejmadi et al 1986) is considered for estimation of sex ratio.** Transitional range of temperature (TRT) where mix sexes are produced is considered as 27^0C – 32^0C for estimation of sex ratio. The temperature ≤ 27^0C is considered 100% Males and temperature ≥ 32^0C is considered as 100% Females.



Hatching and emergence success rate and estimation of threshold temperature for survival of hatchlings specific to the nesting site.

The distinct shifting of the nesting period in Maharashtra since 2002 from winter to summer season could be an impact of climate change on this nesting population. Due to this shift in recent years, high temperature has adversely affected the development, hatching and emergence success rate significantly. Prolonged exposure to a high temperature below the threshold value may not be fatal but would show sub-lethal effect like slow locomotion on the beach and abnormal swimming in water reducing the survival of hatchlings in Ocean (Booth, 2018, Rivas et al., 2019). High temperature during emergence reduces the oxygen level disrupting the muscular coordination of flippers in hatchlings making it difficult for them to come to the surface. This results in dead but developed hatchlings seen stuck inside the nest (Matsuzawa et al., 2002 Segura & Cajade, 2010).

The lethal limit to temperature tolerance varies with species and population. Olive ridley species have a low tolerance to high temperature as compare to other species (Howard et al., 2014)

The developing embryos can survive high temperature above the threshold for a short duration of time. Hatchlings are seen emerging from the nest which has the mean incubation temperature below the threshold limit for the complete incubation period. Prolonged exposure to threshold temperature can seriously hamper their development resulting in decrease hatching and emergence success rate (Maulany et al., 2012).

The study from Costa Rica and Indonesia on this species has reported 33^{0}C as the threshold limit after which the hatching success rate declines drastically below 10% (Maulany et al., 2012; Valverde et al., 2010). Overall there is a limited data set for hatching success and incubation temperature of olive ridley species (*L . olivacea*) (Howard et al., 2014).

The phase II of the project has managed to fill in the knowledge gap of the incubation temperature, threshold temperature and its effect on hatching and emergence success on each nesting sites with a preliminary observation on mitigation.

Estimation of incubation temperature

Avg nest temperature with maximum and minimum temperature value per day is considered for each nest.

Hatching success rate is the number of hatchlings **coming out of eggs**. It is calculated only for Anjarla, Kelshi and Gaokhadi where post-incubation period nest were opened to check the reason of mortality of embryo.

Hatching success rate/nest = Total eggs in the nest – (number of hatchlings released from the nest + dead & piped hatchlings inside the nest)

The emergence success rate is the number of hatchlings **coming out of the nest** and released in water by hatchery managers. It is calculated as % of the data provided by hatchery managers and forest department.

Emergence success rate/nest = Total hatchlings released from the nest / total eggs in the nest

The mortality rate is the unsuccessful emergence from the nest in % calculated by

Mortality rate/nest = Total eggs in the nest – number of hatchlings released from the nest.

Though the temperature is the major factor in determining the hatching success rate other factors such as improper handling practices during relocation, genetic abnormalities, pathogens, environmental toxicity can also affect hatching success. For interpretation, it is assumed that Pathogens, Genetic and Environmental toxicity is not playing any major role in this population.

The examination of the nest method was designed and developed in phase I (2018-19) of the project by Ms Sumedha. The nest was excavated after the emergence stopped or post-incubation period of >55 days. The empty shells were separated and arranged in a row. The unhatched but intact shells are counted and broken to detect the stage of development inside the egg. The piped dead hatchlings and dead hatchlings are then counted. With this observation, an inference can be made regarding the reason of mortality of the hatchlings (see annexe).

The phase II of the project has successfully demonstrated the application of examining the nest for determining the correct reason of mortality. The examination was done by hatchery managers who were demonstrated about this method by Ms Sumedha in phase I of this project. Incubation pattern of the nest based on avg daily temperature of the nest gives a fair idea about the variation in incubation temperature of nest between inter and intra nesting sites.

B6] Region-specific TSD temperature, sex ratio, emergence success, mortality, lethal temperature and incubation pattern of 2019- 2020 olive ridley nesting season in Maharashtra:

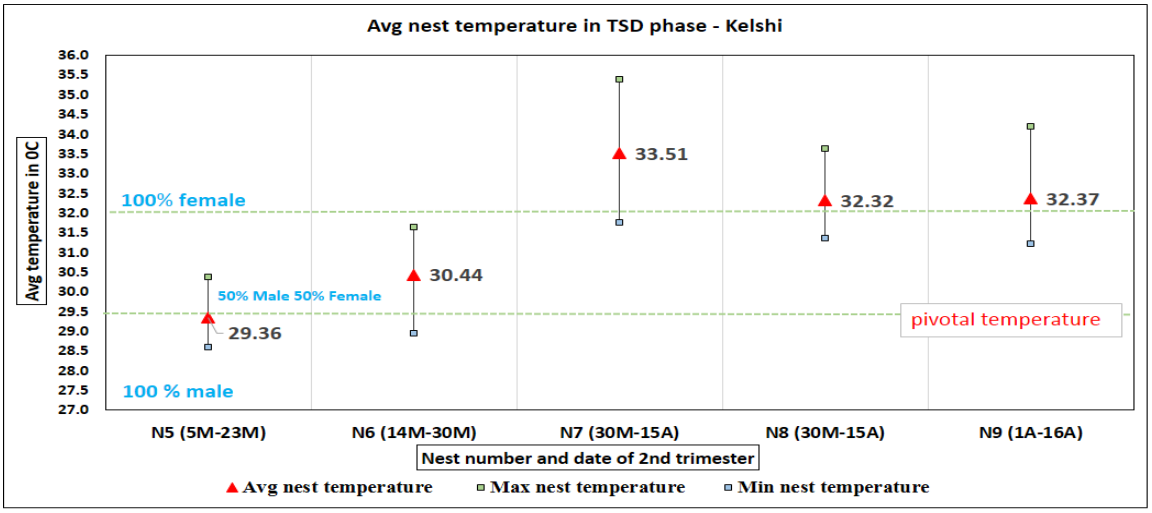
1) Nesting site Kelshi :

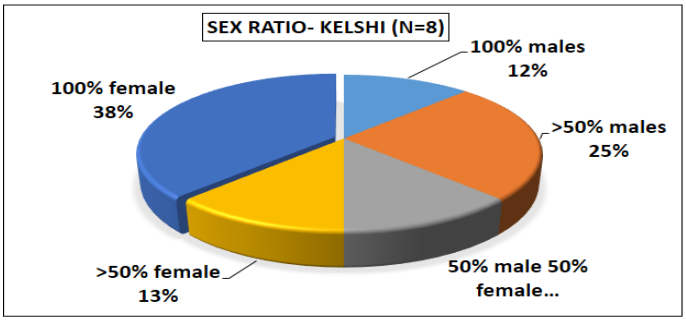
The hatchery is erected on the beach away from the vegetation cover (Casurina plantation) and exposed to the sun. The hatchery is unshaded. The first nest at Kelshi was found in Nov 2019 with subsequent nests in Jan and peak nesting in late Feb and March (Table 3).

	Number of nests				
Nesting site	Jan	early Feb	late Feb	Mar	Apr
Kelshi	2	0	3	3	1

Table 3: Nesting pattern of Kelshi in 2019-2020.

Temperature sex determination and sex ratio:

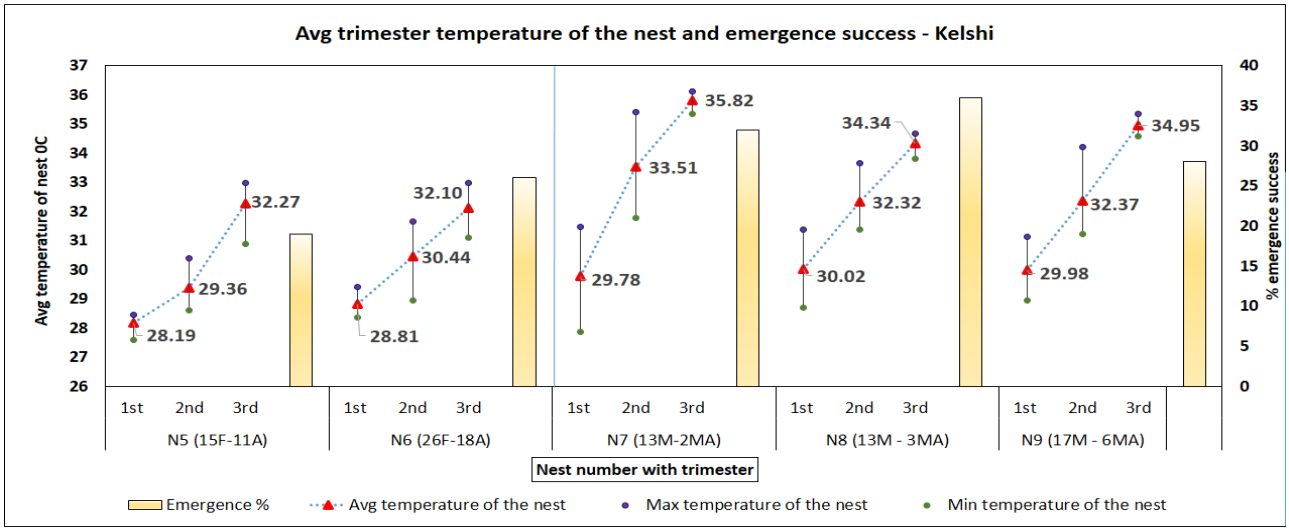




Graph 4: a) Avg nest temperature during 2nd trimester to estimate the sex ratio of hatchlings. b) Sex ratio of hatchlings at Kelshi nesting site for 2019-2020 nesting season.

N10 has 0% emergence. TSD of N5 – N9 is recorded. N5 & N6 shows temperature around pivotal temperature with 1:1 chance of male to female ratio. N7 to N9 has 100% female-biased temperature. The nesting period for N5 & N6 is late Feb whereas that of N7 to N9 is March. For estimating the sex ratio of all nest it is assumed that TSD temperature of N1, N2, N3 will be below 28^0C as the nest were found in Nov and Jan resp. These three nests were assumed to be having more male-biased hatchlings (Graph 4a &b).

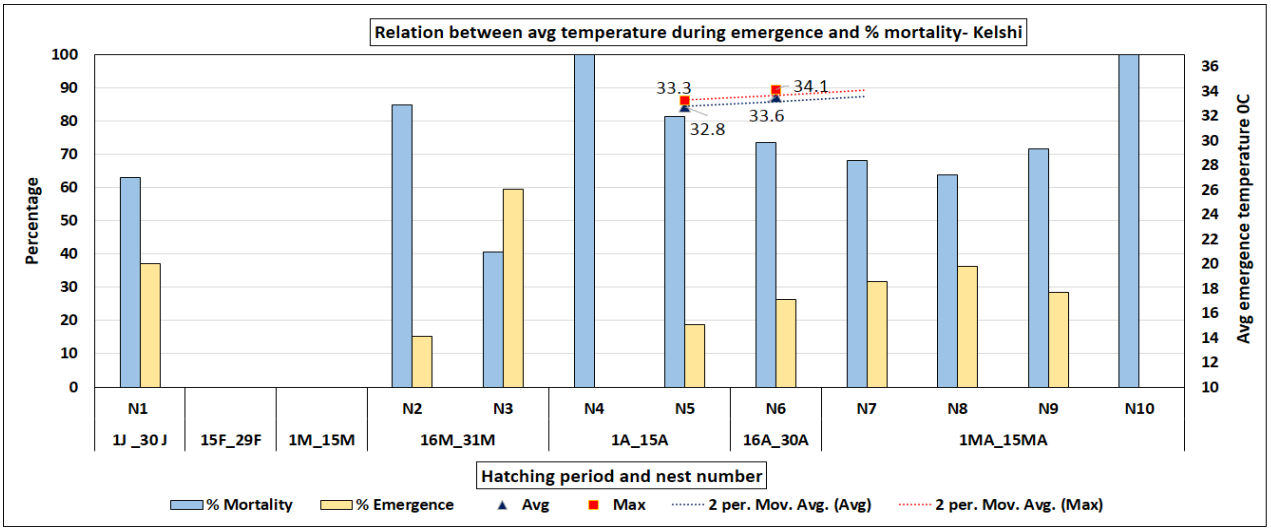
Lethal temperature:



Graph 5: The avg nest temperature of the nest recorded for trimesters and the emergence success of the nest at Kelshi nesting site.

Three nests viz N7, N8, N9 has a third-trimester temperature above the presumed threshold temperature of 33^0C. Still, the emergence % in these nest is greater than N5 & N6. There is a difference of 2 -3^0C between 2nd and 3rd trimester in the nest at Kelshi.

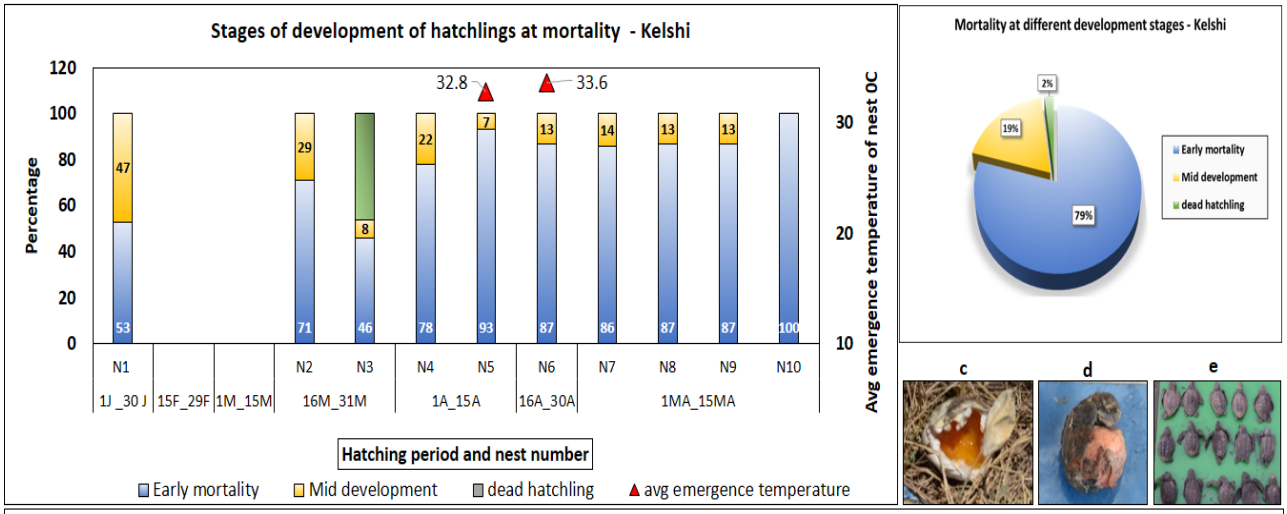
Emergence temperature and mortality:



Graph 6: The mortality rate seen in the nests and the corresponding Avg temperature of nest during the emergence.

The emergence temperature of N5 and N6 is available and shows 33^0C and 34^0C resp. The emergence temperature is above the presumed threshold temperature for N6 (Graph 6). The overall mortality rate is higher than the emergence success rate at Kelshi nesting site. ***The temperature may not be the only factor for the mortality of embryos.***

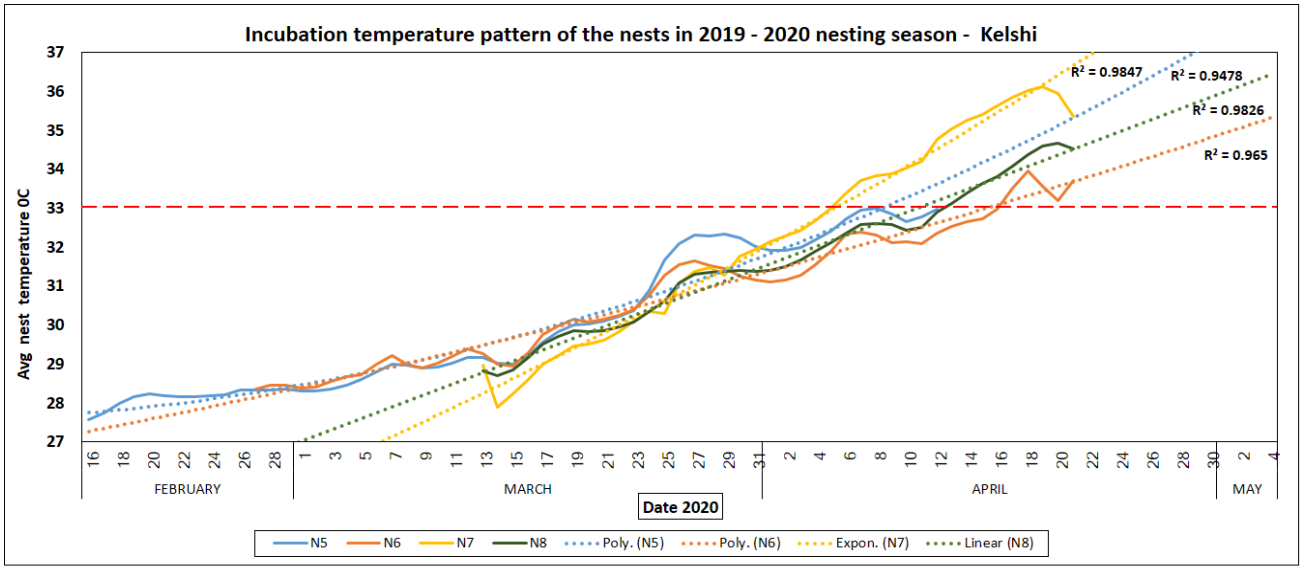
Stages of development at mortality:



Graph 7: The different stages of development of hatchlings at mortality seen after opening the post incubation period nest at Kelshi. a) Graphical representation of stages of mortality and avg nest temperature during emergence. b) Pie chart showing proportion of stages of mortality seen at Kelshi nesting sites. C) early mortality d) mid stage mortality where hatchling size is equal to the yolk e) dead hatchlings. Pc Sumedha Korgaonkar.

The stage of development of embryos at mortality shows 79% early embryonic death. Dead hatchlings were observed inside the N3 nest (2%) which is unexpected and inconsistent with the pattern seen on other sites. The proportion of mid developed embryos is higher in winter nest than in summer nest (Graph 7).

Incubation temperature pattern of the nest at Kelshi:



Graph 8: The overall pattern of incubation temperature of nest at Kelshi based on the avg daily temperature of the nest.

The incubation temperature data of Kelshi is available from 15th Feb till 21st April. The nest N5 and N6 show fluctuations in temperature giving a polynomial curve (R2=0.94 and R2=0.96 resp) whereas N7 has an exponential (R2=0.98) and N8 has linear (R2= 0.98) increase in temperature through their incubation period was simultaneous. The incubation pattern in Feb and March are the same for the nest. ***The variation between nests is seen from the 2nd week of April & onwards.***

The highly skewed female-biased sex ratio of the hatchlings is not concerned at Kelshi nesting site as a sizable number of male hatchlings might have developed from the winter nest. The nest having TSD period in April have 100% female hatchlings. Temperature is not the only factor in the mortality of hatchlings at Kelshi. The early mortality hatchlings are seen in high proportion thereby no conclusions could be made regarding the lethal temperature for developing embryos at Kelshi nesting site

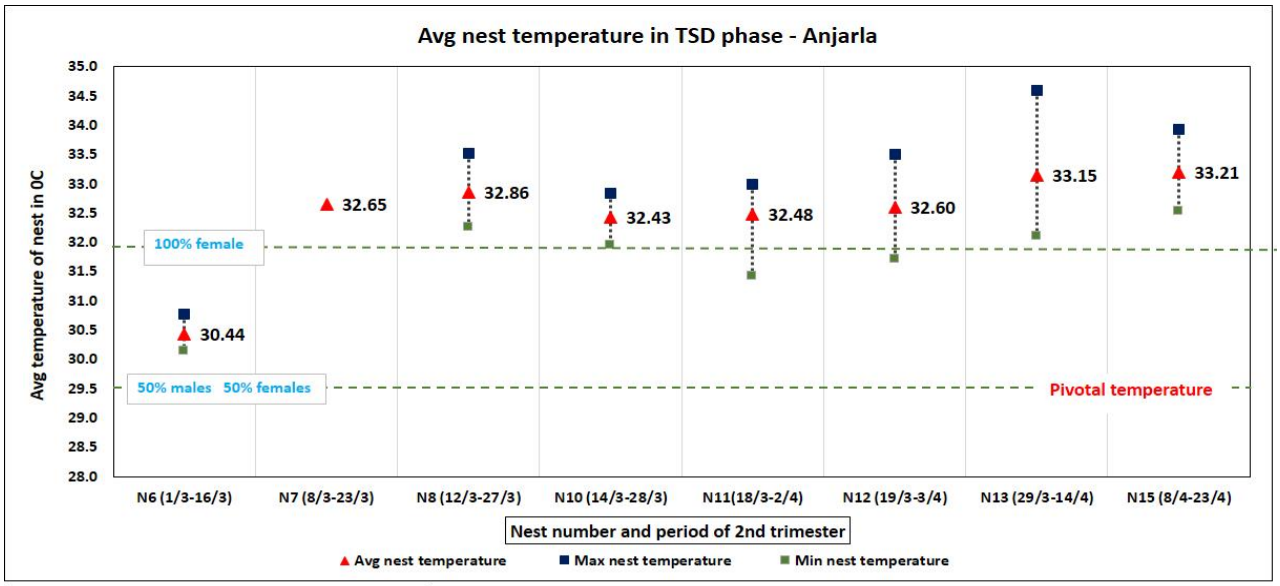
Nesting site Anjarla:

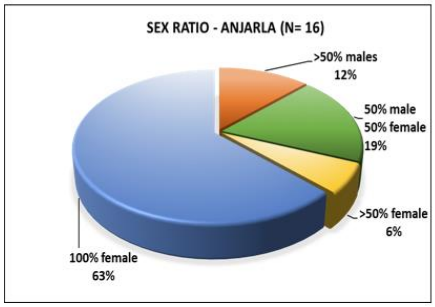
Anjarla nesting beach is narrow with high tide line often touching the foredune. The hatchery is erected over the foredune which does not have any shade of big trees. The nesting period (2019 -2020) of Anjarla started in Jan with peak nesting in late Feb and March.

	Number of nests				
Nesting site	Jan	early Feb	late Feb	Mar	Apr
Anjarla	4	1	5	6	0

Table 4: Nesting pattern of Anjarla in 2019-2020.

Temperature sex determination and sex ratio

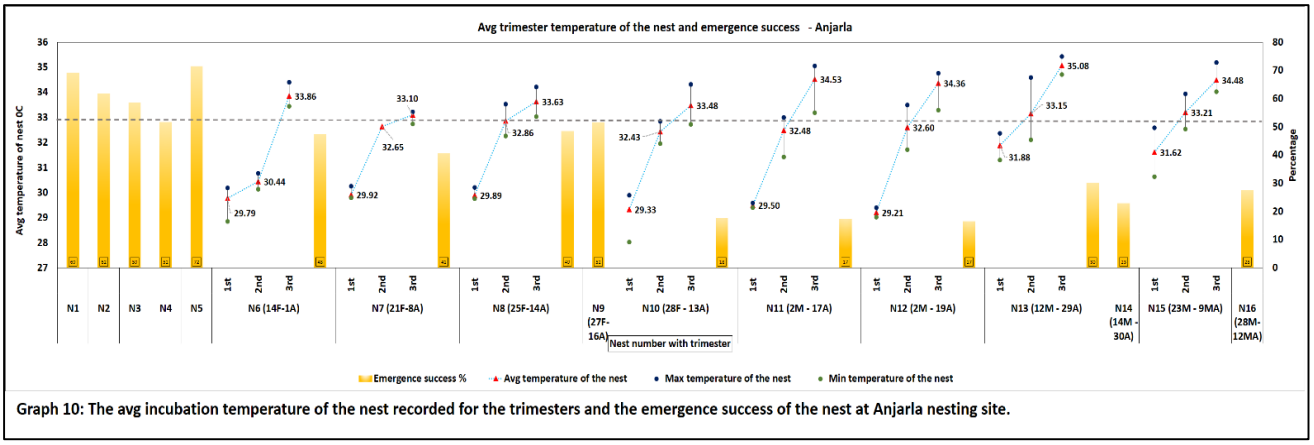




Graph 9: a) Avg nest temperature during 2nd trimester to estimate the sex ratio of hatchlings. b) Sex ratio of hatchlings at Anjarla nesting site for 2019-2020 nesting season.

The temperature data for TSD is available for N6 to 15. The nest had TSD in March and shows considerable high temperature inclined towards female-biased sex ratio. The incubation temperature at Anjarla is on higher side resulting in overall more female hatchlings The Jan and early Feb nest might have 50% of male hatchlings. The sex ratio is highly skewed towards female-biased at Anjarla nesting site (Graph 9 a & b)

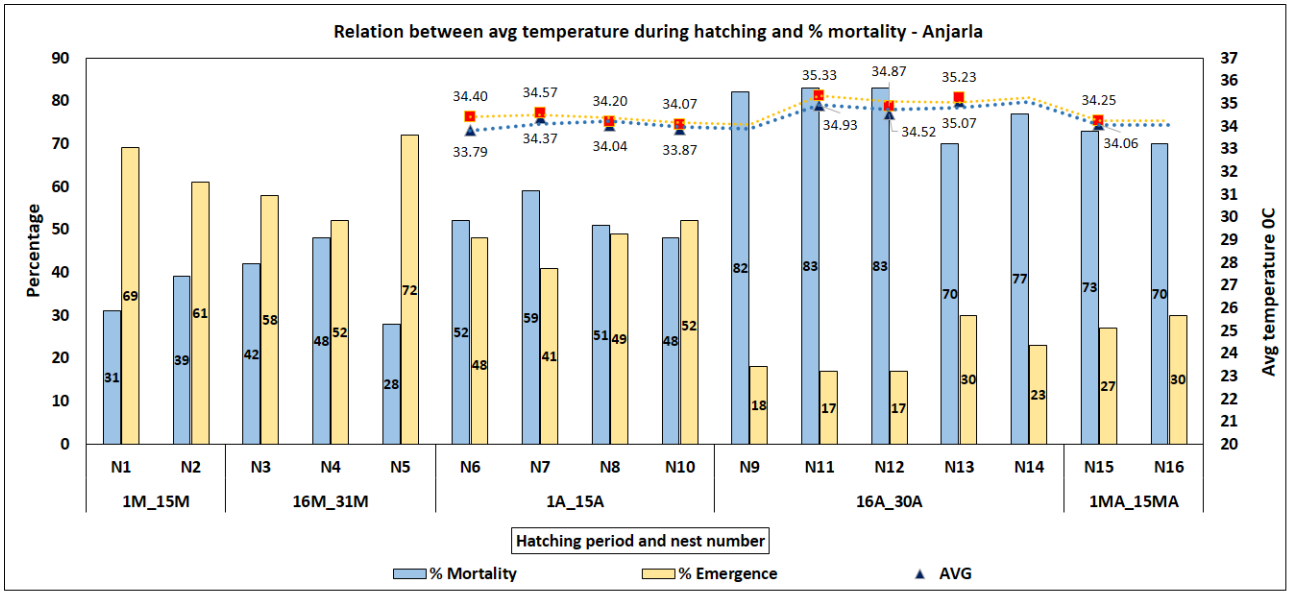
Lethal temperature:



Graph 10: The avg incubation temperature of the nest recorded for the trimesters and the emergence success of the nest at Anjarla nesting site.

Except for N6 & N7, all the nest shows the temperature of 3rd trimester above 33^{0}C with the avg temperature above 34.5 ^{0}C. Considering the N6 temperature which is well below the threshold temperature it can be presumed that N5 – N6 will also be within the limit. In comparison with an emergence, success gives a clear pattern wherein April with a temperature above 33^{0}C the emergence success rate has drastically reduced (Graph 10).

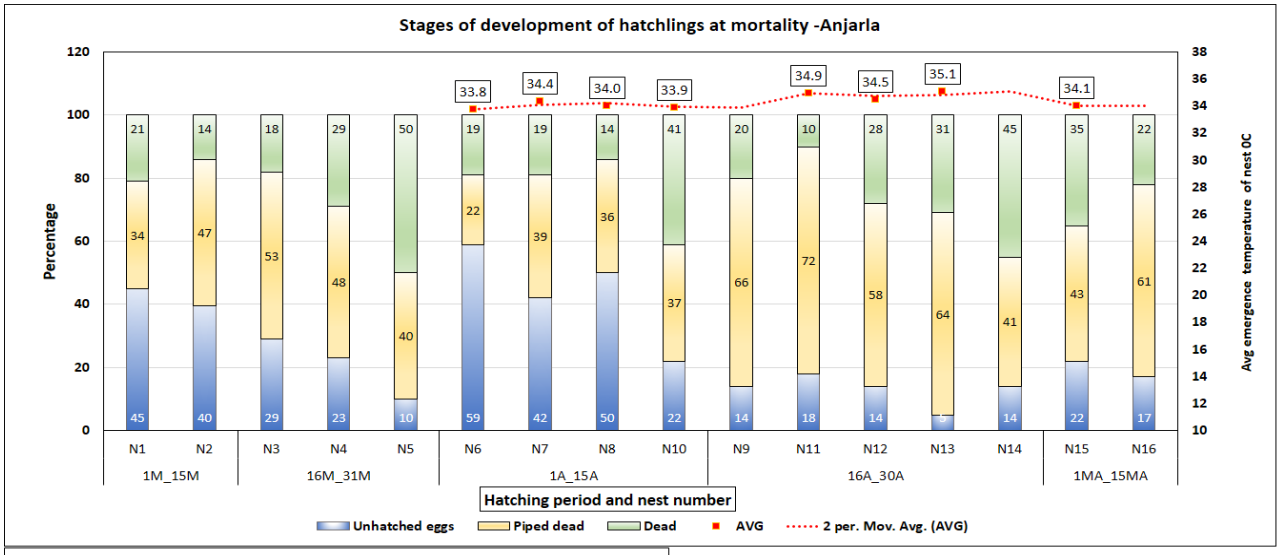
Emergence temperature and mortality:

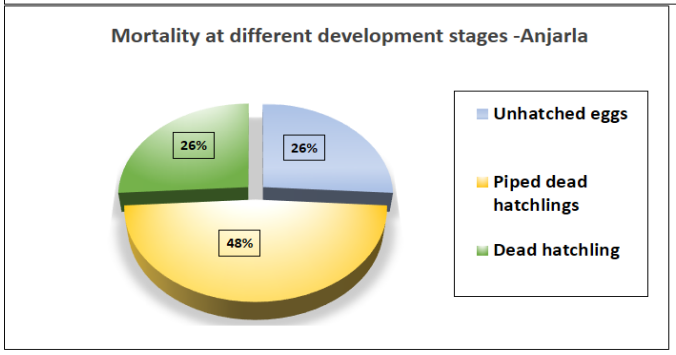


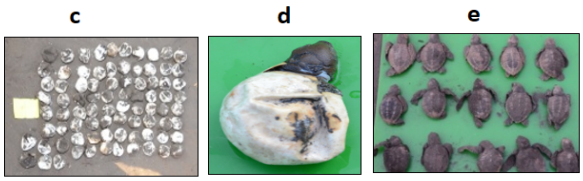
Graph 11: The mortality rate seen in the nests and the corresponding Avg temperature of nest during the emergence.

The emergence temperature at Anjarla is above 33^{0}C. The site shows a typical pattern of survival wherein the % emergence goes on decreasing and % mortality increases as the incubation period progress in hotter months of April and May (Graph 11).

Stages of development at mortality:







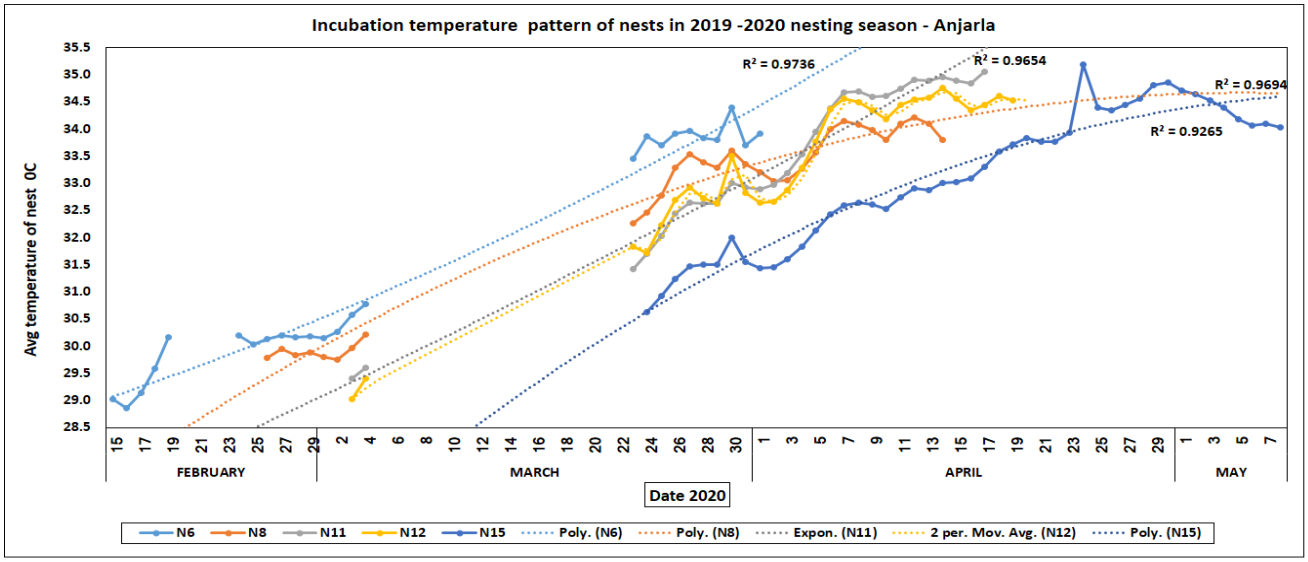
Graph 12: The different stages of development of hatchlings seen after opening the post incubation period nest. a) Graphical representation of stages of mortality and avg nest temperature during emergence. b) Pie chart showing proportion of stages of mortality seen at Anjarla nesting sites. c) unhatched eggs d) Piped dead e) dead hatchlings. Pc Sumedha Korgaonkar.

Detail examination of the nest post-incubation period ie: after the release of hatchlings has given a better insight. **74% of the total mortality is because of dead and piped dead hatchlings that were found inside the nest**.

Mitigation efforts were attempted at Anjarla by the forest department. The hatchery was partially covered by a green shed net provided by the forest department (Fig 6). Based on avg temperature of the nest throughout the incubation which is above 34^0C and high mortality rate it can be inferred that the use of partial shade is not providing any promising results. It needs further examination for use of other appropriate shade.

Fig 6: Partial shade of green net put on the top of hatchery at Anjarla. Pc Ajinkya Kelushkar.

Incubation temperature pattern in Anjarla:



Graph 13: The overall pattern of incubation in nest at Anjarla based on the avg daily temperature of the nest.

Anjarla: the avg incubation temperature of five nests (N6, N8, N11, N12, N15) from 14/2/20 to 23/3/20 gives a variable trend line. N6, N8 and N15 shows polynomial curve with R2= 0.97, R2= 0.96 and R2 = 0.92resp indicating fluctuation in temperature. N11 shows exponential (R2= 0.96) increase in temperature. N12 after the moving average shows a polynomial curve. N11 and N12 are the nests having the same nesting date and corresponding incubation temperature does not show follow the same trend line. ***Fluctuations in temperature are seen around 3rd and 4th week of March and extend till the end but the pattern remains the same. The incubation pattern shows variation between the nest at Anjarla nesting site.***

The persistent high temperature on this site results in sex ratio highly biased towards female hatchling. The threshold temperature for survival for Anjarla can be considered as 33^{0}C. Detailed examination of the nest was useful in finding the exact cause of mortality. Anjarla is a good example where the actual effect of temperature can be pinpointed. . High temperature reduces the oxygen inside the nest affecting the muscular coordination of hatchlings by which the hatchlings cannot come out of the nest resulting in dehydration and death inside the nest.

This suggests rescuing the hatchlings in April and May from the nest by following the appropriate protocol (see annexe).

Nesting site Kolthare:

Fig 7: Nest predation inside the hatchery and damage to the data logger.

Kolthare in recent years has emerged as a major nesting site with maximum nestings. The beach is comparatively wide with dense vegetation. South and mid-side of the beach is narrow and has coconut plantation whereas north side is broad and has dense natural vegetation of screwpine (Kevada) which is in continuation with the forest in the adjacent hill. The hatchery is erected on the mid-north side of the beach away from vegetation (big trees). **Predation by wild animals is a major concern in this nesting site.** The installed data loggers were destroyed by Jackals which predated on protected eggs. The incident happened just before national lockdown and the problem remained unattended. The data logger was removed and no data was collected from this site (Fig 7).

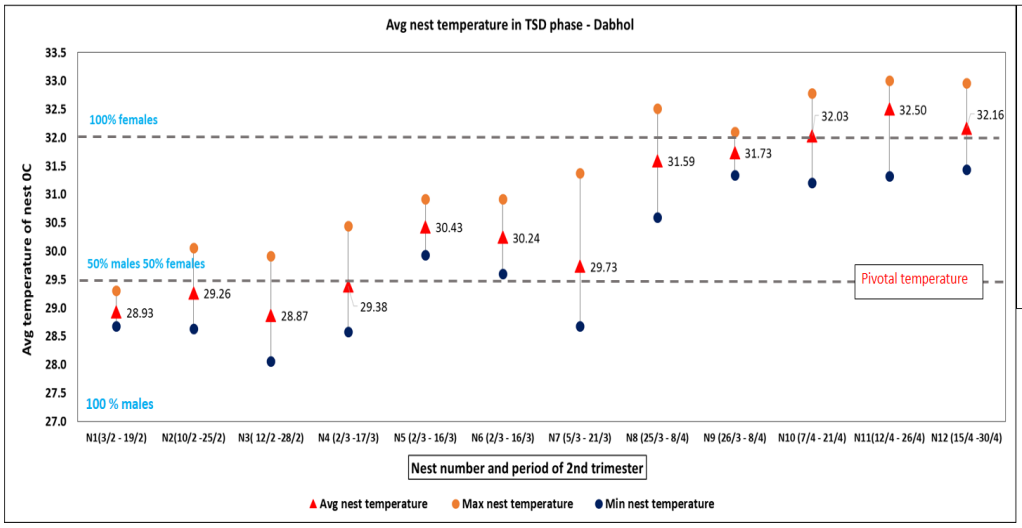
Nesting site Dabhol:

	Number of nests				
Nesting site	Jan	early Feb	late Feb	Mar	Apr
Dabhol	3	0	4	4	1

Table 5: Nesting pattern of Dabhol in 2019-2020.

Dabhol along with Kolthare is a major nesting site with a maximum number of the nest. The beach is comparatively small situated right at the mouth of big estuary having dense plantation of Casurina. The beach is at least 1.5 km away from the village and is very much isolated. The hatchery is erected on the north side of the beach in open space away from Casuarina. The nesting season at Dabhol has started in Jan with peak nesting in late Feb and March (Table 5).

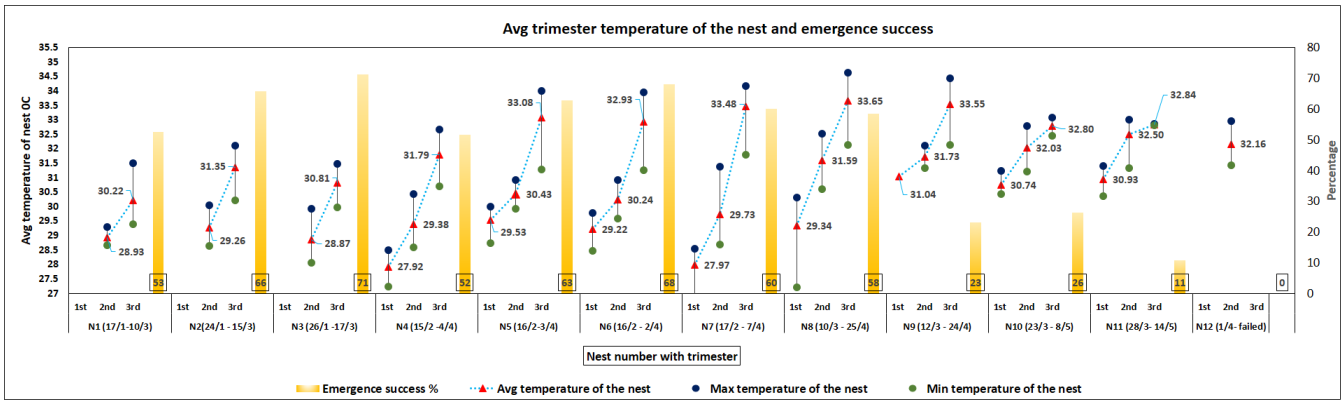
Temperature sex determination and sex ratio:



Graph 14: a) Avg nest temperature during 2nd trimester to estimate the sex ratio of hatchlings. b) Sex ratio of hatchlings at Dabhol nesting site for 2019-2020 nesting season.

The TSD period is spread from Feb till April. N1, N2 & N3 shows >50% male hatchlings proportion in Feb. N4 & N7 shows 1:1 male to female ratio. N5, N6, N8 is >50% females with few male hatchlings. The nest N9 –N12 is 100% females in late March & April. March shows variable TSD temperature (Graph 14). The avg temperature is cooler at Dabhol till mid-March resulting in male hatchling.

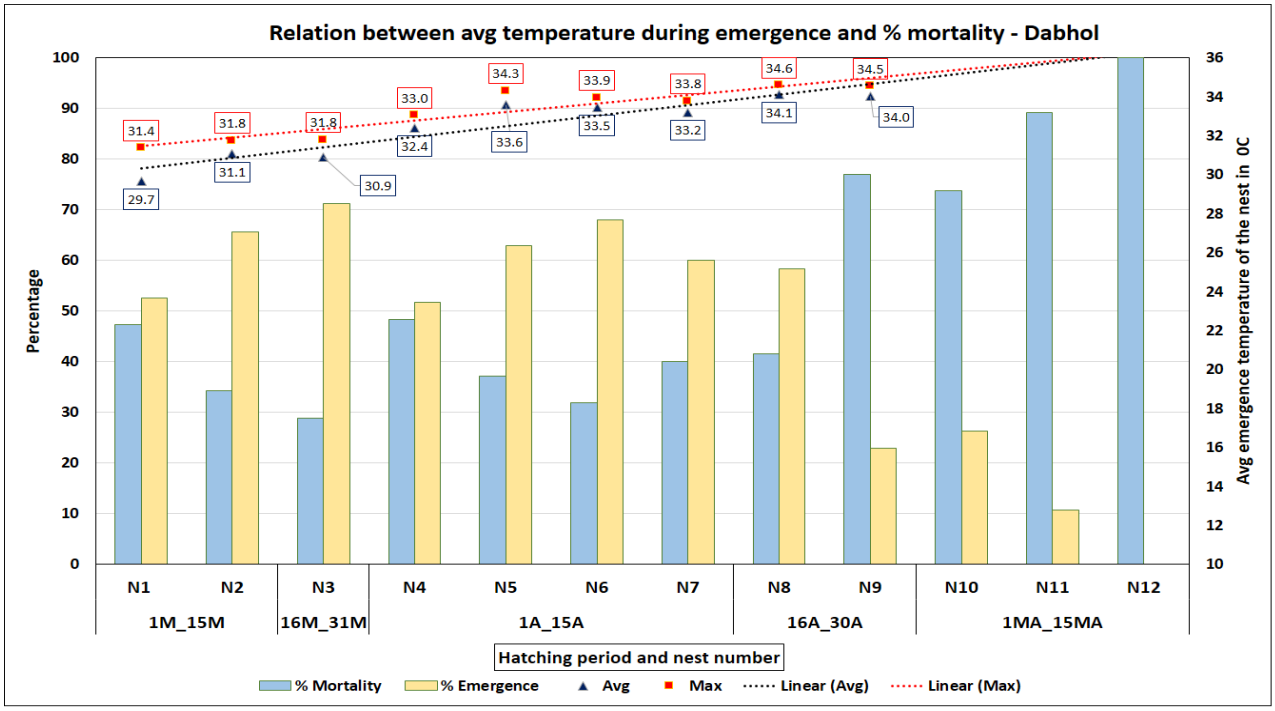
Lethal temperature:



Graph 15: The avg incubation temperature of the nest recorded for trimesters and the emergence success of the nest at Dabhol nesting site.

The incubation temperature from N7 crosses the threshold temperature of 33^0C the emergence success ratio is seen high till late April in N8. 3rd trimester extending to May is giving low success rate even though it is below the threshold value. The high success rate of emergence is because of rescuing of the hatchlings by opening the nest post-incubation period or after the emergence of first hatchlings (Graph 15). Complete temperature data for all the nests are available for this site.

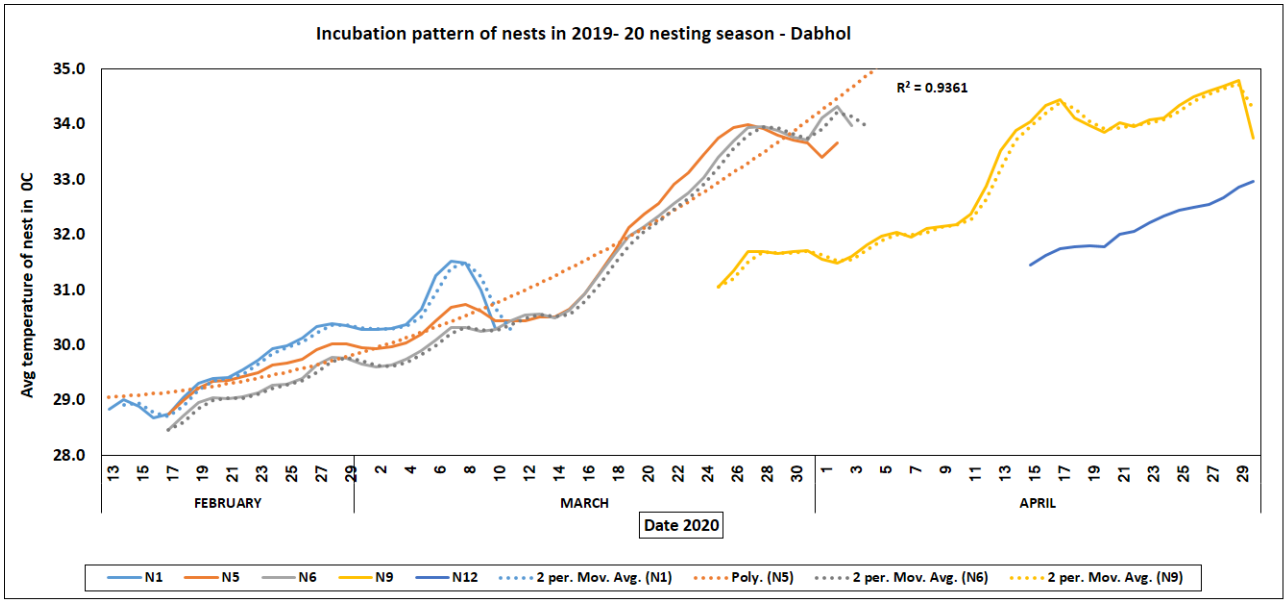
Emergence temperature and mortality



Graph 16: The mortality rate seen in the nests and the corresponding Avg temperature of nest during the emergence.

The relation of temperature and emergence success follows a typical pattern at Dabhol with a decrease in the emergence as the incubation period progress in late April and May. The emergence temperature of N8 & N9 is the same there is a difference in the emergence % (Graph 16). In absence of detailed examination of the post-incubation nest, a firm conclusion cannot be given. The same temperature observations were done in 2018-2019 nesting season. The only difference was in the use of shade. **This year the hatchery was covered on top and west-facing front side with a cotton sheet shade in mid-April as suggested by the forest department. It is not showing any promising results in terms of emergence success.** Further examination is required related to the use of appropriate shade.

Incubation temperature pattern in Dabhol:



Graph 17: The overall pattern of incubation in nest at Dabhol based on the avg daily temperature of the nest.

The incubation period of Dabhol for which incubation temperature data is available is from 15th Feb till 30 April. N5 & N6 has same nesting date. Except for N5 which shows a major fluctuation in temperature (polygonal curve R2=0.92), there is no clear trendline observed at Dabhol nesting site (Graph 17). The moving avg is considered due to distinct fluctuations in temperature at different times in different nest. ***The overall trend shows a lot of variations in the incubation stage of the nest during the same period.***

Though female-biased, considerable male hatchlings might have been released from this site. Shade made of white cotton cloth was used to cover the hatchery in mid-April which might have resulted in maintaining the incubation temperature of 3rd trimester below the threshold temperature. The low emergence success rate in May with temperature below the threshold value is unusual and needs further examination.

Nesting site Gaokhadi:

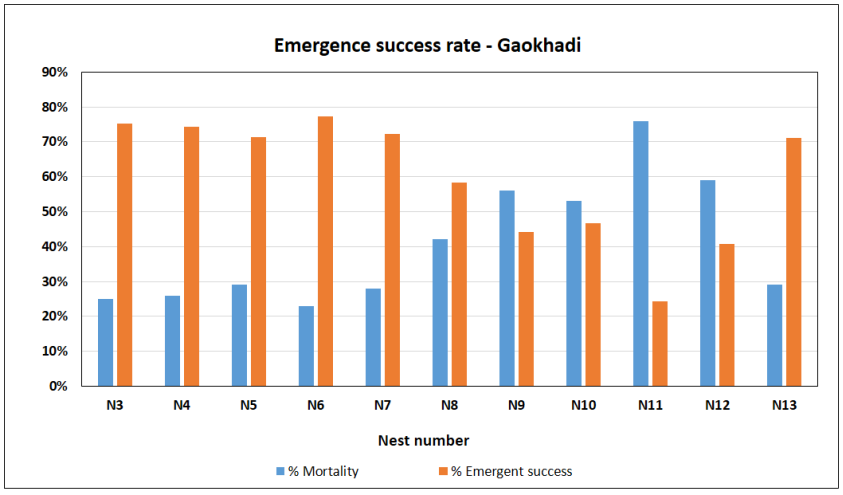
The beach has dense Casurina plantation with a big estuary on the north side. The hatchery is erected on the beach away from Casuarina. A peculiar incident is observed at Gaokhadi in 2018-19 and 2019-2020. The data logger unit malfunctions on the beach but when brought in workshop its starts functioning normally without any repair. Early march the vendor attended to the issue on-site. In mid-March, it stopped working for the second time. Ms Sumedha personally replaced the data logger unit given by the vendor and brought the original data logger to Pune for resolving the issue. No issue was observed in original data logger in the workshop but it could not be installed on-site due to lockdown. The replaced data logger though functioning till the end of the season, unfortunately, could not collect data. The SD card got corrupted. All attempts to retrieve data from the SD card by the vendor has failed to result in a major loss of significant temperature data. The malfunctioning of data logger on this site might be due to the high thermal conductivity of fine and black sand of the beach. The data logger needs to be placed at a height in an insulator box. The data of emergence success and stages of development at mortality collected by Shri Pradeep Dingankar is presented in the report.

	Number of nests				
Nesting site	Jan	early Feb	late Feb	Mar	Apr
Gaokhadi	0	0	3	8	1

Table 6: Nesting pattern of Gaokhadi in 2019-2020.

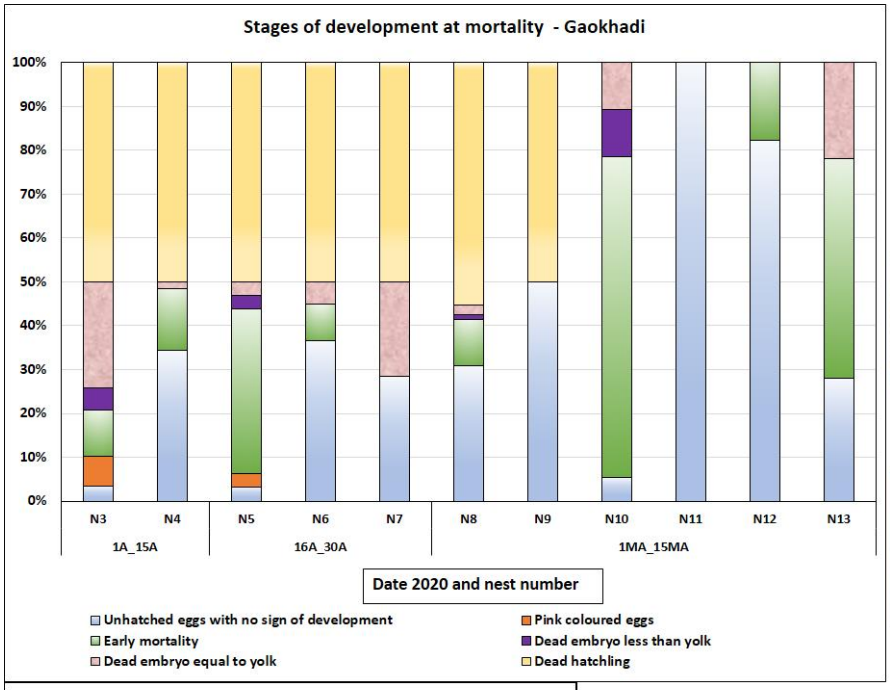
Emergence and mortality rate:

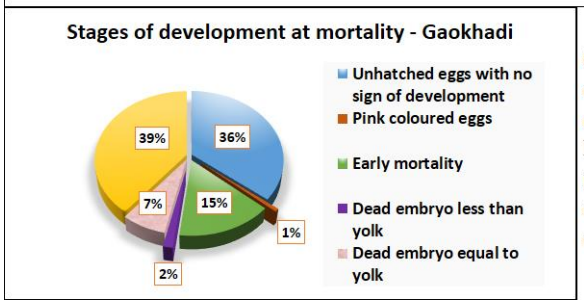
The overall success rate is high at Gaokhadi. The mortality pattern in the graph is typical except for N13 which shows high emergence success than mortality. Unusually this was the last nest with incubation period in May (Graph 18).

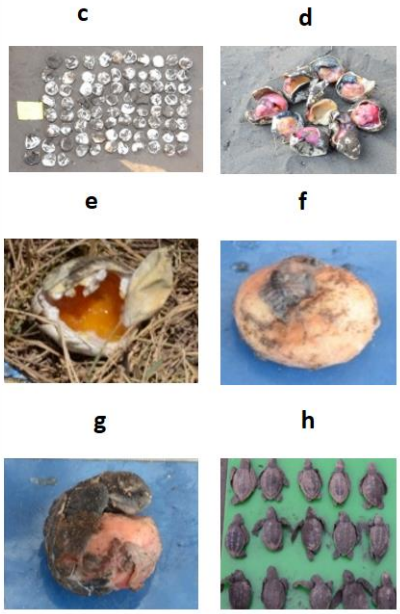


Graph 18: The mortality rate seen in the nests and the corresponding Avg temperature of nest during the emergence.

Stages of development at mortality:







Graph 19: The different stages of development of hatchlings seen after opening the post incubation period nest. a) Graphical representation of stages of mortality and avg nest temperature during emergence. b) Pie chart showing proportion of stages of mortality seen at Gaokhadi nesting sites. c) unhatched eggs d) pink coloured eggs e) yellow coloured early mortality eggs f) embryo less than yolk g) embryo equal to yolk h) dead hatchlings. Pc Sumedha Korgaonkar.

This is the most detailed and ideal examination of the nest done after its post-hatching period. Unhatched eggs are empty hollow eggs without any presence of yolk. It might be unfertilized eggs or early mortality of eggs before relocation. These eggs are seen in a high proportion (36%) at in N11 and N12 nest. Both these nest have an unusual clutch size of 37 & 76 resp and are found after the peak season in late March suggesting inter nesting. 1% of the eggs has pink colouration seen in N3 & N5 suggesting fungal infection. 15% is early mortality caused mainly due to relocation shock. Just 2% of the eggs were in stage having embryo less than the yolk & 7% of the eggs have embryo equal to the yolk. The stages of early mortality and mortality of half-developed embryo is mostly because of the high temperature affecting the developing embryo. Till N9 developed but dead hatchlings (39%) were observed seen stuck inside the nest. From N10 onwards the hatchlings were rescued and released.

The reason for mortality can very well be interpreted with confidence 37% mortality is for natural cause, 15% is due to relocation shock, 48% mortality would be due to temperature.

Gaokhadi had completely covered shade on the top of hatchery with green garden shade on 20th March. Though temperature data is not unavailable the effect of using shade net over hatchery can be inferred by looking at detailed mortality data. The presence of dead hatchlings inside the nest was high even with a shade. Prima facie the covering of hatchery with green shed net does not look promising and a detailed examination for appropriate method needs to be evaluated for Gaokhadi.

Fig 8: complete shade of green net over the hatchery. Shade provided at Gaokhadi from this project. pc Pradeep dingankar

Gaokhadi	Incubation period (days)		
	Avg	Max	Min
2019-2020	50	55	47
2018-2019	50	54	47

Table 7 : Compatison of incubation period between 2019 and 2020 nesting period.

The shed net put in Gaokhadi hatchery (see fig) does not have any impact on the incubation period. The table (7) gives the incubation period of 2019 -20 and 2018 – 19 of Gaokhadi. The days are same with or without shed net indicating there might be no change in the incubation temperature of the nest. In absence of temperature data, the interpretations of results are inconclusive and need detail study in next season

The data of Gaokhadi though was lost the interpretation for emergence success and mitigation efforts can be given based on observations on other sites. The examination of the nest is the most ideal way of evaluating the nest for mortality. Temperature affects the incubation period of the nest. Higher the temperature less is the incubation period. At Gaokhadi nesting site no difference is observed in the incubation period with and without the use of shed net. Detail examination is required to confirm the observation.

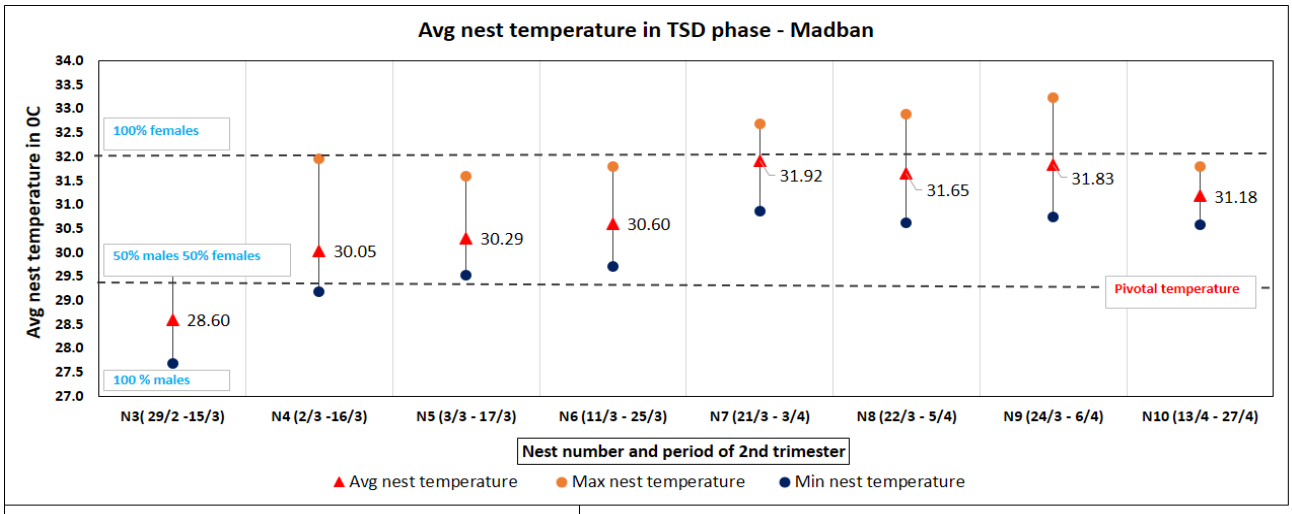
Nesting site Madban:

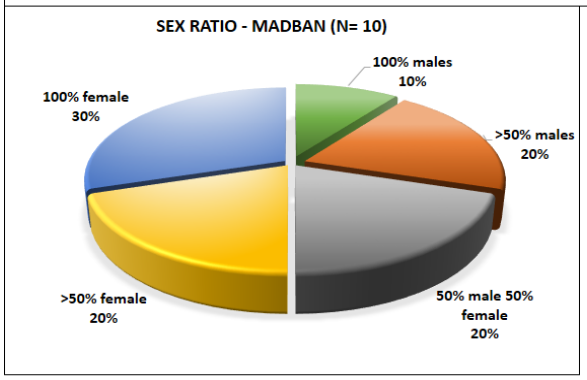
Madban the southernmost tip of Ratnagiri district shows the variation in beach morphology. It has emerged as a good nesting site. The hatchery is erected on the place well covered by tall Casurina trees. It receives direct sunlight late in the morning.

	Number of nests				
Nesting site	Jan	early Feb	late Feb	Mar	Apr
Madban	1	1	4	3	0

Table 8: Nesting pattern of Madban in 2019-2020.

Temperature sex determination and sex ratio:

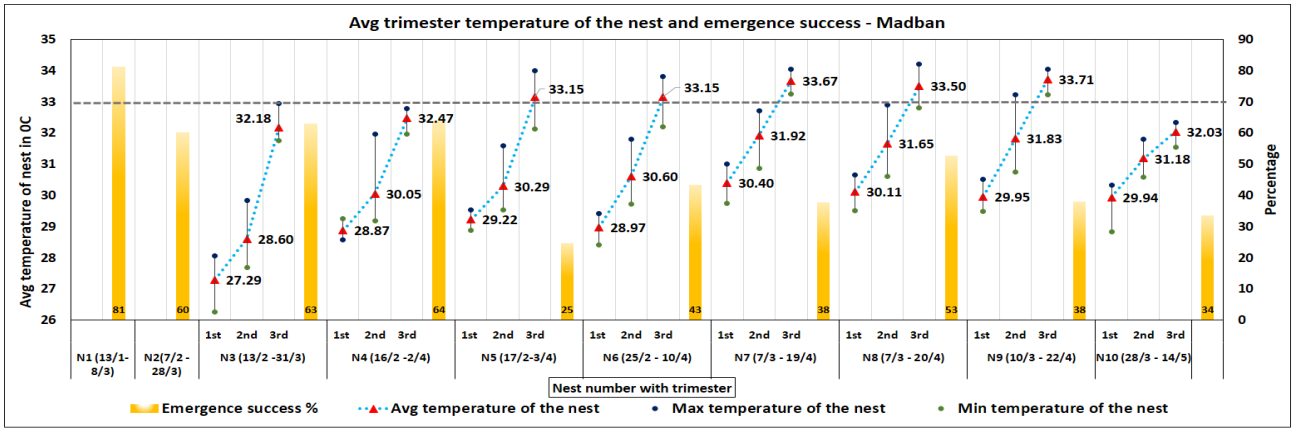




Graph 20: a) Avg nest temperature during 2nd trimester to estimate the sex ratio of hatchlings. b) Sex ratio of hatchlings at Madban nesting site for 2019-2020 nesting season.

The early Jan & Feb nest (N1, N2 & N3) must have given rise to male-biased sex ratio. N4, N5 & N6 is > 50% females. And rest 30% of the nest is 100% female-biased. ***The avg temperature of the nest in 2nd trimester is considerably cooler till 1st week of March resulting in a sizable number of hatchlings.***

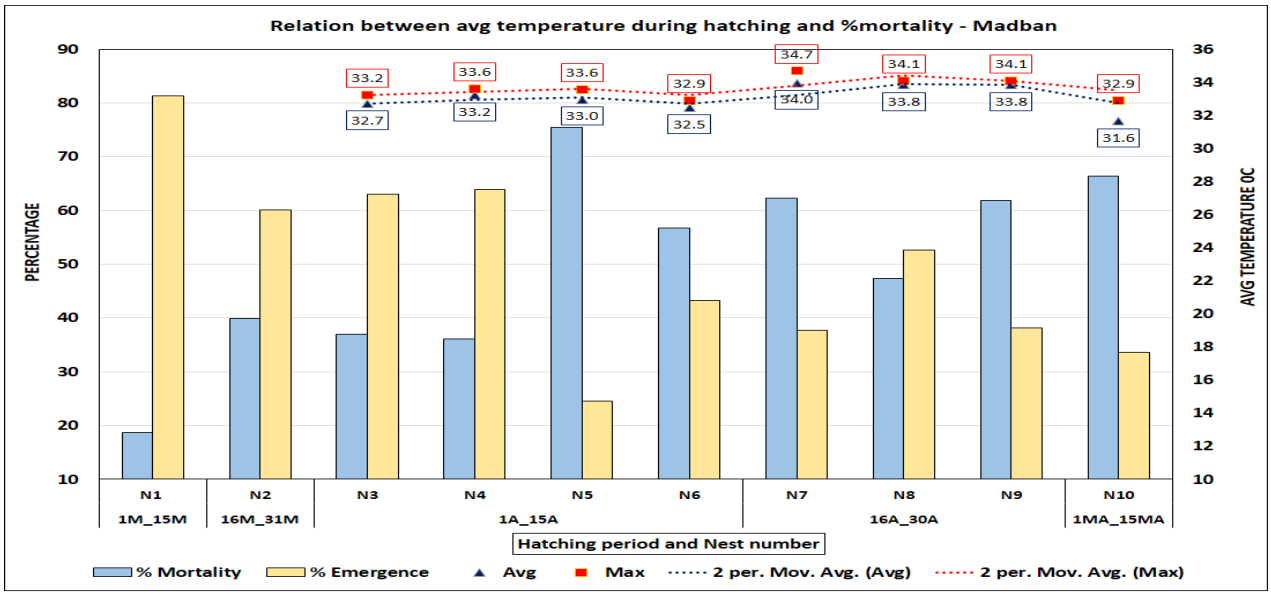
Lethal temperature:



Graph 21: The avg incubation temperature of the nest recorded for trimesters and the emergence success of the nest at Madban nesting site.

The nesting site shows an inconsistent pattern of a success rate as compared to other sites wherein from N5 it reduces drastically. The incubation period of all the nest is within the threshold value of 33^0C still the emergence is reduced from April and May. Since detail examination of the nest were not done the exact reason of mortality could not be interpreted.

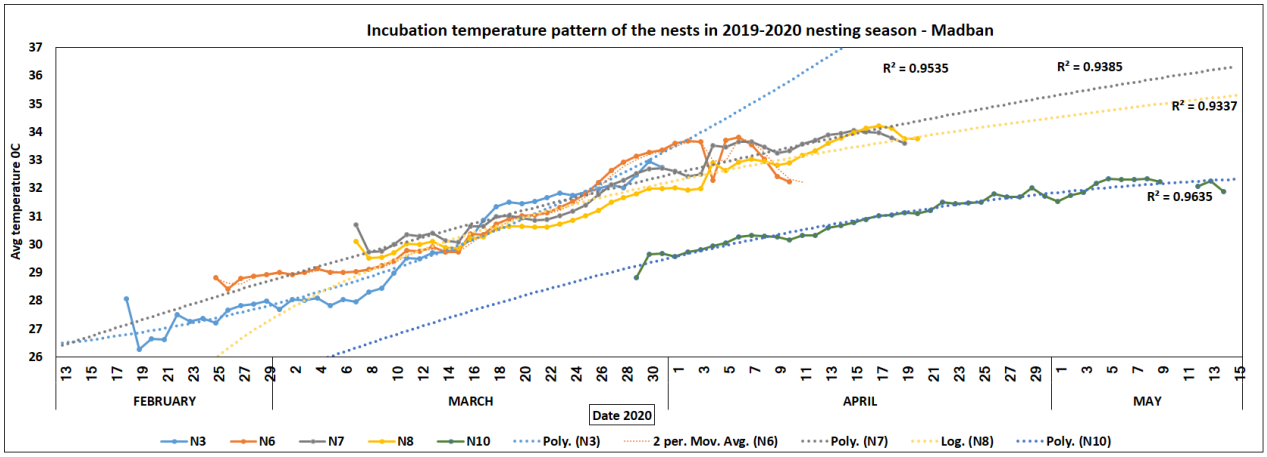
Emergence temperature and mortality



Graph 22: The mortality rate seen in the nests and the corresponding Avg temperature of nest during the emergence.

The trend of emergence success is typical with success rate till mid - April followed by a decrease in emergence and increase in mortality. The increased mortality is not consistent with the emergence temperature. The nest were not opened to check the hatchling stuck inside the nest. Detail examination of the nest is recommended to check the reason for mortality.

Incubation temperature pattern in Madban:



Graph 23: The overall pattern of incubation in nest at Madban based on the avg daily temperature of the nest.

Madban has incubation period from13th Feb to 15th May based on the availability of incubation temperature data. All the nest except N8 shows polygonal curve indicating major fluctuations in incubation temperature over the incubation period. N8 nest has a logarithmic trend line (R^2= 0.95) showing an increase in the rate of change of temperature in 1st week of April.

The nesting site having a sizable number of male hatchlings are present in the clutch. The inconsistent pattern of emergence and threshold temperature does not give a clear picture of the threshold value for this site. The reason for mortality is required to be assessed by opening the nest. There is a fair chance that hatchlings are stuck inside the nest at the time of emergence thereby reducing the emergence success rate.

Nesting site Vayangani (Vengurla)

This is the only beach selected from Sindhudurg district for this project. The beach is broad and the sand is white and coarse than other sites. Instead of single hatchery erected on the beach, the relocated nests are kept separately at a distance and is protected by fishing nets (Fig 9). The relocated nest are placed on the north side of the beach having shrubs and settlements. The nesting is spread across Jan till early March with peak season in Feb (Table 9).

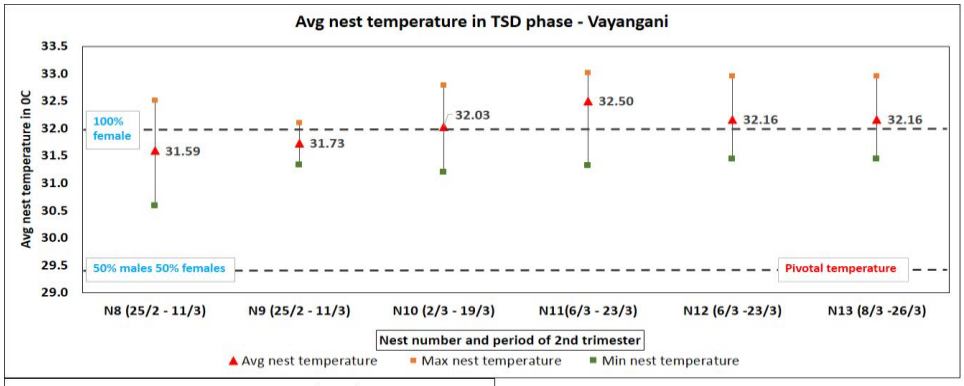
Fig 9: Nest are protected separately at Vayangani 2019 and 2020. pc Sumedha Korgaonkar 2019 and Prakash Khobrekar 2020

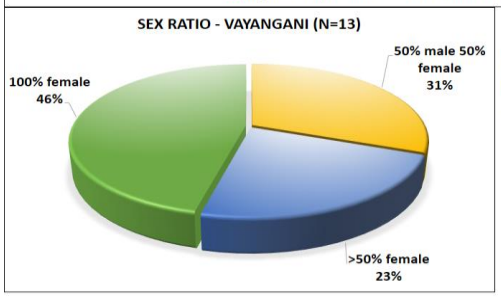
	Number of nests				
Nesting site	Jan	early Feb	late Feb	Mar	Apr
Vayangani	6	3	5	5	0

Table 9: Nesting pattern of Vayangani in 2019-2020.

Temperature sex determination and sex ratio:

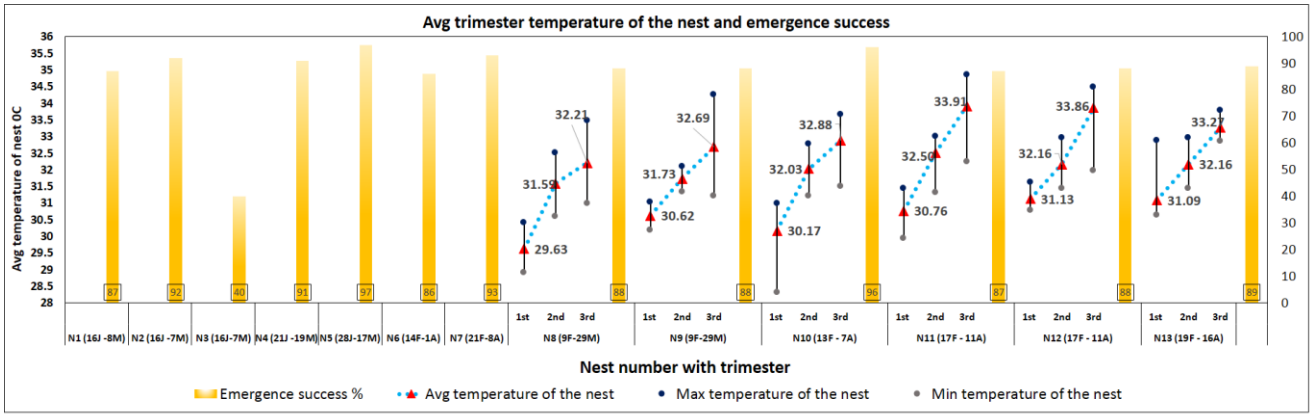
Considering the incubation temperature in Feb it can be presumed that this nesting site has a highly skewed female-biased sex ratio. N8 –N13 with TSD period in Feb and March has temperature supportive of a high number of female hatchlings this nesting season.





Graph 24: a) Avg nest temperature during 2nd trimester to estimate the sex ratio of hatchlings. b) Sex ratio of hatchlings at Vayangani nesting site for 2019-2020 nesting season.

Lethal temperature:

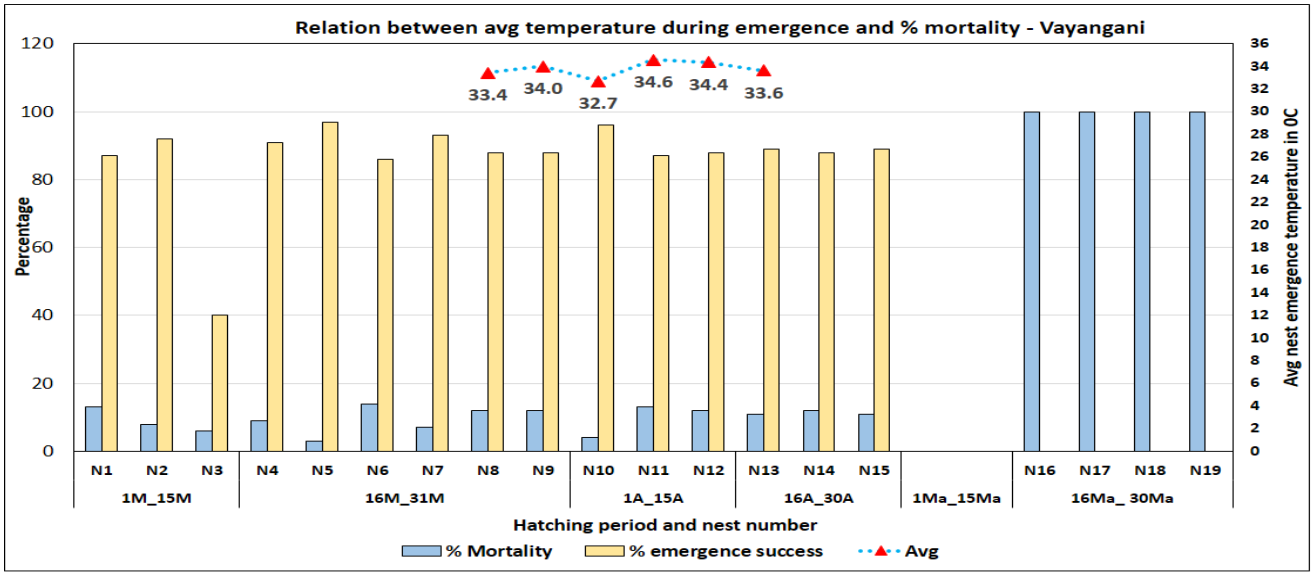


Graph 25: The avg incubation temperature of the nest recorded for trimesters and the emergence success of the nest at Vayangani nesting site.

The overall success rate shows excellent results at Vayangani. The success rate is one of the highest among other rookery sites. Such success is doubtful even in ideal condition for a species showing type I survivorship curve where mortality is high at the early stages than in adults. Assuming the data is correct then we can say that the tolerance temperature is above 34 ^{0}C for this subset of the population. Again this does not go by scientific observations and is inconsistent with observations from other sites.

The data looks unrealistic in absence of nesting data provided by hatchery managers. The nesting and hatchlings released data is provided by the forest department which is showing major discrepancy not just at Vayangani but also on other nesting sites. The lethal temperature could not be suggested with the available data. Detail nest examination is needed to comment on the findings

Emergence temperature and mortality:



Graph 26: The avg incubation temperature of the nest recorded for trimesters and the emergence success of the nest at Vayangani nesting site.

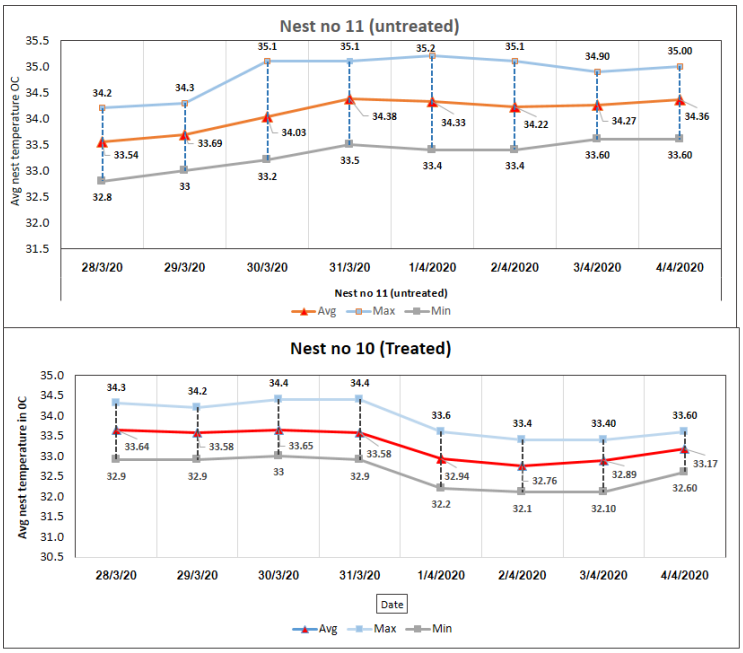
The data used is from the forest department which had a discrepancy in nesting and hatching dates. N16 – N19 which shows 100% mortality was not recorded at Vayangani nesting sites. No nesting was found in April at Vayangani (pers. comm with hatchery manager). Detail nest examination is required to interpret the results.

Mitigation of high temperature:

The first experimental set up regarding reducing the nest temperature was done at Vayangani, Madban and Gaokhadi. In this set up dry coconut leaves were placed directly over the upper sand above the nest. Water was sprinkled sparingly on the coconut leaves during noon. The coconut leaves were removed after 4 days of observation as there was no change in nest temperature and it proved to be inconvenient to the hatchery manager. At Vayangani the

Fig 10: Nest covered with dry coconut leaves inside the hatchery. Representative image from Gaokhadi. Pc Pradeep Dingankar

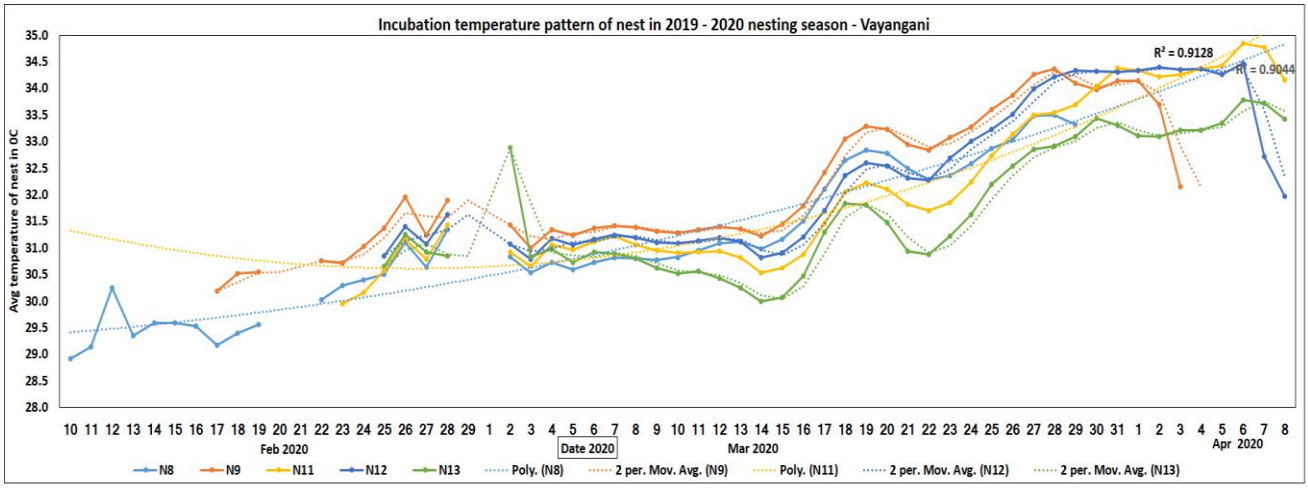
experimental set was continued with coconut leaves replaced by a cane basket kept inverted on the sand above the nest N10 (as treated). A jute gunny bag was placed over the basket. The jute gunny bag was wet by seawater twice at 9.00 am and evening at 6.00 pm from 30th March till 3rd April. The Adjacent nest N11 was kept exposed to the sun (untreated). Both the nest received the same amount of sunlight, the nesting date and incubation period coincided.



Graph 27: Avg nest temperature of the nest with and without cane basket and wet cloth used in experimental set up at Vayangani. Experiment performed by Prakash Khobrekar and Suhas Toraskar on field.

On 28th and 29th, March both treated and untreated nest show similar avg temperature of 33.6^{0}C. On 30th with the use of cane basket and wet gunny bag on it the temperature of nest no 10 shows the promising result. It shows a reduction of avg, max and min temperature by1^{0}C till 3rd April. As compared to the untreated nest the difference of temperature was almost 1.5^{0}C. Afterwards, the temperature is seen increasing due to discontinuation of experimentation. The trial of mitigation method on the field was done by Shri Prakash Khobrekar (voluntary participation) and Shri Digambar Toraskar (of Mangrove foundation, voluntary participation) with hatchery manager Shri Suhas Toraskar having telephonic coordination with Ms Sumedha.

Incubation temperature pattern in Vayangani:



Graph 28: The overall pattern of incubation in nest at Vayangani based on the avg daily temperature of the nest.

Studying the incubation temperature of a nesting population of olive ridley turtles (*Lepidochelys olivacea*) in the coast of Maharashtra with advance data logging system (Phase II) – Submitted by Sumedha Korgaonkar (Nov 2020).

The incubation period is in Jan till April first week. The nest having same incubation period is showing the same trend of hills and valleys in the graphs. The nest N8 (R^2= 0.90) & N11 (R^2=0.91) shows a polygonal curve indicating major fluctuations in incubation temperature over the incubation period. All the other nest has to move avg trend line as they do not show a clear trend.

Unexpected flooding of the nest during strong spring tide

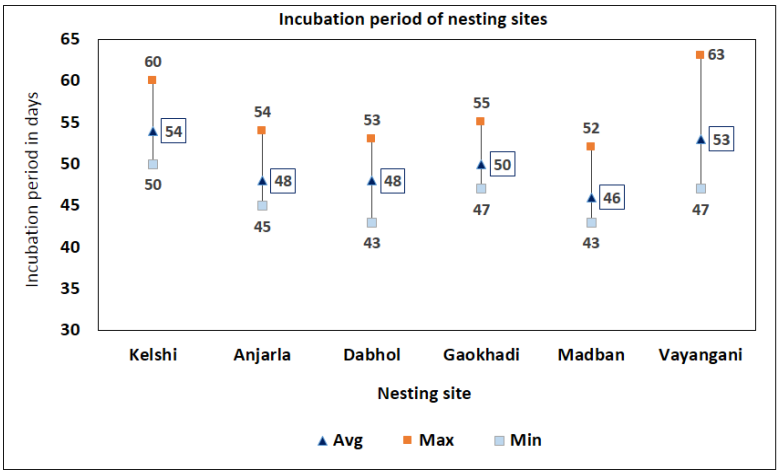
The nesting was abruptly stopped on the 9th of April due to inundation of seawater during strong springtide. Fortunately, days before flooding most of the nest had opened naturally and hatchlings released The last two nest were at hatching stage of incubation. The data logger was removed and eggs of last two nest were relocated to a safer place skillfully by Shri Suhas Toraskar (Fig11). The hatchlings later emerged successfully from the rescued nest. The incident has demonstrated that the relocation of the nest at advance stage of incubation can be done swiftly with utmost precautions when conditions like flooding arise. This is not known or practiced in Maharashtra as general hatchery management. Ms Sumedha has personally observed this technique done by skilled and experienced hatchery manager in Gujarat where flooding of the nest is commonly observed. Shri Suhas Toraskar with his experience of more than 15 years has shown exceptional skill in using the same technique (self-developed) to protect the nest. With the narrowing of the beach due to erosion and rising of sea level, the incident of unpredictable flooding of the nest will tend to increase. This technique with detail SOP needs to be drafted and given to hatchery managers for implementation on the field.

Fig 11: Unpredicted flooding of nest during strong spring tide. Two nest at advance stage of development were relocated to above tide line skilfully by Suhas Toraskar. Hatchlings later emerged from the relocated nest indicating successful relocation. pc Prakash Khobrekar and Digambar Toraskar

The sex ratio of Vayangani is highly female-biased even if the TSD period was in Feb. This might be due to placing of the relocated nest on the part of the beach getting maximum sunlight throughout the day. A sizeable number of males might have released from the Jan nest as the emergence of success is high for the nesting site. Though not much can be interpreted about lethal temperature and mortality rate the other methods of hatchery management is worth mentioning from Vayangani. Preliminary results of reducing the nest temperature are promising but there is a need to study this in detail before implementing on different sand types and hatcheries. Other nesting sites may give different results with the varying type of sand. The shades should be used only for maintaining the nest temperature at or below 32.5 ^{0}C.

Comparison of the Incubation period of the nesting site:

To avoid confusion the Incubation period is calculated from the date of relocation till the date of emergence of 1st hatchling. The incubation period is directly related to the incubation temperature. Higher the incubation temperature less is the incubation period and vice versa.



Graph 29: Comparison of incubation period of all nesting sites in 2019-2020 nesting season.

The incubation period of Kelshi is 50 - 60 days with avg of 54 days towards a minimum of 50 days. Anjarla has an incubation period of 45 – 54 days with avg days of 48 and weighted towards min of 45 days. The temperature of Anjarla is persistently high throughout the nesting season (see fig graph of trends in temp). Dabhol and Madban show an incubation period range of 43 days till 53 days. Dabhol avg is 48 days and centred weighted whereas Madban's avg is 46 days and weighted towards minimum. Gaokhadi has a range of 47 to 55 days with avg 50 days weighted towards a minimum of 47 days. Vayangani among all the sites shows a huge difference in the incubation period. The range is 47 -63 days with an avg of 53 days.

The incubation period should not be generalized for all the nesting sites in Maharashtra. Incubation period which is dependent on the microenvironment of the nest shows significant variation even within the nesting site. At many sites depression in the nest before emergence is not observed resulting in the sudden emergence of hatchlings.

Conclusion:

The scientific evidence as an outcome of the project is a support for the evaluation of the project. ***The shift in nesting season from winter to summer results in an increase in mortality of developing embryos and hatchlings***. The mortality rate can be reduced by appropriate mitigation methods. The mitigation methods may differ due to variation of sand type between the nesting sites. This variation may be seen on the same nesting over a while. This necessitates a site-specific temperature monitoring unit for deciding on the conservation efforts. The decision of adopting the mitigation methods over a while can be done by hatchery managers if they are trained to be ***Parabiologist. The local hatchery managers are the only unchangeable stakeholders in turtle conservation who witness the change on their site***. There is a need to give advance training to the hatchery managers from these major rookery sites. The overall sex ratio of hatchlings from Maharashtra is female-biased but a sizable number of male hatchlings are also released. These male hatchlings have a better chance of survival than the female hatchlings hence balancing the adult sex ratio (Sönmez et al., 2016). Based on average temperature method for sex determination highly skewed sex ratio as of now is not a concern for olive ridley turtle nesting population in Maharashtra. ***Any attempt to alter the sex ratio should not be encouraged on the nesting sites.*** Instead, the early nest found from Nov to Jan end should be highly protected at all sites as this will ensure the male-biased sex ratio of hatchlings.

Temperature is affecting the developing embryo and emerging hatchling***. More focus should be given to reducing the nest temperature below the threshold temperature of 33^0C.*** Preliminary evidence suggests the use of a green shade net over the hatchery as a mitigation method has its limitations and is not sufficient to reduce the nest temperature. Other alternative methods need to be investigated further for its efficient application specific to the nesting sites. ***The high nest temperature not only reduces hatching and emergence success rate but also affects the healthy normal development of the hatchling reducing their survival rate in open sea (Mueller et al., 2019).*** The hatchery management information that was disseminated to hatchery managers over a period needs major adaptation based on these scientific pieces of evidence. Maharashtra being a major nesting site for olive ridley sea turtle has come a long way in pragmatic conservation of this species. Maharashtra can take lead actions in introducing this scientific evidence for adapting the hatchery management practice. It will ensure not just the increase in hatching success but also maintaining a healthy stock of olive ridley population of the Indian Ocean west.

Recommendations

1) Designing a protocol for hatchery management practice based on the knowledge acquired through this scientific evidence. The hatchery practice implemented till now is generalized and based on the distinct nesting behaviour of Arribada population. With the outcome of this project, the conservation program in Maharashtra can have effective hatchery management protocol designed, updated and implemented specifically for the nesting sites.

2) The olive ridley conservation programme in Maharashtra can take a leader steps in training and developing hatchery managers of major nesting sites as Parabiologist. This will ensure the successful implementation of conservation management for many years.

3) Climate change is happening and its effect on terrestrial life of sea turtle is seemingly disastrous. Globally conservationist has suggested robust mitigation efforts (Vindas-Picado et al., 2020). The conservation efforts in Maharashtra through the installation of temperature data logger system has taken a step ahead in introducing effective mitigation. It is one of its kind project which can be implemented for at least a decade for achieving long term conservation goals.

4) Phase III of the project is needed for both research and correct implementation of conservation strategies completing the developmental phase of the project.

5) The indigenously developed units are robust and can be used for more than 15 years. Some advance features like analytical software and mobile apps is needed for its convenient use and effective application. This can be established in phase III of the project.

6) Establishing the database of nest temperature and nesting data at a nodal agency is required which could be shared with the researcher globally and regionally to identify trends over a long period.

7) Funds are required to ensure the continuation of the project for a prolonged period. Identifying and having a sponsored funding partner on board can be sought in phase III of the project. A 5-year contract could be signed between the funding partner and implementing agency (Mangrove cell / Mangrove foundation / Forest department (WL)).

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Project Team

Funding agency

MANGROVE FOUNDATION

Nodal agency

महाराष्ट्र वन विभाग

Research

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

Dr K Sivakumar (Scientist F, WII) Project supervisor

Ms Sumedha Korgaonkar (PhD scholar, WII) Principal investigator

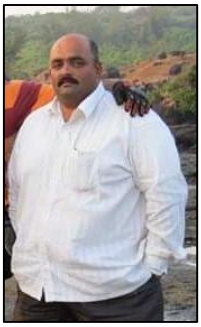
Hatchery managers

Lahu Dhopavkar - Kelshi

Ajinkya Keluskar - Anjarla

Kedar & Pravin Todankar - Kolthare

Dattaram Vanarkar - Dabhol



Pradeep Dingankar -Gaokhadi

Shyamsunder Gavankar - Madban

Suhas Toraskar - Vayangani

Studying the incubation temperature of a nesting population of olive ridley turtles (*Lepidochelys olivacea*) in the coast of Maharashtra with advance data logging system (Phase II) – Submitted by Sumedha Korgaonkar (Nov 2020).

Details of the functioning of data logger unit for evaluation

Dl no	Place of installation	Network strength	Data transfer	Data logger working	Placing of data logger
TO1	Gaokhadi	On beach is good	GSM data available 9/2 – 1/3. SD card shows corrupted so no data could be retrieved.	Data logger needed upgrading once. Later it stopped working on field so replaced. The replaced data logger was working till the end but no GSM data transfer and SD data available.	Initially data logger was placed on sand. After initial transfer it stopped working. So It was placed on a 3 feet stool. The hatchery was covered on the top by green net cloth for shade.
T02	Vayangani	BSNL network on beach is weak though it has a tower nearby. By holding the antennae high the issue was later solved.	GSM data available from 10/2 – 9/4. SD card data from 23/2 – 9/4. 20/2- 21/2 and 29/2 – 01/3 no data is available in both. 75% of the data has 2 entries of 0.59 hr in both GSM and SD card with complete data entry. 25% has 0.59 hr as multiple entries resulting in incomplete data received through GSM.	No malfunctioning of the data logger was observed. The data logger was used till 10th of April.	Data logger was placed in the middle of the hatchery above on a platform raised at a height of 5.5 feet above ground. The antenna was mounted on the long stick and raised further which helped to solved network issue. With this data transfer through GSM was consistent.
T03	Kelshi	Poor network connectivity. SIM card was change to Idea from BSNL. Intermittent data was transferred from 25/3 till 12/4.	GSM data not received of 10/2 – 18/2, 25/2 -26/2, 27 /2 -24/3 (30 days) SD card all the data is available till 21/4. No data after that even though the data logger was working. Most of the data has repetitive entries at 0.59 hrs. The GSM data received was incomplete but in SD card was complete. Repetitive entries at 0.50 hr see 3/4/20. On 29/3 and 25/3 incomplete data was recorded in both GSM and SD card.	No malfunctioning of the data logger was observed. The data logger was used till May end on field.	Data logger was placed on the sand inside the hatchery and antennae was tied to the pole of hatchery.

Dl no	Place of installation	Network strength	Data transfer	Data logger working	Placing of data logger
T04	Madban		GSM data available from 9/2 -13/3. No data transfer after 13/3 SD card – data available is 9/2 -8/6. Most of the data has repetitive entries at 0.59 hrs. The GSM data received was incomplete but in SD card was complete. 16/3 has 27000 entries of 0.59 hr. No data available from 13/2 -17/2 but battery showed 100%	No malfunctioning of the data logger was observed. The data logger was used till May end on field.	The hatchery was built in comparatively cooler place and data logger was placed on the sand with antennae tied to pole.
T05	Anjarla	After initial issue with the network later we could get good network connectivity with BSNL SIM card	Data available from 17/2 – 8/5. 20/2 -23/2, 3/3, 5/3 -22/3, 9/5 – 11/5 both GSM and SD card data missing (25 days). Most of the data has repetitive entries at 0.59 hrs. The GSM data received was incomplete but in SD card was complete.	No malfunctioning of the data logger was observed. The data logger was used till May end on field.	Partial shade was put on the hatchery in March. Data logger was placed on the sand with antennae tied to pole.
T06	Dabhol	Very good BSNL network received regular data till 30/4	Data available from 10/2 – 30/4 Most of the data has repetitive entries at 0.59 hrs. The GSM data received was incomplete but in SD card was complete. No loss in data	No malfunctioning of the data logger was observed. The data logger was used till May end on field.	Data logger was hidden inside the sand with antennae tied to pole. April and May hatchery was completely covered by bed sheet on the top. Also the side facing west side was covered
T07	Kolthare	No network available except JIO	No GSM data available. SD card data is seen till its use.	Data logger was not used as it was destroyed by Jackals just before lockdown.	

Remark:

1) The data logger hardware has no observable issues.
2) The lid of IP65 box needs to be transparent or have a transparent window through which regular monitoring of data logger could be done without opening it.
3) The sensors wire needed to be double the size. Ie 6mt
4) Antenna wire if long can help to install it at higher place to receive signal. This was done in Vayangani.

Note: remark 2, 3 and 4 can be done with an extra cost for next season.

Studying the incubation temperature of a nesting population of olive ridley turtles (*Lepidochelys olivacea*) in the coast of Maharashtra with advance data logging system (Phase II) – Submitted by Sumedha Korgaonkar (Nov 2020).

Monitoring and Evaluation plan of project

	Project Outcome/ Impact	Evaluation Question	Sub questions	Indicator(s)	Data collection method(s)	Evaluation design	Person(s) responsible for data collection	When was data collected	limitations	Key assumptions
1	Climate change the driving force behind shift in nesting pattern resulting in high nest temperature reducing hatching success rate	Q1) Is climate change the driving force behind the shift in nesting pattern resulting in high nest temperature reducing the hatching success rate?		Direct observation	Direct baseline nesting data , bt survey	Survey	FD	2015-2020	Missing data	The forest department has correctly documented the nesting dates.
2	Developing the datalogger and customising for turtle conservation with advance GPS system	Q2) Are the deployed data loggers robust in their application on field?		Uninterrupted data receiving	Direct observation and Vendor evaluation	Initial and Final quantitative measure	PI , Vendor HM	2019 & 2020 nesting season	No third party evaluation done	There is a full network coverage from study sites
		2a) Has the data from data logger helped in collecting information filling up the knowledge gap at study site?	What types of dataloggers has been deployed in such projects in other countries or in India. Is this project unique in any way?		literature review	Deskwork survey	PI	2020 nesting season	published work considered	Excluding unpublished work
		2b) Is it in anyway harmful or dangerous to the incubating nest or emerging hatchlings?		No hatchlings are observed entangled in the wire or sensor stick.	Common platform for information sharing like whatsapp, questionnaire survey	Focus group survey	PI	2020 nesting season		The focus group provides honest answers
3	Hatchery managers as parabiologist to achieve long term conservation goal	Q3) How the long term goal of the project be achieved by involving the local hatchery managers and training them as Parabiologist?		Change in their perspective and hatchery skills after the project	Questionnaire survey and data sheet filling	Focus group survey	PI	2020 nesting season		The hatchery managers give a true and appropriate answers to questionnaire.
4	Mitigation of high temperature for emerging hatchlings	Q4) Are there completely developed hatched but dead hatchlings seen in the nest post incubation period?	What temperature is best suited during the emergence period of hatchlings?	Decrease in proportion of dead hatchlings inside the nest	Questionnaire survey and photographic evidence of past nesting season	Survey of focus group and direct before after observation on field	PI & HM	2019, 2020, 2021 nesting season		Dead hatchlings are dehydrated because of high temperature
		4a) Is it correct to open the nest as hatchery practice at the time of emergence to rescue the hatchlings if the hatchlings fail to emerge?	When to start the mitigation of the temperature?	Decrease in proportion of dead hatchlings inside the nest	Questionnaire survey and photographic evidence of past nesting season	Survey of focus group and direct observation on field	PI & HM	2019, 2020, 2021 nesting season		Nest forming solid rock like is because of high temperature and humidity
		4b) What method should be implemented for the mitigation of temperature?	Will the method remain same at all the nesting sites?	Providing shade and maintainance of temperature at its threshold value. Increase in hatching an emergence success rate.	Direct evidence from data analysis of datalogger data. Experimental design using appropriate shade.	Before after results, Quantitative measure	PI & HM	2019 & 2020 nesting season	sample size is less	Basic natural shading matreial can help reduce the incubation temperature.

Datasheet nesting and emergence and mortality stages

Sumedha Korgaonkar, PhD scholar (WII)

Hatching success datasheet

		N 1	N 2	N 3	N 4	N 5	N 6	N 7	N 8	N 9	N 10	N 11	N 12	N 13	N 14	N 15
Dead embryo bigger than yolk																
Dead embryo with yolk sac																
Dead embryo with yolk absorbed																
Piped dead																
Dead hatchling																
Other observations																

Project : Studying the incubation temperature of nesting population of olive ridley turtles (*Lepidochelys olivacea*) in coast of Maharashtra with advance data logging system (Phase II).
Funding : Mangrove and Marine Biodiversity Conservation Foundation of Maharashtra.

Sumedha Korgaonkar, PhD scholar (WII)

Hatching success datasheet

Name of the beach:_____ Name of beach managers:_____

		N 1	N 2	N 3	N 4	N 5	N 6	N 7	N 8	N 9	N 10	N 11	N 12	N 13	N 14	N 15
Date of nesting																
No of eggs																
Date of hatching																
Live hatchling released																
Empty shells																
Data of un hatched eggs																
1) No of un hatched eggs																
2) No development																
a) Pink colouration																
b) Yellow colouration																
Dead embryo less than yolk																
Dead embryo equal to yolk																

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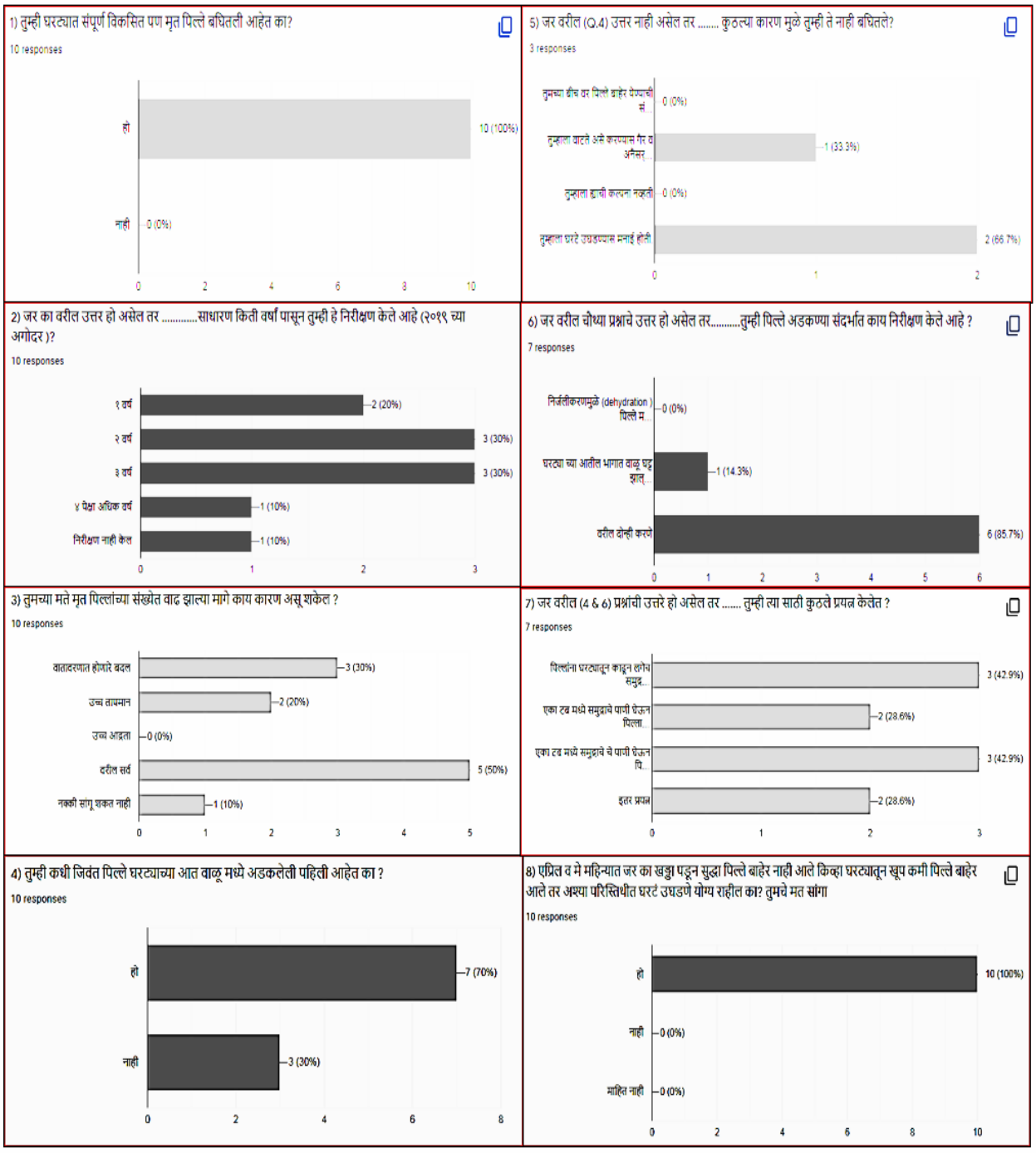
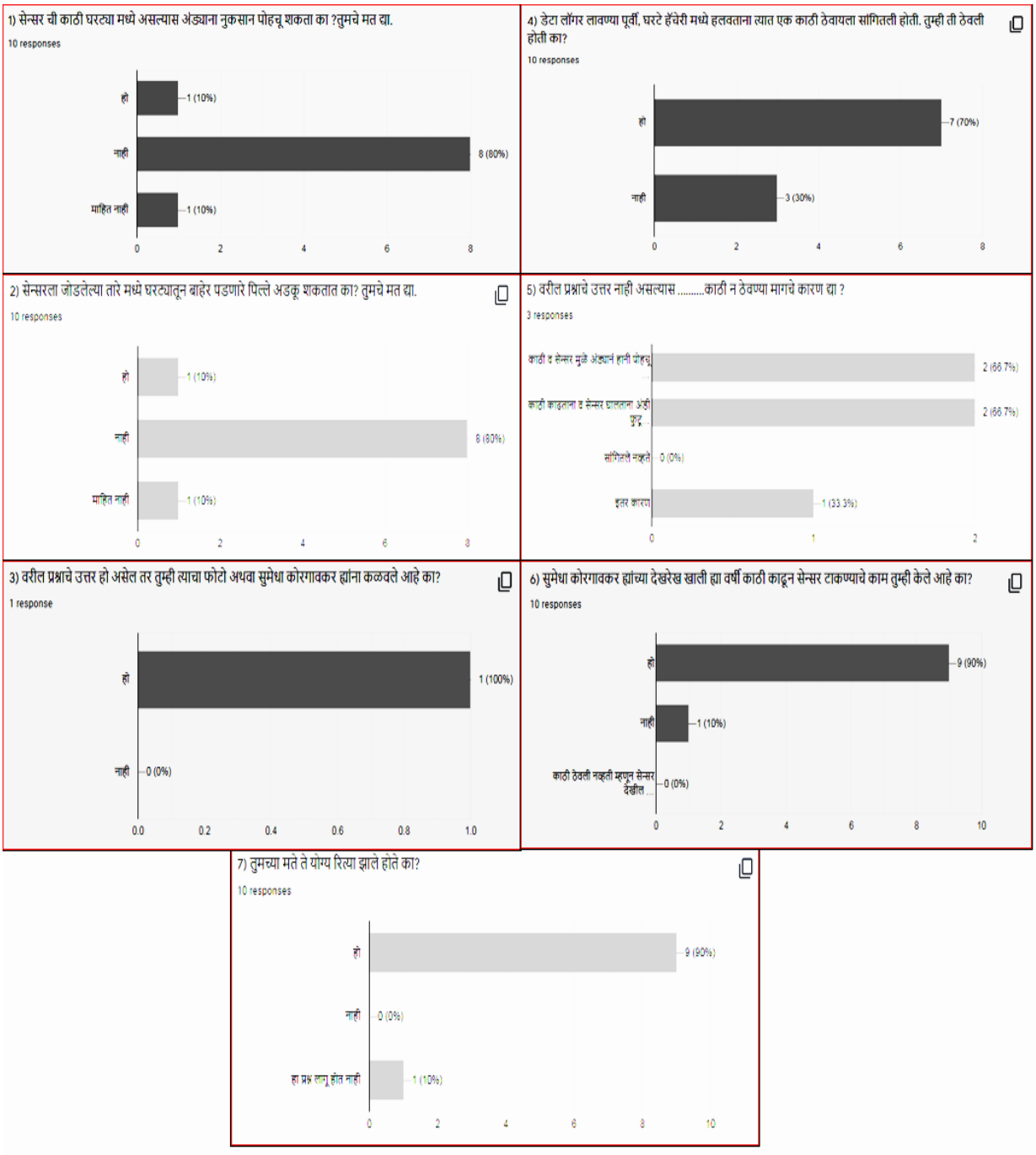
Studying the incubation temperature of a nesting population of olive ridley turtles (*Lepidochelys olivacea*) in the coast of Maharashtra with advance data logging system (Phase II) – Submitted by Sumedha Korgaonkar (Nov 2020).

Survey Questionnaires



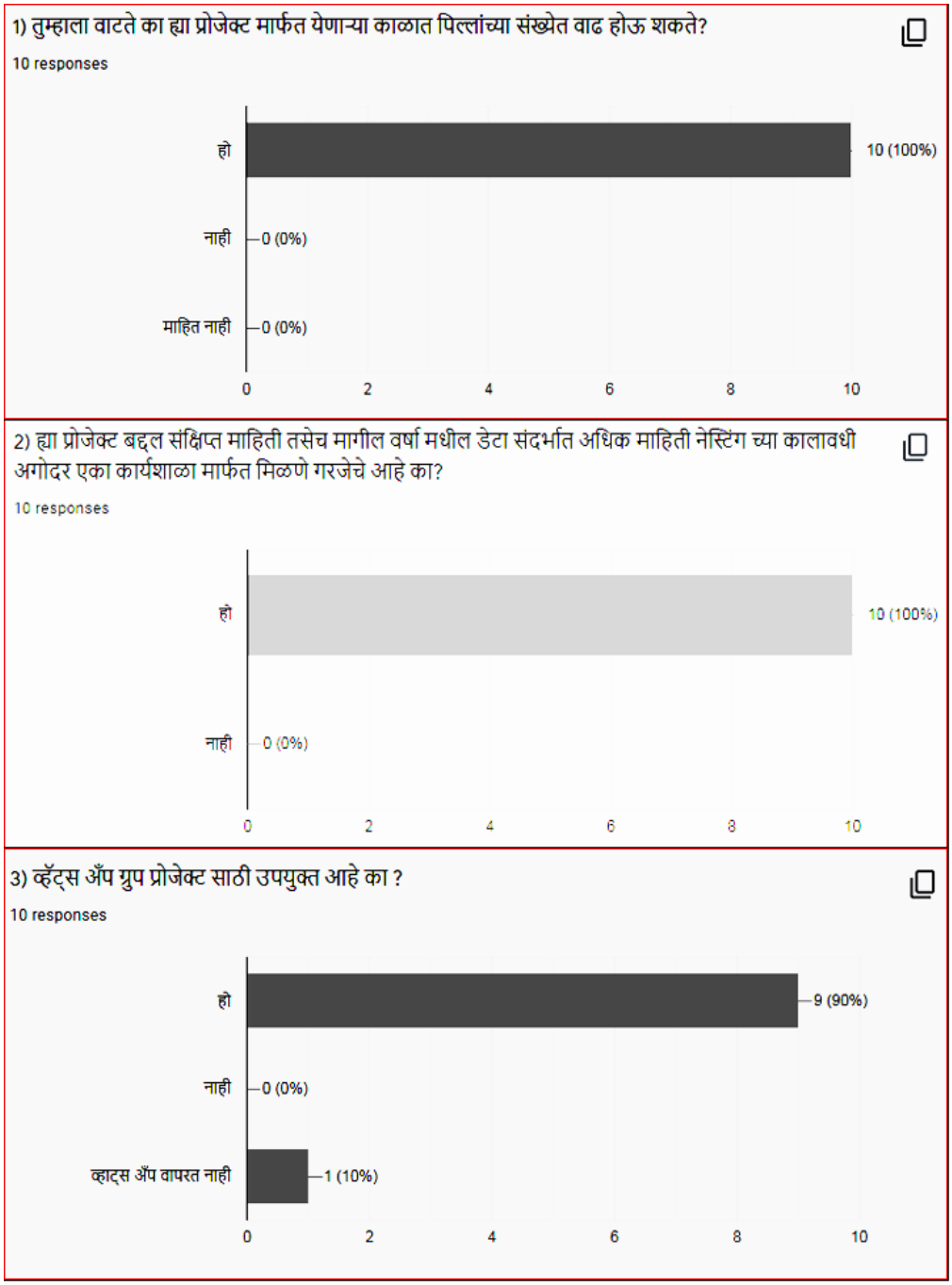
Section 1: Hatchery manager knowledge and observations regarding hatchlings getting stuck inside the nest. 1) 60% of them has observed dead hatchlings for more than 2 years. 3) 90% know the reason behind this is high temperature and change in climate. 4) 70% of them has also observed live hatchlings stuck inside the nest. 5) 30% who did not see reasoned that they were forbidden to do so (20%) or it is unnatural (10%). 7)70% of hatchery managers who has seen hatchlings stuck inside the nest believes the reason behind it is hardened nest and dehydration. 8) 50% kept the hatchlings in tub filled with sea water and then released them.

Section 2 of Questionnaire:



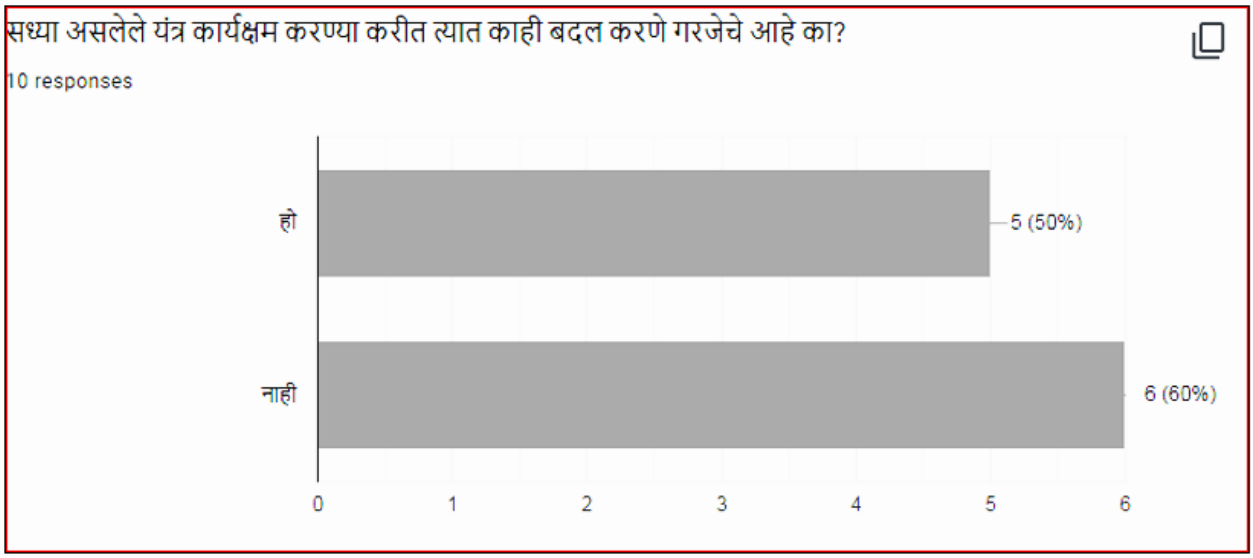
Section 2: hatchery manager perspective regarding sensors usage. 1)80% HM believe there the sensor does not harm the nest entangling the hatchlings. 3) The 10% (viz 1HM) who believes it would harm told Ms Korgaonkar at the start of the project but has not reported it happening. 4) 70% followed the protocol of placing the wooden stick in the nest (see SOP) in absence of sensors. Q5 seems misunderstood. 6) Ms Korgaonkar was personally present on all site where ever this procedure was done. All HM managers believe that the procedure was done properly.

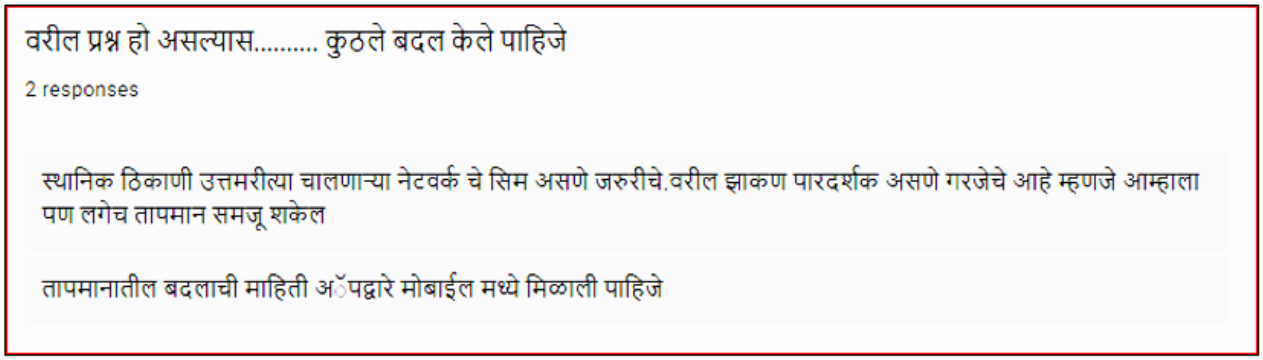
Section 3 of Questionnaire:



Section 3 deals with the perspective of HM regarding the working and continuation of the project. 1) All the HM believes the intervention of the project would increase the hatching success rate. 2) They are interested to get information about the findings every year at the start of the project. 3) Coordination and networking through whatsapp group has proved to be beneficial to them.

Section 4 of the questionnaire:

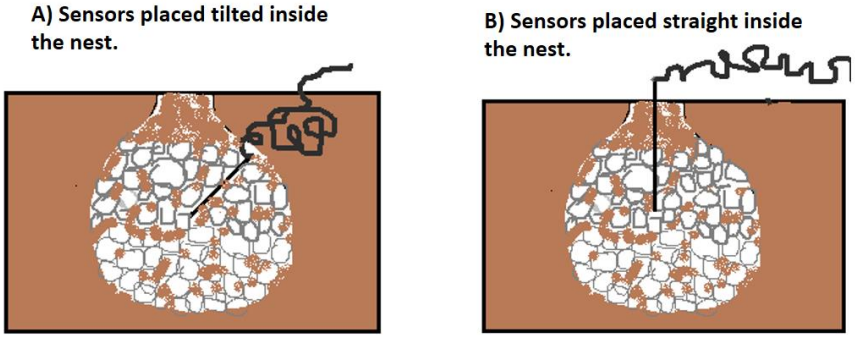




Section 4 is regarding the improvement in the data logger unit. 50% believe some improvement is required which is using SIM of company providing good network, transparent upper lid of IP 65 box, mobile app to see the avg temperature so that they can inform and decide on the mitigation

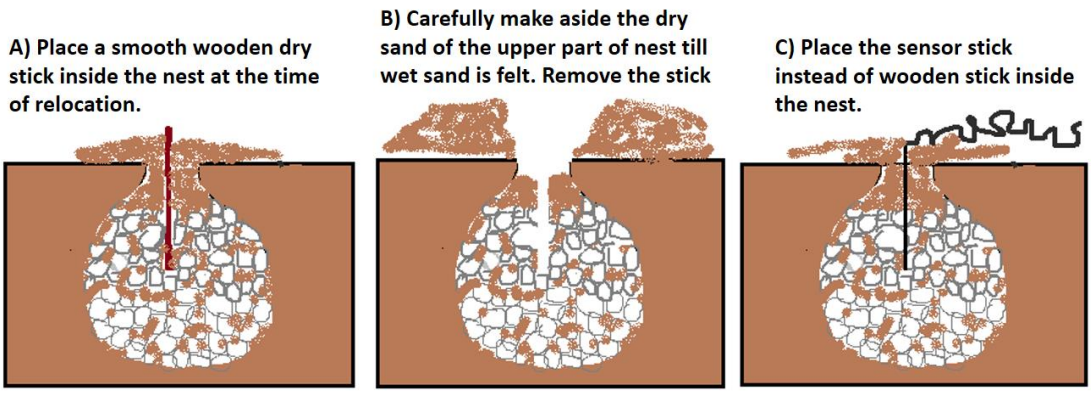
SOP for installing the sensors inside the nest

- Sensors 2 cm in length are present inside the tip of the sensor stick. The sensor stick is made 15 cm long.
- The sensor stick is non vibrating and do not pose any harm to the developing embryo.
- It should be placed at the time of relocation of nest when the relocated nest is half filled with eggs and sand.
- The stick can be placed in two ways as follows.



In case nest are found before the installation of data logger unit or all the sensors are occupied then

- Place a smooth dry wooden stick of the diameter of the sensor in the same way as that of sensor inside the nest (see A).
- Cover the nest as usual.
- Whenever the sensors become free they can replace the wooden stick
- Before replacing, carefully remove the upper dry sand till we feel the moist sand of the nest (see B)
- Slowly remove the wooden stick and replace it immediately with sensor stick (see C).
- The only precaution is the upper dry sand kept aside should not fall inside the nest.



SOP for Opening the nest post incubation period/ emergence

This method can be used to observe the stages of development at the time of mortality and /or to check the presence of hatchling stuck inside the nest.

The method is well tested and standardized on field. Use gloves while digging the nest and handling dead eggs.

Opening the nest after normal emergence of hatchlings for estimating the reason of mortality

- During normal emergence of hatchlings from the nest (mostly winter nesting) the nest should be opened at least 3 days after the hatchlings stop emerging from the nest.
- Number of hatchlings that have emerged and the total number of eggs present in the nest gives fair idea of further emergence. Considering this the nest can be opened.
- Segregate the unhatched eggs, empty shells, dead hatchlings, piped dead hatchlings. Count 3/4th empty shells as one egg. The count can be tallied with the number of hatchlings released. Photograph if required
- Unhatched eggs should be opened and the stages of development at mortality should be noted by tally mark method.
- Same way dead and piped dead hatchlings can be counted and noted.

Opening the nest (mostly summer nesting) when the nest fails to open after the incubation period of 50 days.

Or few (10%) hatchlings had emerged and then the emergence has stopped.

Or 4 days after the first emergence

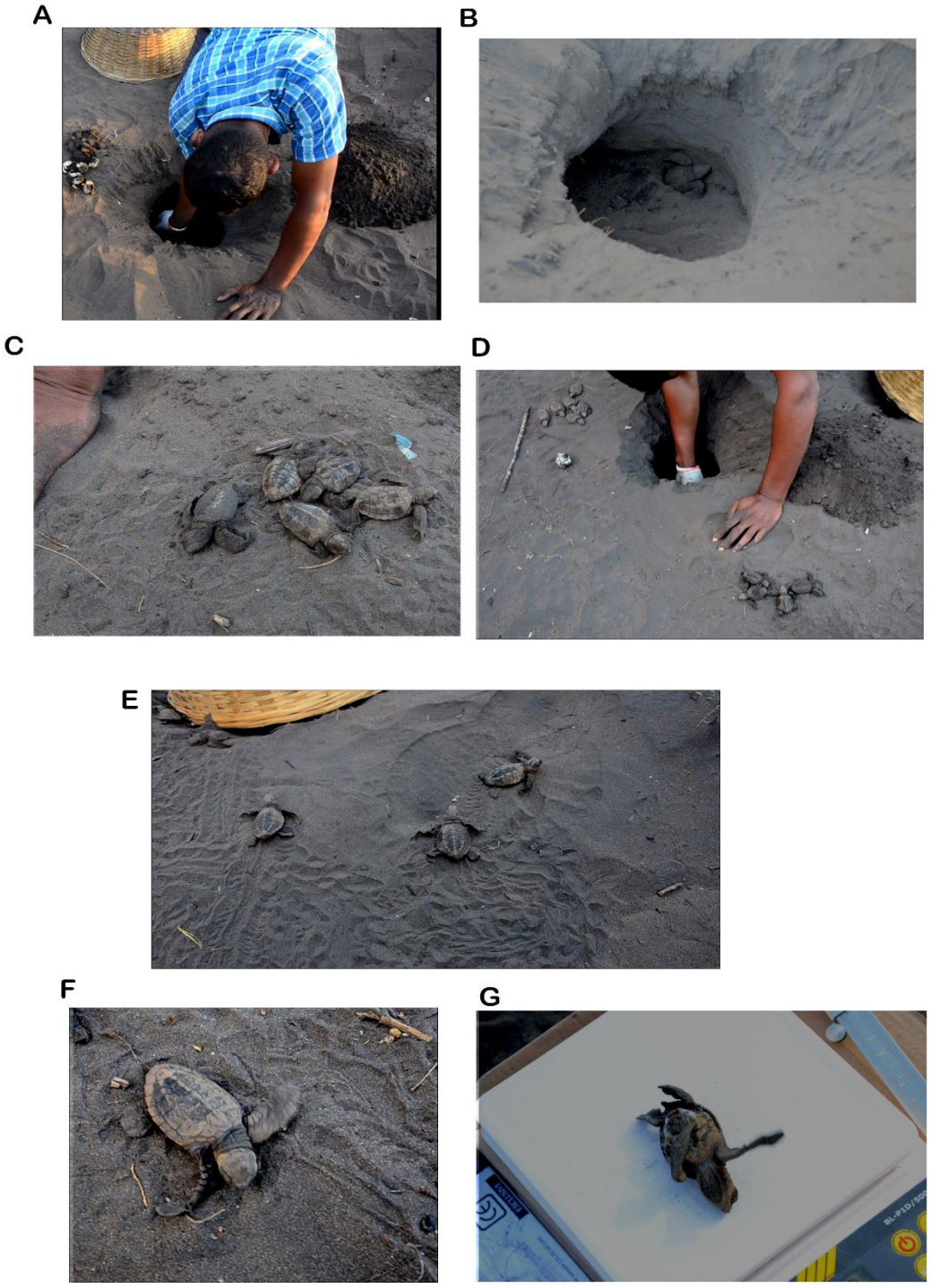
This should be strictly done before 7.00am or after 6.00pm (especially during summer months)

Wear new sterile gloves while opening the nest and handling the hatchlings

- Carefully remove the upper dry sand and keep it far aside to prevent mixing with the nest sand
- Remove the upper moist sand of the nest and keep it aside separately as a heap (A). This moist sand can be put inside the nest again in case no hatchlings are seen stuck.
- The nest becomes hollow when hatchling are present inside the nest and a depression is seen. At many sites depression over nest is not observed before the emergence period. It might be due to hardening of sand.
- Check for any live hatchlings stuck inside the nest. Check the side wall of the nest to observe the hardening of sand (B).
- If the nest is hard then check for an opening where hatchlings might have been stuck (B).
- If hatchlings are seen inside the nest with or without hard sand then observe their condition
- If the hatchlings are normal in size but inactive then remove them and keep them in a basket half filled with dry sand. Release them as per normal procedure(C).
- If hatchlings are small in size, inactive with contracted body and flippers (but not dry) then keep the hatchlings as it is inside the nest for some time. Cover the opening of nest with a cane basket keeping dry jute gunny bag over it. Or alternatively they can be cautiously removed, kept in a basket filled half with dry sand and covered with cane basket or jute gunny bag. Check them intermittingly and release upon activity.

- If hatchlings are weak, inactive, dry and looks dehydrated. Keep then in shade for some time wrapped in clean wet cotton cloth (wet by sea water). Check their activity and release them when active. Don't transfer the hatchling in water filled bucket. They might get in swimming frenzy phase exhausting their remaining energy ultimately dying when released in the sea.

Rescue of hatchlings stuck inside a hardened nest



A) Heap of moist sand of the nest B) hatchling seen stuck inside the nest (before fully excavated). The nest wall is hardened C) Rescued hatchlings are weak with body contracted D) Dead hatchlings and rescued hatchlings. E) The rescued hatchlings becoming active after 15 min F) Non contracted body and active rescued hatchling G) weight of the hatchling was 15gms which is in normal range. The hatchlings were released as per standard procedure early in the morning. This work was done under the guidance and supervision of Ms Sumedha Korgaonkar in 2019 who has intimated the forest officials and she takes responsibility of the work.

Studying the incubation temperature of a nesting population of olive ridley turtles (*Lepidochelys olivacea*) in the coast of Maharashtra with advance data logging system (Phase II) – Submitted by Sumedha Korgaonkar (Nov 2020).