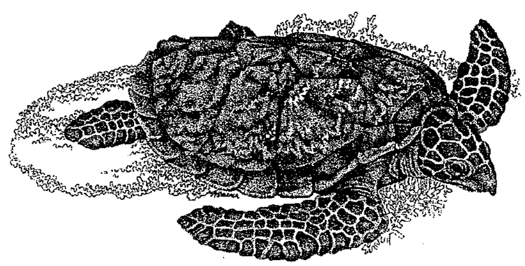
MARINE TURTLES OF INDONESIA

POPULATION VIABILITY AND CONSERVATION ASSESSMENT AND MANAGEMENT WORKSHOP

December 11-14, 1995
Taman Safari, Indonesia
Cisarua, Indonesia

Jansen Manansang, Dwiatmo Siswomartono, Tonny Soehartono, Colin Limpus, Ulysses Seal, Philip Miller, and Susie Ellis (Editors)



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Perlindungan Hutan Dan Pelestarian Alam (PHPA)
Taman Safari Indonesia
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In Association With:
The Conservation Breeding Specialist Group (IUCN/SSC/CBSG)
and
The Marine Turtle Specialist Group (IUCN/SSC/MTSG)

A contribution of the IUCN/SSC Conservation Breeding Specialist Group and the Marine Turtle Specialist Group.

The primary sponsors of the workshop were Sea World and the Enoshima Aquarium.

Cover photo: Green turtle (*Chelonia mydas*). Courtesy of the Center for Marine Conservation.

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3 February 1997

MARINE TURTLES OF INDONESIA

POPULATION VIABILITY AND CONSERVATION ASSESSMENT AND MANAGEMENT WORKSHOP

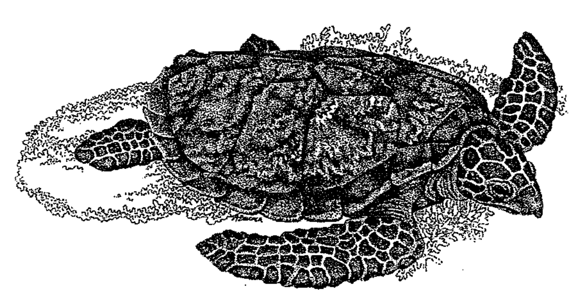
Table of Contents

MARINE TURTLES OF INDONESIA

POPULATION VIABILITY AND CONSERVATION ASSESSMENT AND MANAGEMENT WORKSHOP

December 11-14, 1995
Cisarua, Indonesia

Section 1:
Executive Summary and Recommendations



EXECUTIVE SUMMARY

The seven species of marine turtles have been classified, on a global basis, in the new IUCN Categories of Threat by the IUCN/SSC Marine Turtle Specialist Group as Critically Endangered for *Lepidochelys kempii* (Kemps' ridley) and *Eretmochelys imbricata* (hawksbill); Endangered for *Caretta caretta* (loggerhead), *Chelonia mydas* (green), *Lepidochelys olivacea* (olive ridley), and *Dermochelys coriacea* (leatherback); and Vulnerable for *Natator depressus* (flatback). All of these species except for Kemp's ridley occur in Indonesian waters. All species are listed on Appendix I of CITES. These classifications reflect the intensity of the global population decline of these species and their continuing exploitation beyond their capability for replacement.

Data supporting the threatened status for the Indonesian marine turtle populations, although limited, are available from egg harvest information, numbers of turtles returning to some nesting beaches, and the distances fishermen are traveling to collect turtles for the Bali market. Marine turtle egg harvests since 1950 in Pangumbahan, Java show a 90% decline from 2-4 million eggs to 300-400,000. The nesting turtle population at Meru Betiri National Park, eastern Java has been declining at the rate of 8% per year since 1980. Fishermen collecting green turtles for the Bali market now travel more than 1500 km to harvest about 20,000 turtles per year.

Marine turtles are highly migratory animals. This is particularly true of the adults. Each turtle typically lives for years at its specific feeding area and only leaves this feeding area at the beginning of the reproductive season when it migrates to the area of its birth for breeding. At the end of the reproductive season the adult turtle returns home to the same feeding area in which it lived prior to the breeding migration. Male and female marine turtles show breeding site fidelity, returning to natal areas to reproduce. Most of the knowledge of migration of marine turtles has been learned from the capture of adult female turtles that have been originally tagged while laying eggs on nesting beaches.

Within a single nesting season each female typically lays several clutches (up to 5-7 clutches) at about two week intervals. During that two week period she does not need to find a new mate, she moves just offshore from the nesting beach to make the next clutch of eggs, fertilizing them with sperm collected during the breeding season. The breeding turtles do not feed, or feed to only a limited extent while migrating, courting or making eggs at the nesting beach area. They live off the stored fat reserves deposited before the breeding season began.

Each female usually chooses to return to the same beach or island to lay several clutches within the one nesting season. However, a small percentage of females can be expected to lay on more than one beach within a few hundred kilometers of the initial nesting site. At the completion of the nesting season, the females return to their respective distant feeding grounds, each to the same area that she left at the start of her breeding migration. After two to eight (or more) years many of these females will make yet another breeding migration, each generally returning to nest on the natal beach.

Wherever there has been organized harvesting or large-scale killing of the turtles and/or their eggs over several decades, the turtle population has undergone significant decline. There has never been successful management of a marine turtle population at stable population levels while subjecting it to large-scale mortalities.

Forty-four biologists and managers attended an Indonesian Marine Turtle Conservation and Viability Assessment Workshop in Cisarua, Indonesia at the Safari Garden Hotel on December 11-13, 1995 to apply recently developed procedures for risk assessment and formulation and testing of management scenarios to the Indonesian turtle populations. The workshop was carried out at the invitation of PHPA and was a collaborative effort of the PHPA, TSI/PKBSI, the Conservation Breeding Specialist Group (CBSG) and the Marine Turtle Specialist Group of the Species Survival Commission/World Conservation Union (SSC/IUCN). The purpose was to review data on the wild populations, nesting grounds and feeding areas, as a basis for assessing extinction risks, assessing different management scenarios, evaluating the effects of removals from the populations, and developing preliminary stochastic population simulation models. Other goals included determination of habitat and capacity requirements, role of hatcheries and head start programs, and prioritized research needs.

The first day consisted of a series of presentations on the basic biology of marine turtles including reproduction, migration behavior, genetic identification and characterization of stocks, and the decline in turtle stocks in Indonesia. After presentations on population biology and the Workshop process, the participants formed three working groups on the marine turtle nesting populations in Kalimantan, Malaka, and Jawa with instructions to summarize information on the major stocks and rookeries in each region. They evaluated the location and current status of the rookeries and populations, current and needed management practices, new information needed, and made recommendations.

The second day the groups reported on their progress. An extensive effort was made to build a VORTEX model for a population of green turtles following a brief presentation of population biology and modeling. It became clear that much of the needed information is not available for the Indonesian populations. Preliminary stochastic population simulation models were developed and initialized with ranges of values for the key variables to explore. Using sensitivity analysis, the effects of different levels of mortality from egg removals or increased adult mortality on the wild population were examined. Using data compiled from the literature and by consultation with workshop participants, a series of very rough-guess, baseline population values for the parameters required by the VORTEX program were developed. However, before further computer-based simulations of the Indonesian marine turtle populations can be attempted, more data are required to improve the accuracy of the model. Further, as a result of the design limitations of VORTEX (designed primarily for small populations of relatively short-lived, slowly-reproducing species) other available computer based models for marine turtle populations also should be evaluated and used to assist in the conservation management of Indonesian marine turtles.

This workshop report includes a set of recommendations for conservation, research and management of the wild populations as well as sections on the life history of marine turtles, history of the populations, management, and the population biology and simulation modelling of the population.

RECOMMENDATIONS

National Marine Turtle Conservation Strategy for Indonesia

Specific National Recommendations

1. **Develop a national Indonesian marine turtle information database on a site basis for conservation management.** Develop a national information network on turtle conservation and establish links to the international network.

2. **Complete the identification of the management units (stocks) of each species breeding in Indonesia using genetics research.** Australian scientists have offered to collaborate and this is recommended.

3. **Identify key monitoring sites for each stock or management unit.** Survey known and suspected areas and use historical data to determine relative importance. Develop a research and monitoring program for all selected sites. Place the data in the national database on a current basis.

4. **Begin assessment of the stocks of each species.** Identify distribution, relative density, and seasonality of nesting. Determine distribution of actual and potential foraging areas.

5. **Identify threats and threat processes by species and region.** Include the information in the national database and in the local management plans.

6. **Assess the utilization of unprotected species of turtle.** Law enforcement nees to be enhanced to sustain and restore their populations in Indonesia.

7. **Re-examine the effectiveness of the head-starting program.** Evaluation of alternative management programs is needed.

8. **Form a National Task Force for development and implementation of national and local strategies for marine turtle conservation.** Include the full range of government and non-government management agencies (stakeholders) whose activities affect marine turtle conservation. Include, as advisors, Indonesian and international marine turtle biology specialists.

General National Recommendations

9. **Implement and improve existing marine turtle conservation legislation.** Provide legal and physical facilities for marine turtle conservation and law enforcement at the national and field levels.

10. **Develop national and local awareness of the need for marine turtle conservation by extension and education programs.** Include an education project to educate fishermen,

egg harvesters, and other users on the biology and management of turtles. Develop alternative income generating sources for the local communities surrounding the nesting areas.

11. **Provide continuing training at local level for managers, rangers, and protection staff.** Topics should include marine turtle biology, management, protection, conservation, and research.

12. **Facilitate and conduct collaborative marine turtle cnservation and research activities.** Work with leading international institutions to assist Indonesian management, research and conservation of turtles.

Essential Data Needed for Conservation Management for Turtle Rookeries

(Other data are required from turtles in feeding areas.)

1. **Census (counting) of nesting population.**
   Choose a representative site for each species and/or stock within a species.
   Count for each species using standard beach length and standard time of year.
   Count either tagged turtles or clutches or eggs or tracks.

2. **Conduct saturation tagging of turtles at selected turtle nesting sites.**
   Count the number of turtles tagged.
   Using these tagged turtles:
   - Measure size of nesting turtles.
   - Count the number of clutches laid by each turtle for the season.
   - Quantify nesting success.
   - Map distribution of nests within rookery.
   - Count eggs per clutch.

3. **Measure hatchling production**
   For each of the selected nesting beaches and hatcheries:
   - Count numb er of clutches laid on beach
   - Count number of clutches (eggs) removed from beach.
   - Count number of clutches (eggs) moved to hatchery.
   - Count number of clutches incubated on beach.
   - Count number of hatchlings produced per clutch from hatchery.
   - Count number of hatchlings produced per clutch from beach. (Count hatchlings and/or hatched shells)

4. **Long-term tag recoveries**
   Using tagged turtles:
   - Determine remigration interval (years between nesting seasons).
   - Determine long distance movement by recovery of tags and turtles.

Regional Marine Turtle Conservation Strategies

Kalimantan

1. High priority nesting areas for conservation include: South Natuna, Sumbar Gelap, Kepulau and Derawan.

2. Tag turtles landing on major turtle nesting sites.

3. Provide facilities for law enforcement.

4. Develop community participation around the turtle conservation and non-conservation areas using awareness and extension activities.

5. Conduct collaborative research with institutions which have an advanced activities on marine turtle biology.

6. Develop protection staff and train them for turtle conservation activities.

Maluku

1. Provide an appropriate number of trained staff to manage the important turtle nesting sites (the Reserve) in the region.

2. Stop the hunting of green turtles from the Aru Tenggara strict Nature Reserve and other declared turtle reserves.

3. Stop the trawling operations near the nesting areas in the nature reserve.

4. Secure long term budget allocation for the support of the management and protection of turtles in the Reserve areas.

5. Develop alternative income generating sources for the local communities surrounding the nesting areas.

6. An extension and education program is needed to empower the local community for support of turtle management.

Java

1. The most important turtle nesting sites in Java and Bali are Taman Nasional Alas Purwo, Meru Betiri (Jember), Cipatujah (West Jawa), and Kepluauan Seribu Taman Nasional (North Jakarta), and Nusa Barong Island.

2. All of these areas should be protected and have an information database located at the local office.

3. Alas Purwo: do tagging program and add to the existing facilities especially for the research program.

4. Jember: increase the exchange of information with international society.

5. Cipatujah: add to the existing facilities .

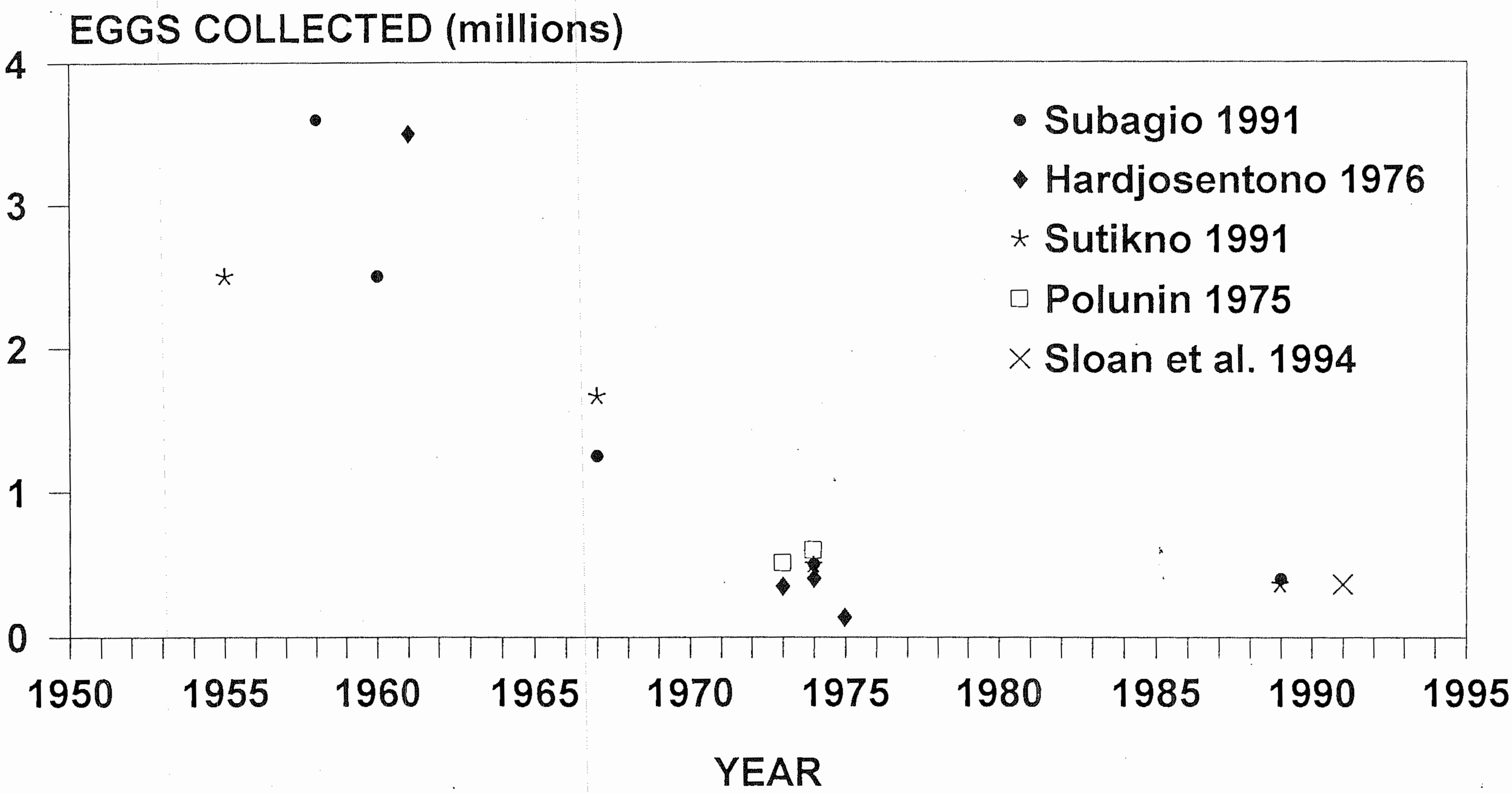
6. Bali: develop rearing at this area so the consumption for food or religious ceremony will not exploit the natural stock.

7. Survey area for turtle feeding grounds. Protect and improve habitat of feeding grounds.

8. Develop a local turtle conservation education campaign.

MARINE TURTLES IN INDONESIA

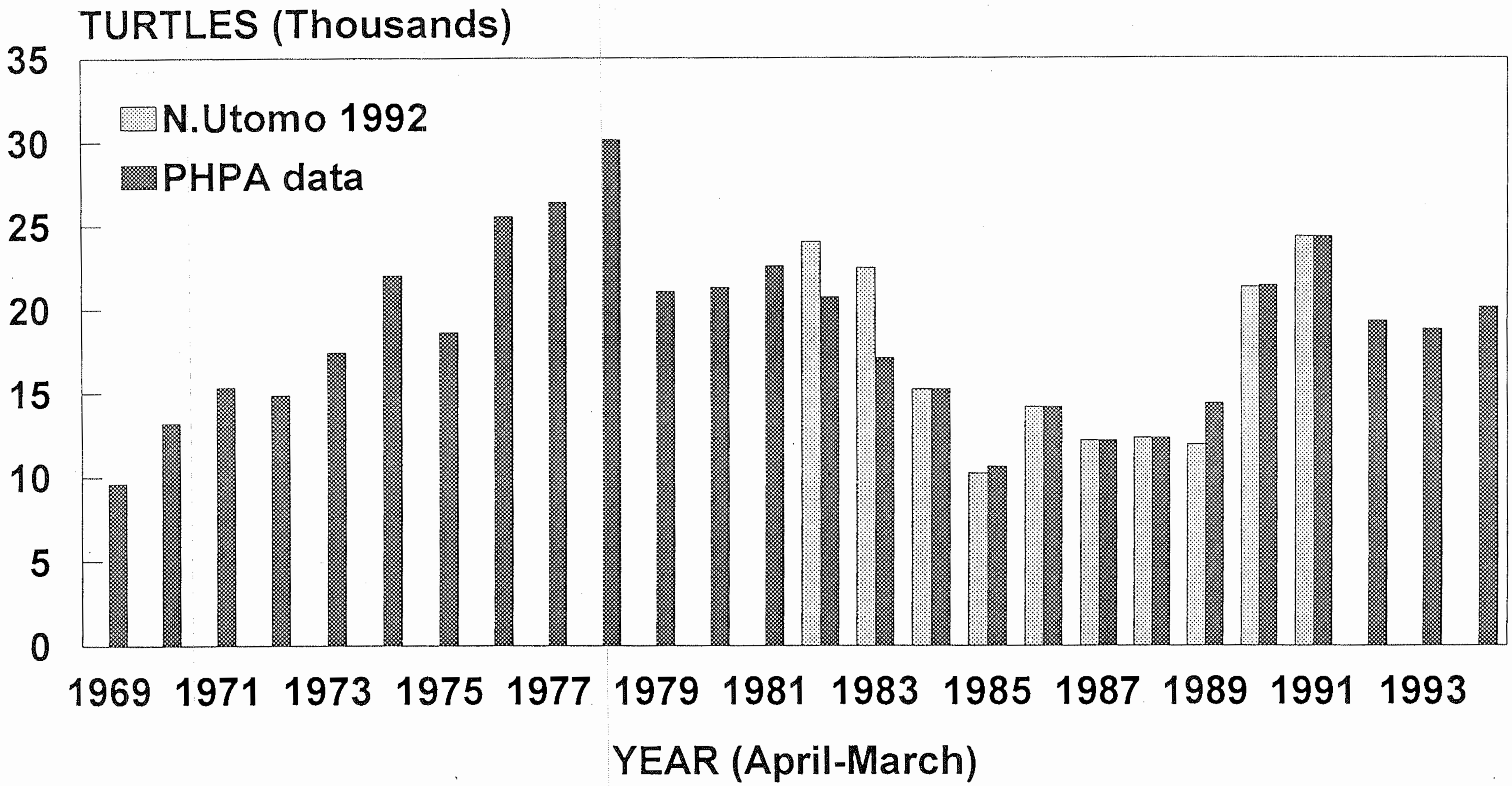
TURTLE EGG HARVEST : PANGUMBAHAM, JAVA



Annual egg harvest as a population index (Mostly Chelonia eggs).

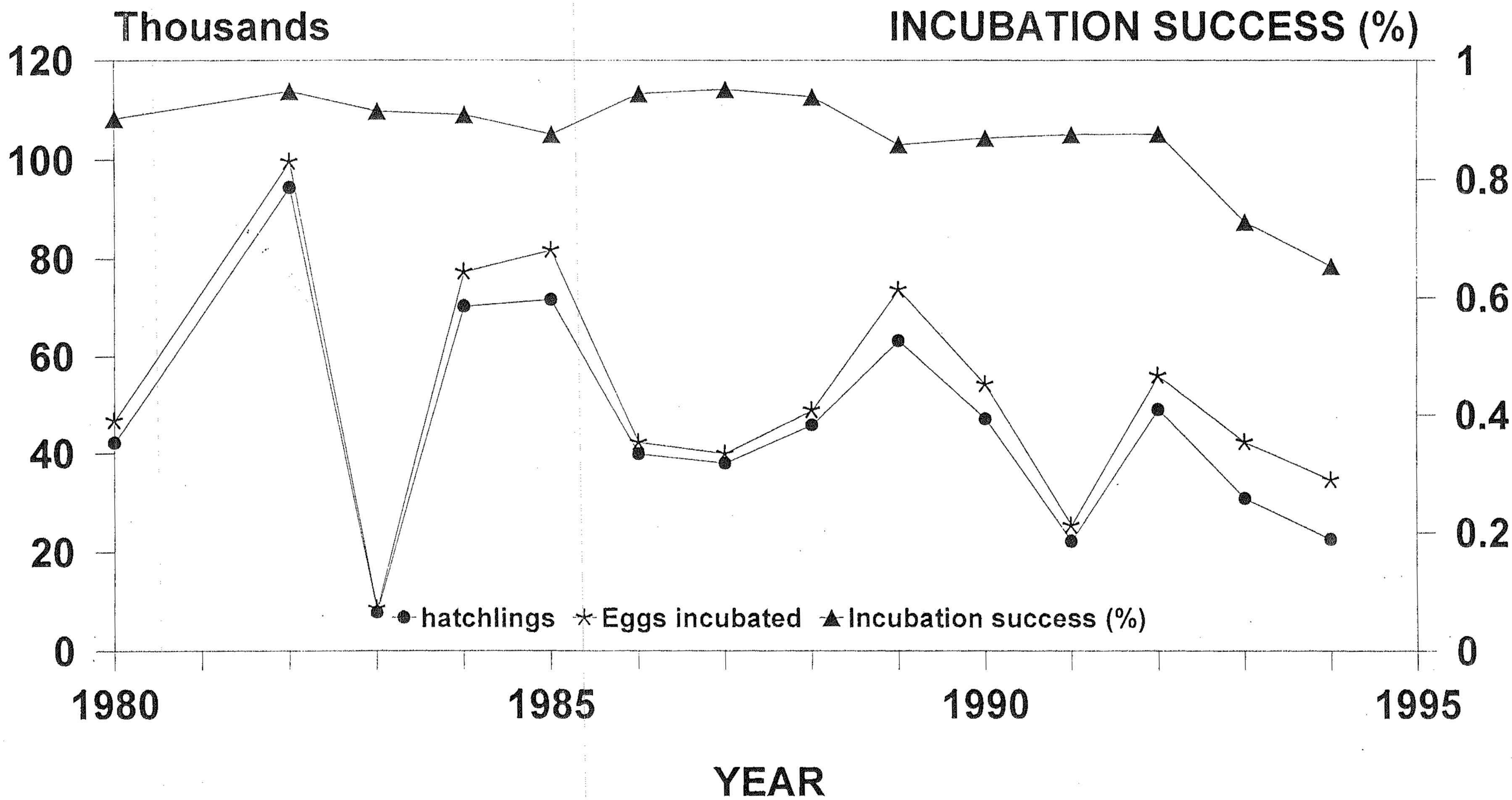
MARINE TURTLES IN INDONESIA

TURTLES LANDED : TANJUNG BENOA, BALI



These data do not include turtles killed during capture & transport.

Suka Made, Meru Betiri National Park, East Java
PENYU HIJAU (Chelonia mydas)



Note: 1995 data up to September only

MARINE TURTLES OF INDONESIA

POPULATION VIABILITY AND CONSERVATION ASSESSMENT AND MANAGEMENT WORKSHOP

December 11-14, 1995
Cisarua, Indonesia

Section 2: Workshop Invitation and IUCN Threat Status Report

DEPARTEMEN KEHUTANAN
DIREKTORAT JENDERAL PERLINDUNGAN HUTAN DAN PELESTARIAN ALAM

Alamat : Gedung Pusat Kehutanan Jl. Jend. Gatot Subroto Telp. 5730315, 5734818 JAKARTA
Jl. Ir. H. Juanda No. 15 Telp. 311615 BOGOR

No. 730A/DJ-VI/BKSAKFF/95

DATE: 30 August 1995

TO: Ulysses Seal, IUCN/SSC Conservation Breeding Specialist Group (CBSG),12101 Johnny Cake Road, Apple Valley, MN 55124, USA

FAX: 1-612-432-2757

FROM: Ir. Soemarsono, Director General of PHPA, Department of Forestry, Indonesia

SUBJECT: Indonesian Sea Turtle PHVA Workshop

We would like to request the assistance of CBSG to coordinate a PHVA workshop for sea turtles in Indonesia. This workshop should be in cooperation with the Australian based conservation programs underway in Indonesia and we invite you to contact them directly about their participation. The workshop can be held in conjunction with the already scheduled PHVA workshop for Komodo monitors, which is during the first week in December 1995. The best time would be the week before the Komodo meeting. The Komodo workshop is with PHPA, the National Zoo, Minnesota Zoo and Miami Zoo. Please contact Mr. Jansen at Taman Safari Indonesia about the details of both workshops. He can assist you in arranging the sea turtle workshop.

We would appreciate the support of about 20 PHPA staff to attend the sea turtle workshop so that we can learn from the experience and be part of the process in developing a conservation action plan for sea turtles. Thank you for your offer to assist us in this very important issue in Indonesia and we look forward to your reply.

Sincerely,
Direktor Jeneral

DEPARTEMEN KEHUTANAN
DIREKTORAT JENDERAL PERLINDUNGAN HUTAN DAN PELESTARIAN ALAM

Ir. Soemarsono
080019732

Perlindungan Hutan dan Pelestarian Alam, Departemen Kehutanan
Gd. Manggala Wanabakti, Blok. I. Lt.8
Jl. Gatot Subruto, Jakarta 10270
Republic INDONESIA

Conservation Breeding Specialist Group

Species Survival Commission
IUCN -- The World Conservation Union
U.S. Seal, CBSG Chairman

Date: **October 16, 1995**

To: **Marine Turtle PHVA Workshop Participants**

From: **PHVA Workshop Coordinators:**
Ulysses Seal, IUCN/SSC CBSG
Susie Ellis, IUCN/SSC CBSG
Philip Miller, IUCN/SSC CBSG
Dwiatmo, PHPA
Tony Soeharto, Species Conservation PHPA
Jansen Manansang, Taman Safari Indonesia

Subject: **Marine Turtle PHVA Workshop: 11 - 14 December 1995**

Purpose

The Conservation Breeding Specialist Group, part of the Species Survival Commission (SSC) of IUCN, the World Conservation Union, is conducting a Population and Habitat Viability Assessment Workshop on Indonesia populations of marine turtles at Taman Safari Indonesia 11-14 December 1995. The PHVA Workshop is designed to be a working session for Indonesian Forest Protection and Nature Conservation (PHPA) staff to develop management strategies for marine turtle populations in and around Indonesia. Most discussions during the workshop will be encouraged to be in Bahasa Indonesia. The current conservation status of all marine turtle species inhabiting Indonesian waters will be examined using the available population biology, distribution, and habitat data appropriate for each species and/or population. This process will be similar to the Conservation Assessment and Management Plan, or CAMP process developed by CBSG to assess the status and degree of threat of species of a particular taxonomic group or geographical region. In addition, a more detailed PHVA analysis will be conducted on two species considered to be most critically threatened: the green turtle (*Chelonia mydas*) and the leatherback (*Dermochelys coriacea*). A primary goal of the workshop will be to present data on the distribution and status of marine turtles in Indonesia, the nature and status of remaining coastal habitats supporting marine turtle populations, and other issues critical to the development of long-term management strategies that recognize the importance of multi-national cooperation and direct participation.

12101 Johnny Cake Ridge Road, Apple Valley, MN 55124-8151, USA
Tel: 1-612-431-9325 Fax: 1-612-432-2757 E-mail: cbsg@epx.cis.umn.edu

The workshop is limited to about 40 participants: 10-15 from PHPA; 10-12 from PKBSI; 3-4 from LIPI and the University of Indonesia; 4-5 participants representing local non-governmental organizations (NGOs); 4-5 possible participants from outside Indonesia; and representatives from the IUCN/SSC Conservation Breeding Specialist Group.

Dates and Site
This workshop is scheduled to be held 11-14 December 1995 at the Taman Safari Indonesia (Safari Garden Hotel), Cisarua near Bogor, West Java. Arrival and late registration is on 10 December; the workshop will begin promptly at 9:00AM on 11 December. Participants need to arrange their own transportation to the Safari Garden Hotel.

Accommodations
Daily costs per person for workshop accommodations (including rooms, meals, meeting rooms, and all breaks) are estimated to be about 80,000Rp (US$40) for double occupancy (single occupancy may be slightly higher). To ensure reserved accommodations, participants contact Jansen Manansang, Cisarua, Bogor, Java (Tel: 62-251-253221; Fax: 62-251-253225).

Funding
CBSG is currently working to secure funding for this workshop.

Preliminary Agenda

10 Dec. Workshop Coordinators Meeting (Afternoon)

11 Dec. Workshop convenes; opening comments
- Overview of Indonesian marine turtle biology, distribution, status, and threats
- PHVA process overview / initial modelling of marine turtle populations
- Possible working groups:
  - Marine turtle distribution and status
  - Indonesian protected areas
  - Population biology and VORTEX modelling
- Discussion and data verification in working groups

12 Dec. Status reports of working groups
- Overview of Indonesian marine turtle management strategies
- Working group evaluation of management strategies

13 Dec. Working group reports: Integration of management strategies
- Workshop draft recommendations

14 Dec. Group concensus of workshop recommendations

Tentative List of Workshop Participants from Indonesia

Direktor Jendral PHPA (Bapak Soemarsono)
Direktur Perlindungan Alam (Bapak Dwiatmo)
Sub-Directorate of Species Conservation, PHPA (Bapak Soehartono)
Jatna Supriatna, Universitas Nasional, Jakarta
Widodo Ramono, Conservation Planning, PHPA
Gen. D. Ashari, PKBSI and SEAZA
Jansen Manansang, Taman Safari Indonesia

Tentative List of Workshop Participants from Outside Indonesia

Ulysses Seal, IUCN/SSC CBSG
Susie Ellis, IUCN/SSC CBSG
Philip Miller, IUCN/SSC CBSG
Rick Hudson, Fort Worth Zoo
Joop Schulz, IUCN
Karen Bjorndal, IUCN/SSC Marine Turtle Specialist Group
Perran Ross, IUCN/SSC Marine Turtle Specialist Group
Colin Limpus, IUCN/SSC Marine Turtle Specialist Group
Alexis Suarez, United States
Chris Starbird, United States

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To: Phil Miller
c/o Jansen Manansang
Taman Safari

From: Karen Bjorndal, Chairman
Marine Turtle Specialist Group

Date: 8 December 1995

Total Pages: 1

The Executive Committee of the Marine Turtle Specialist Group developed the following category designations (with appropriate criteria in parentheses) for marine turtles and sent them to SSC Headquarters.

Lepidochelys kempii -- Critically Endangered (A1:a,b)
Eretmochelys imbricata -- Critically Endangered (A1:a,b,d and A2:b,c,d)

Caretta caretta -- Endangered (A1:a,b,d)
Chelonia mydas -- Endangered (A1:a,b,d)
Lepidochelys olivacea -- Endangered (A1:a,b,d)
Dermochelys coriacea -- Endangered (A1:a,b,d)

Natator depressus -- Vulnerable (A2:c,d,e)

Good luck with the meetings and best wishes.

MARINE TURTLES OF INDONESIA

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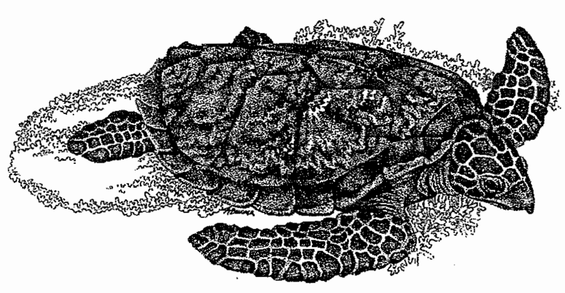
Section 3: An Overview of Marine Turtle Biology



Marine Turtle Biology[1]

Colin J. Limpus, Ph.D.

1. Introduction

Millions of years ago, sea turtles were very diverse. They belong to something like seven families. There used to be three genera of the family Chelonidae or hard-shelled sea turtles. In addition, there used to be five families of leatherbacks. However, we have only a few species left of this past great diversity. Today, there remains only seen species belonging to two families and six genera at the global level. Sea turtles are remnants of the age of the dinosaurs, but they are dying out.

These animals already had a biological problem even before humans started interfering with them. They are not in a stage of expansion of species; rather, they are already contracting. When we interfere with the system, it is not surprising to expect a population decline. Of these seven remaining species, only the Kemp's ridley is found in the Atlantic Ocean. The flatback is restricted primarily to the Australian continental shelf and occurs in eastern Indonesia, New Guinea and Australia. The remaining five occur throughout the Indo-Pacific territory.

Any of these species cannot survive if their environment is not healthy. In the conservation of marine turtles, there must be simultaneous conservation of the marine environment. Since marine turtles are highly migratory, marine conservation should be large-scale in scope.

2. Mating and Nesting

The feeding grounds of sea turtles are often far and different from their nesting beaches. At the start of the breeding season, the adult males and females migrate over long distances to congregate and copulate near the nesting area. There is no pair bond between individuals. It is normal for turtles to have different partners during the mating season. The female stores the sperm that she received from several males for fertilization of eggs later. When mating is finished, the males depart, presumably returning to the distant feeding grounds. Each female moves to an area adjacent to her selected nesting beach and begins to make eggs. She fertilizes the eggs with the sperm previosly deposited by the males. Due to the mixture of sperm she received during mating, several males usually contribute to the fertilization of eggs in a clutch. The female then comes ashore, usually at night, to nest several weeks after her first mating. For those beaches fronted by reef flats, nesting coincodes with the higher tidal levels. Witin one nesting season, each female typically lays several clutches at an interval of about two weeks. During that two-week period, she moves offshoe from the nesting beach to make the next clutch of eggs, fertilizing them with sperm she has previously received. No further mating is necessary.

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[1]From: Proceedings of the First ASEAN Symposium — Workshop on Marine Turtle Conservation. Manila, Philippines, 1993.

The breeding females do not feed. However, they feed to a limited extent while migrating, courting or making eggs at the nesting beach area. They survive by using the fat reserves they have stored prior to the breeding season.

Each female usually chooses to return to the same beach or island to lay several clutches during one nesting season. However, a percentage of females can be expected to lay eggs on more than one beach within 100km of the initial nesting site. At the completion of the nesting season, the females do not use the adjacent shallow water habitats as feeding grounds but return to their respective distant feeding grounds, to the same area that she left at the start of her breeding migration. After 2 to 8 years, many of these females will again make another breeding migration, each generally returning to nest on the precise beach of her birth. In reality, however, the homing mechanism is probably not that exact. Genetic studies suggest that the female returns to breed in the general region of her birth. For example, a turtle born in the southern Great Barrier Reef should return to breed in the southern Great Barrier Reef after reaching maturity.

Females lay their eggs high up on the beach usually within the vegetated strand. No parental care is exercised. A nest site will be selected and the nester deposits the eggs into an egg chamber. At this point, the eggs are very tolerant to handling. At the stage, the egg contain a pinhead-sized embryo that is developed into middle gastrulation. However, futher development is temporarily stopped a couple of days before the nester comes ashore. The embryp will not develop and further until the egg is laid. At this point, the egg will tolerate lots of bouncing and rolling and tumbling. However, after 2 hours of being laid, the embryp inside wll resume development. When the embryo resumes development, just a simple roll of the egg is sufficient to tear apart the embryo and kill it.

3. Incubation

The eggs hatch about 7 to 12 weeks after laying. The rate at which the eggs incubate is a function of temperature. A cool nest (25°C) will have an incubation period of 12 to 13 weeks. On the other hand, a warm nest (32°C) will have an incubation period of 7 weeks. Also, at the middle of incubation, the temperature determines the sex of the hatchlings. For example, a nest at 26°C produces all male hatchlings. The ratio of female to male hatchlings increases when the temperature rises. At 30°C, all of te hatchlins are female. This sex ratio typically applies to all sea turtles. A cool nest will result in all male hatchlings, while a warm nest will result in all female hatchlings. A mixture of sexes is obtained at intermediate temperatures.

4. Pivotal Temperature

There is a theoretical temperature or pivotal temperature with which an equal sex ratio is obtained. For a particular population, 50% male and 50% female results from a temperature of 28.6°C. The pivotal temperature varies from species to species. Likewise, different populations of the same species in different parts of the world will have different pivotal temperatures. The pivotal temperature is one parameter that needs to be determined in a givan population. This is a very important consideration in hatchery operations. It is feasible that a hatchery will produce only one sex. This has been the experience in hatcheries in Peninsular Malaysia, Sarawak, and the Turtle Islands of the Philippines. A hatchery where the nests are totally exposed to sunlight will produce nearly all, if not totally, females. Thu, a hatchery must have both shaded and unshaded nests to produce males and females. Despite popular misconception, males are an important part of the turtle population.

5. Hatching and Emergence

The hatchlings emerge from the nest usually at night. It takes them about 2 to 5 days to dig to the surface. As a group, the hatchlings dig their way unaided from the egg chamber which is about 50 centimeters deep until they reach the surface. On the surface, they become imprinted with the earth's magnetic field. The imprinting occurs as they first come in contact with the light. There is also indication that as the hatchlings enter the water, they are imprinted with the odor of the water. However, more esearch still needs to be done on this aspect. Except for the flatback, the hatchlings reaching the deep water area continue to swim away from the beach. The activity presumably brings them under the influence of the open ocean currents where they drift for the first few years of their lives. On the other hand, the post-hatchling flatback turtles remain within the continental shelf. The newly hatched turtles do not reside in the vicinity of their natal beaches. On sufracing, they immediately cross the beach to the sea. They swim towards the light on the horizon. As they swim away from the beach, the baby turtles orient themselves perpendicular to the wave fronts. These are very subtle behavioral responses of the little turtles n the first hours of life. They do not feed while on the beach or while swimming out to sea.

6. Predation and Mortality

For most eastern Australia turtle rookeries, only a small percentage of hatchlings are lost to terrestrial predators during the beach crossing. In the coral reef areas when the hatchlings are crossing the reef flat, they are probably exposed to the greatest predation during their life cycle. In the Berau islands, less then 2% of the hatchlings are lost due to predation from the time the hatchlings leave the nest until they enter the sea. This fogure applies to almost all turtle rookeries that have been quantified. The baby turtle is at is greatest risk once it is in the water, while crossing the shallow waters adjacent to the nesting beach and heading out to sea. During the first hours at sea, it is most likely to be preyed upon by fish and sharks. Once it reaches deep ocean water, predation levels decrease dramatically. The baby turtle goes into a nonstop swimming frenzy lasting for about two to three days, neither sleeping nor eating.

Some people have the misconception that hatchlings are so delicate and must be cared for a few days before they can evade predators on their own. Keeping the baby turtle for a few days would result in the loss of its instinctive swimming frenzy. The hatchling will not swim as vigorously to bring it far from the shore. This would probably increase predation. Irregardless of size, turtles are not safe from predators. The young to adult sized turtles are potential prey to large cod, grouper, sharks, crocodiles and killer whales. In general, the bigger the turtle, the less chance of being eaten. However, there is predation at all levels in their lives. In many countries, however, man continues to be the most significant predator. Green and olive ridley turtles are harvested in big numbers especially for meat; the hawksbill turtle is hunted for tortoiseshell. All species are hunted for leather, oil and their eggs.

Incidental capture of turtles in fishing gear can also cause significant fishing mortalities. Prawn trawls, drift nets, large mesh nets and long lines are examples of these fishing gear. In some areas, ingestion of plastic and other debris has been identified as a significant cause of mortality. Boat strikes are common in shallow areas with high-density recreational boating.

Wherever there has been organized harvesting or large-cale killing of the turtles and / or their eggs over several decades, the turtle population has undergone significant decline. No one has successfully managed a marine turtle population at stable population levels while subjecting them to large-scale mortalities.

7. Feeding and Diet

Once the hatchlings disperse from the nesting beach and swim the sea, they are virtually "lost" for the next few years. This is the part of their life cycle where scientific research is lacking. In this drifting phase, the turtles presumably feed on the macroplanktonic algae and / or animals at the surface. Except for the leatherback, the young sea turtles "reappear" when they reach the size of a large dinner plate (curve carapace length of approximately 35-40 centimeters). They are possibly 5-10 years old at this time, but the age has not yet been firmly determined. At this size, they take up residence in the shallow water habitats of the continental shelf, and depending on the species, feeding principally at the bottom on plants and animals. Green turtles feed mostly on seaweed, seagrass and mangrove fruits; loggerheads feed mostly on shellfish and crabs. Flatbacks feed mostly on soft corals and sea pens; olive ridleys feed mostly on small species of crab. The hawksbill turtles feed mostly on sponges. These turtles will also eat jellyfish and Portuguese man-of-war occasionally. Immature turtles may remain in one feeding ground for extended periods, perhaps years, before moving to another major area. Several shofts occur in the life of the turtle in this coastal shallow water benthic-feeding phase. The leatherback turtle, which remains an inhabitant of oceanic waters for almost all its life, feeds mostly on jellyfish. From a drifting existence, post-hatchlings settle to sitting at the bottom and feeding. They continue to grow up in these places.

8. Tagging and Population Studies

One way to find out about the biology of sea turtles is through tagging. Tagging is a research tool where we can recognize her as an individual and we can follow her through time.]

Tagging studies conducted within the Great Barrier Reef suggest that sea turtles are many decades old at first breeding and that they can have a breeding life spanning many decades more.

Except for the leatherback, the best place to put a tag is up in the armpit area of the turtle. For leatherbacks, the best location for tag application is on the hindflippers since tags applied in other parts of its body are all likely to fall off.

Typically, the tag carries an identifying number on one side and an address stamped on the other side. The tag with its number allows us to follow an individual in time. Tagging is an important tool that allows us to count exactly how many diffeent individuals there are in an area.

As you tag individuals, you find different indivduals lay eggs every night. We tagged turtles in this manner and after two weeks, we got the same group of turtles that we had tagged two weeks before.

Jim Richardson from the United States sent me some information on a hawksbill he has been studying in Antigua in the Caribbean. This particular turtle has a rather complicated tag, No. PPNO11. He tagged that particular turtle on August 21, 1987 for the first time, and it laid 147 eggs. At that time, the turtle was 88.7cm long. Fourteen (14) nights later, the turtle returned to the same beach. We are talking about a small beach, about a mile long, but he did not count the eggs it laid for that night. On September 19, 15 days later, it came and laid 157 eggs; and 14 nights later, it came back to the same beach and laid 135 eggs. On October 17, it laid a fifth clutch of about 187 eggs. They never saw her again for the rest of the season. Two years later, that turtle came back to the same beach. It was recorded that that turtle came back to the beach on six different occasions and laid six clutches with an interval of approximately 14 days between the clutches. Then, it disappeared again. And it was another two years later when it returned and laid another six clutches of eggs, again with an interval of about two weeks. They counted the first clutch and it contained about 160 eggs. As you can see, this is in the range the turtle laid four years before. Over this period of time, the turtle has grown about 3.5cm in four years. So as an adult turtle, it is growing at less than 1cm per year. This example is fairly typical of hawksbill turtles in that area.

In eastern Australia, a loggerhead was tagged in December, 1982 that laid 4 clutches that year. We happened to know that it was her first breeding season. At the end of that season, she disappeared and we did not encounter her again for 9 years.

We found out that when we tag a group of green turtles, few of them come back a year later; and 2 to 3 years later, we again encounter a few. After 4 to 8 years, we see large numbers of our green turtles coming back to the same place to lay their eggs. We are monitoring green turtle nestings throughout the Pacific under the SPREP program, and we can say categorically that these turtles do not go elsewhere to lay their eggs. The only place we get our recapture data is in the traditional area where they were originally tagged. For green turtles, 5 to 8 years between breeding seasons seems to be the nesting interval. For loggerheads, the interval is about 4 years. For flatbacks, the interval is about 2 to 3 years. Different species have different nesting intervals. And the same turtle just does not breed everywhere.

9. Migration

Turtles come from many places to breed and then they go back to their particular feeding area. The turtles are likely to come from an area within a radius of 2,500 kilometers around the nesting area. In the Northern Barrier Reef, we have turtles that live in Australia, New Caledonia, Fiji, Papua New Guinea, and in Indonesia. Turtles that are nesting in Papua New Guinea come way over from western Irian Jaya, Indonesia or from Papua New Guinea. Turtles from Sabah are being captured in eastern Indonesia or the Philippines. We have these animals crossing international boundaries, swimming in many directions to go to their traditional breeding sites.

Many green turtles nesting in Micronesia are being encountered in the Philippines; some of them swim all the way up to Taiwan. There are reports that turtles from Hawaii are encountered in Japan and Taiwan. Since these animals transcend international boundaries, they are a shared resource among countries. Thus, these countries have a common responsibility and ownership of a particular population.

The range of the loggerheads in Eastern Australia can span eastern Indonesia, Papua New Guinea, Solomom Islands, New Caledonia, and Australia. Recently, we got a tag recovery in western Australia from Java. The Philippines got some interesting tag recoveries of loggerheads nesting in Japan. The loggerheads nest in the temperate areas rather than the middle of the tropics but they feed in the tropical areas.

Finally, hawksbills have actually been studied and the few tag recoveries also show that they are migratory. Hawksbills nesting in the Solomon Islands are being caught in Papua New Guinea and Australia. Hawksbills that have been tagged in Sabah are being captured in the Philippines.

10. Age at First Breeding and Sex Ratio

Through tagging, the development of turtles to maturity has been monitored. When studies were first conducted in 1974, it was theorized that turtles would be sexually mature in 10 years. A turtle measuring 80cm was tagged in 1975. This individual was monitored for 13 years until her first breeding. The growth rate was recorded to be 1cm per year. The first nesting was recorded 1,700km from the area where she was tagged. The only time she left the area was during the breeding season.

Part of the studies was to understand the composition and function of a herd. The term "herd" is used in the same sense as a herd of cattle or sheep. Questions that need to be answered include: how many males, females, adults, youngsters are there in a herd? A surgical technique was developed using laparoscopy to examine female reproductive systems to come up with answers to these questions.

Using this procedure helped determine the sex ration of mature turtles in the wild. Results revealed that tere seems to be much fewer males in the population compared to females. Seventy percent (70%) of the marne turtle population around the world is composed of females while the remaining thirty percent is composed of males.

Furthermore, only a very small proportion of the adult females actually breed in any one year. For example, out of 100 turtles living in the feeding area, only two or three individuals are breeding for that particular year. In other words, for one nester to crawl up the nesting beach, there has to be between 50-70 turtles living out in the feeding grounds within 2,500 kilometers. To have 1,000 nesting females on the beach in one year, there has to be between 50,000-70,000 turtles out in the feeding grounds. Since the turtles take so long to reach maturity, many young male and female turtles are needed in each year class. You need the females that are not breeding this year as well as the ones that are. You need vast numbers of turtles at the feeding grounds just to have small numbers at your nesting beach. We have to rethink how the turtle population is put together.

11. Nesting Trends

Turtles have distinct nesting seasons. If a census is conducted year after year, the nesting season of turtles are very predictable. There are instances when that species is going to turn up in abundance and there are instances when they are not so abundant. This fluctuation has been observed from data in the Sarawak Turtle Islands green turtle population. The data indicate that there is a repetitive high density nesting and low nesting density, and this is a feature of that population. However, in some species, there are months with no nesting, followed by a very distinct breeding season. Then the turtles just disappear. For example, in the west coast of Thailand, the leatherbacks arrive and nests for a period of six months. After the six months, no turtles nest. Some species have an "all-year-round" nesting with a high density at one time.

For green turtles in particular, the number of turtles visiting the nesting beach will vary tremendously from one year to another. What we are now finding is a feature of green turtles around the world. In 1974 and 1984, huge numbers of turtles were recorded. It was later found out was that there is a very high correlation between the El Niño phenomenon two years before a breeding season and how big the breeding season will be. Nesting could be predicted two years before it actually occurs, using the southern oscillation index (*the difference in atmospheric pressure between Darwin and Tahiti*). These fluctuations are not a measure of how many turtles are out at sea. Rather, they are a measure of a climate event that occurred some two years before. It is now known that it takes more than 12 months for a turtle to prepare for a breeding season. The existing climatic conditions affect the biology of sea turtles, but scientists still do not understand how they are linked together. Information on the factors that make the turtle prepare for breeding is still lacking. However, in some years large numbers of turtles prepare to breed and in other years, very few turtles breed.

12. Beach Surveys

When the turtle finishes laying the eggs, she then conceals the nest, covers the egg pit with sand so the eggs do not dry up or get exposed to the sun. She then goes back to the sea. The turtle leaves her tracks on the beach. We can learn many things from the tracks. Those who have spent a lot of time with turtles know that we can recognize the species from the tracks. In addition, one can determine whether that turtle successfully laid eggs or not.

Other researchers interpret turtle tracks from aircraft flying at around 100 knots at an altitude of 200-300 feet. At that altitude and speed, you can count the tracks going up or going down the beach. One can count how many turtles came up the beach; and you can determine what species were present by looking at the characteristic shape of the tracks. The flight is usually conducted early in the morning, before the tide washes away the tracks made the night before. One can actually cover a vast section of coastline (about 400-500 km) in a single flight before the tracks are washed away. This rapid survey can allow observers to obtain an overview of the way the nesting is occurring, and what species of turtles are using the beaches.

Twenty five (25) years ago, aerial surveys were conducted along the Australian coasts to determine the major nesting concentrations of our turtles. Green turtles nest in big numbers on thirteen islands in the Southern Barrier Reef. They nest on five islands in the North Barrier Reef; and on three islands in the Gulf of Carpenteria. Also, many green turtles nest in the neighboring areas of Southeast Asia.

Turtles have been extensively studied on the nesting beach. In South East Asia, almost all of the studies that have been done were on the nesting beach. However, sea turtles spend most of their lives in the sea.

There is a need to study their feeding habitats. Some species live in seagrass areas while others live in coral reefs. Several direct capture methods have been employed in the feeding grounds. In Australia where we have clear waters, we use a direct capture technique. This technique involves rounding the turtles from a speedboat and a diver jumps after them, grabbing a turtle, and brings it back to the boat. The turtle is roped to the side of the boat and is measured. In other places, people catch turtles by using nets. It does not matter how you catch them.

13. Sustainable Harvest

Predictive population models are being developed in order to address how the turtles should be managed in terms of sustainable utilization. For Solomon Island, hawksbill harvest was too high to accommodate the demands of the Japanese turtle shell industry. The hawksbill population in that area used to be thousands of nesting females a year. We need to determine the impact of harvesting various numbers of females each year. To determine the impact, researchers converted the number of turtles to the weight of the turtle shell that the industry was taking. For example, about 3,500 kg of turtle shells are being harvested each year. A harvest of 600 nesting females a year will yield 580 kg of turtle shell. However, 580 kg of turtle shell is much less compared to 3,500 kg of actual harvest. If the level of harvest is sustained for ten years, a 92% decrease in population will be recorded. Thus, gross overharvesting is occurring. In terms of sustainable harvest, only a small percentage of animals should be harvested so that there will be very little change in their population. The amount of turtle shell that one gets from these animals is barely sufficient for the village handicraft industry within the Solomon Islands. It is not sufficient to maintain a large-scale export.

There is still a lot to learn about how to predict the levels of harvest. However, this much we know: you need about ten to fifteen 80cm green turtles growing up in the next 10 to 15 years to give you one adult turtle. This means that the same impact will happen to the population if 80cm turtles are being harvested. It is recommended to shift the harvest from big breeding turtles to the immature size ranged turtles but not increasing the harvest numbers. In some cases, we will need to decrease the number of turtles being taken.

What level of egg harvest is sustainable? According to the population model, about 70% of the clutch must be maintained to produce hatchlings that will maintain a stable population at a regional level.

Sea turtles are still beset with management problems. We have made progress and I think we can still go further trying our best at managing them. However, very serious monitoring and research have to be conducted.

About the Presenter

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THE MARINE TURTLE LIFECYCLE.

Marine turtles all have a similar life cycle that is summarised in Figure 1 (Page 35).

Marine turtles utilise feeding grounds often far removed from the nesting beaches. With the onset of the breeding season adult males and females migrate to copulate near the nesting area. There is no pair bond between individuals and copulation with a number of different partners during the mating season is normal. The female stores the sperm from her several mates for use later in the breeding season. At the completion of mating the males depart, presumably returning to the distant feeding grounds. Each female moves to an area adjacent to her selected nesting beach and commences making eggs, fertilising them from her sperm store. Because of the mixture of sperm she carries, several males usually contribute to the fertilisation of any one clutch. The female comes ashore, usually at night, to nest several weeks after her first mating. For those beaches fronted by reef flats, nesting coincides with the higher tidal levels. Within the one nesting season each female typically lays several clutches at about two weekly intervals. During that two week period she does not need to find a new mate, she moves just offshore from the nesting beach to make the next clutch of eggs, again fertilising them from her sperm store. The breeding turtles do not feed, or else feed to only a limited extent, while migrating, courting or making eggs at the nesting beach area. They live off the stored fat reserves they deposited before the breeding season began.

Each female usually chooses to return to the same beach or island to lay several clutches within the one nesting season. However, several percent of females can be expected to lay on more than one beach within a few hundred kilometers of the initial nesting site. At the completion of the nesting season the females do not use the adjacent shallow water habitats as year round feeding grounds but return to their respective distant feeding grounds, each to the same area that she left at the start of her breeding migration. After two to eight years many of these females will make yet another breeding migration, each generally returning to nest on the same beach as before. This behaviour and the annual use of traditional nesting beaches has led to the assumption that a marine turtle returns to nest on the precise beach of her birth. In reality the homing is probably not that exact. Genetic studies suggest that the female returns to breed in the general region of her birth. For example, a turtle born in the southern Great Barrier Reef, when it grows up, should return to breed in the southern Great Barrier Reef.

Females lay their eggs high up on the beach usually within the vegetated strand. No parental care is exercised. The incubation period and the sex of the resulting hatchlings is a function of the temperature of the surrounding sand. A warm nest at mid incubation results in all or mostly female hatchlings while males come from cool nests. The eggs hatch about 7 - 12 weeks after laying. The hatchling turtles dig their way unaided and as a group through the 50 cm or more of sand to the surface. On surfacing they immediately cross the beach to the sea. This hatchling emergence is almost entirely nocturnal. For most eastern Australian turtle rookeries only a small percentage of hatchlings is lost to terrestrial predators during the beach crossing. Immediately the hatchlings reach the water they begin oriented swimming which takes them away from the beach and into deep water. The hatchlings at this stage are living off a yolksac internalised just prior to hatching. They do not feed while on the beach or while swimming out to sea. In coral reef areas when the hatchlings are crossing the reef flat, they are probably exposed to the greatest level of predation during their life cycle. This is a period of transfer to predatory fish of nutrients derived from adult turtles via eggs and hatchlings. For all except flatback turtles, the hatchlings, on reaching the deep water areas, continue to swim away from the beach and this activity presumably brings them under the influence of the open ocean currents where they drift for the first few years of their lives. The post hatchling flatback turtles remain over the continental shelf. The newly hatched turtles do not feed nor take up residence in the vicinity of where they were born.

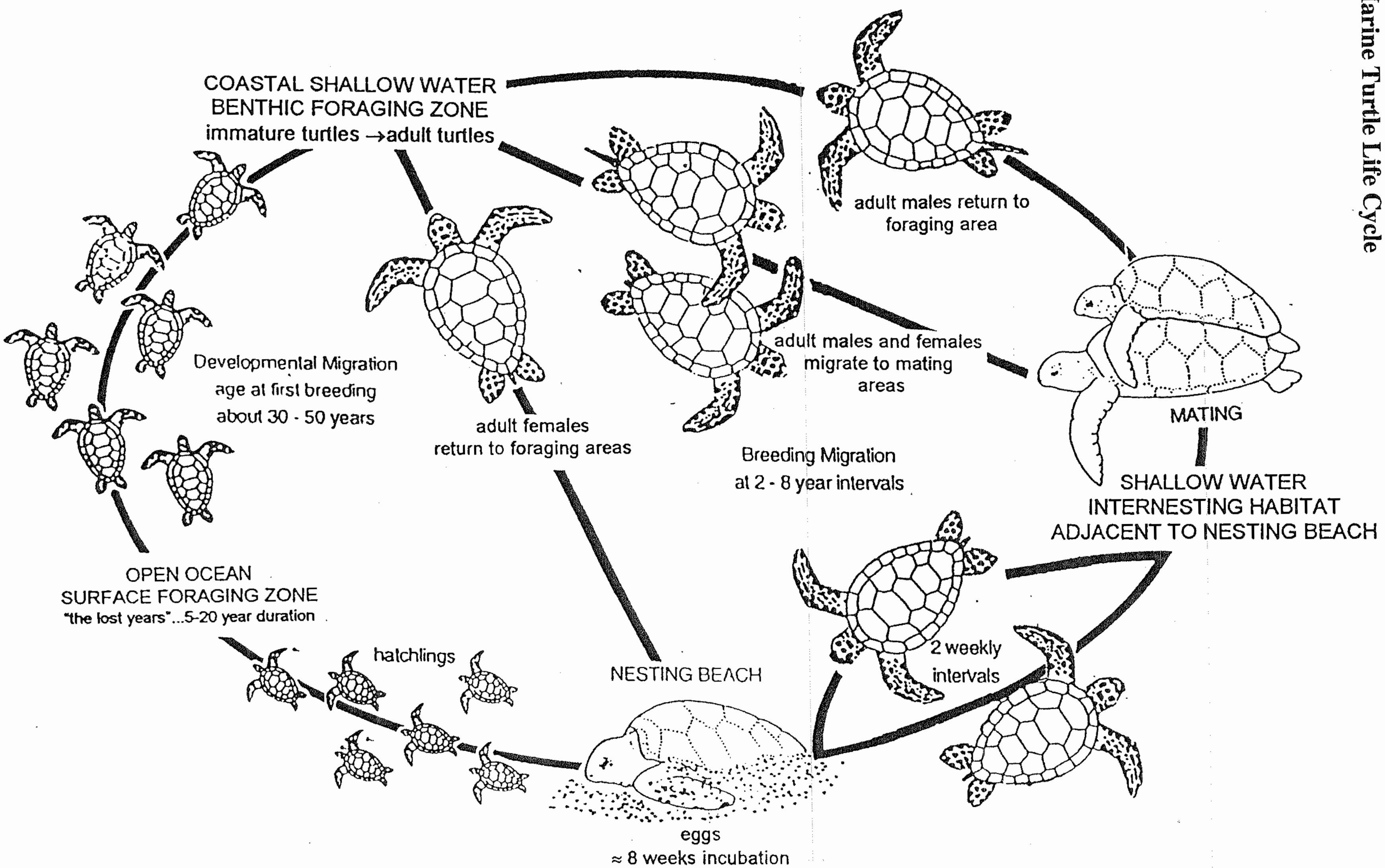
When the hatchlings disperse from the nesting beach they are virtually lost to study for the next few years. While in this drifting phase the turtles presumably feed on the macroplanktonic algae and/or animals at the surface. The young of all marine turtles except the leatherback turtle 'reappear' at about the size of a large dinner plate (curved carapace length 35-40 cm, age undetermined but possibly 5-10 yr old). At this size they take up residence in the shallow water habitats of the continental shelf, feeding principally at the bottom on plants and animals depending on the turtle species. Green turtles feed mostly on seaweed, seagrass, and mangrove fruits; loggerhead turtles feed mostly on shellfish and crabs; flatback turtles feed mostly on soft corals and sea pens; olive ridley turtles feed mostly on small species of crab and shellfish and hawksbill turtles feed mostly on sponges. These turtles will also eat jellyfish and Portuguese man-of-war on occasions. These immature turtles may remain in the one feeding ground for extended periods, perhaps years, before moving to another major area. At least several such shifts occur in the life of the turtle in this coastal shallow water benthic-feeding phase. The offspring of a particular female will not all recruit to the same feeding area but are expected to recruit throughout the entire region occupied by the breeding unit. The leatherback turtle, which remains an inhabitant of oceanic waters for almost all its life, feeds mostly on jellyfish.

Tagging studies of turtles living within the Great Barrier Reef, suggest that they are many decades old at first breeding and can have a breeding life spanning many more decades. At no stage in their life are sea turtles free of predation. The young to adult sized turtles are potential prey to large cod, grouper, sharks, crocodiles, and killer whales. In many countries, however, man continues to be the most significant predator. Green and olive ridley turtles are harvested in big numbers especially for meat; the hawksbill turtle for tortoiseshell. All species are hunted for leather, oil and their eggs.

Incidental capture of turtles in fishing gear can also cause significant mortalities of marine turtles, especially in prawn trawls, drift nets, large mesh set nets and long lines. In some areas, ingestion of plastic and other debris has been identified as a significant cause of mortality. Boat strikes are common in shallow areas with high density recreational boating.

Wherever there has been organised harvesting or large scale killing of the turtles and/or their eggs over several decades, the turtle population has undergone significant decline. No one has ever successfully managed a marine turtle population at stable population levels while subjecting them to large scale mortalities.

Figure 1.
The Marine Turtle Life Cycle



MIGRATION OF MARINE TURTLES IN INDONESIA. Colin J. Limpus

Marine turtles are highly migratory animals. This is particularly true of the adults. Each turtle typically lives for years at its specific feeding area and only leaves this feeding area at the beginning of the reproductive season when it migrates to the area of its birth for breeding. At the end of the reproductive season the adult turtle returns home to the same feeding area as where it was living prior to the breeding migration.. With later breeding seasons the adult will migrate again to the same breeding site as it used in the past.

Most of the knowledge of migration of marine turtles has been learned from the capture of adult female turtles that have been originally tagged while laying eggs on nesting beaches.

The following is a summary of long distance migration data gathered from two sources:

1. recoveries of tagged turtles originally tagged while nesting at rookeries in Indonesia. (These are few in number because there has been only limited tagging of nesting turtles in Indonesia.)
2. recoveries of tagged turtles in Indonesian feeding areas which had been originally tagged at nesting beaches in neighbouring countries. (There are many of this type of recapture because large numbers of nesting female turtles have been tagged while nesting on beaches in neighbouring countries.)

***Chelonia mydas*, penyu hijau, green turtle** **(Figure 1)**

Adult females tagged while nesting in southern Java have been captured for food by indigenous hunters in northen and western Australia (Limpus *et al.* 1992).

There are now numerous tag recoveries from within Indonesia of adult female *Chelonia mydas* tagged while nesting at rookeries in neighbouring countries including:

- eastern Australia (Great Barrier Reef, eastern Torres Strait): Limpus *et al.* 1992; Miller and Limpus (1991).
- Western Australia (Northwest Shelf: R. Prince, personal communication.
- Papua New Guinea (Long Island): Geerman s (*****).
- Malaysia (Sabah Sulu Sea): de Silva (1982).
- Malaysia (Terengganu): Liew et al. (in press).

These turtles were captured for food. At least some of these turtles were transported live from eastern Indonesia to Bali.

***Dermochelys coriacea*, penyu belimbing, leatherback turtle** **(Figure 2)**

An adult females tagged while nesting in southern Java has been captured by indigenous hunters western Australia (R. Prince, personal communication). An adult female tagged while nesting in northwestern Irian Jaya has been captured in the Philippines.

There has been at least one tag recoveries from within Indonesia (Kalimantan) of adult female *Dermochelys coriacea* tagged while nesting at Terengganu in neighbouring Malaysia.

***Eretmochelys imbricata*, penyu sisik, hawksbill turtle** (**Figure 3**)
There has been very few Eretmochelys imbricata tagged on nesting beaches in Indonesia. Therefore there are no long distance migration recoveries of this species from the Indonesian rookeries.

There has been one tag recoveries from within Indonesia (eastern Irian Jaya) of an adult female E*retmochelys imbricata* tagged while nesting in the northern Great Barrier Reef in neighbouring Australia where a tagging project on nesting females for this species.

***Caretta caretta*, penyu tempayan, loggerhead turtle** (**Figure 4**)
There are two tag recoveries from within Indonesia of adult female *Caretta caretta* tagged while nesting at rookeries in neighbouring countries:

- eastern Australia (southern Great Barrier Reef): Limpus *et al.* 1992.
- Western Australia (Northwest Shelf: R. Prince, personal communication.

Both these turtles were captured in fishing nets.

***Natator depressa*, penyu pipih, flatback turtle** (**Figure 5**)
There are two tag recoveries from within eastern Indonesia of adult female *Natator depressus* tagged while nesting at rookeries in neighbouring northern Australia (Limpus et al. 1993).

Lepidochelys olivacea, penyu lekang, olive ridley turtle
There are no migration data available for this species from the Indonesian region. This reflects the lack of tagging of this species in the Southeast Asian region.

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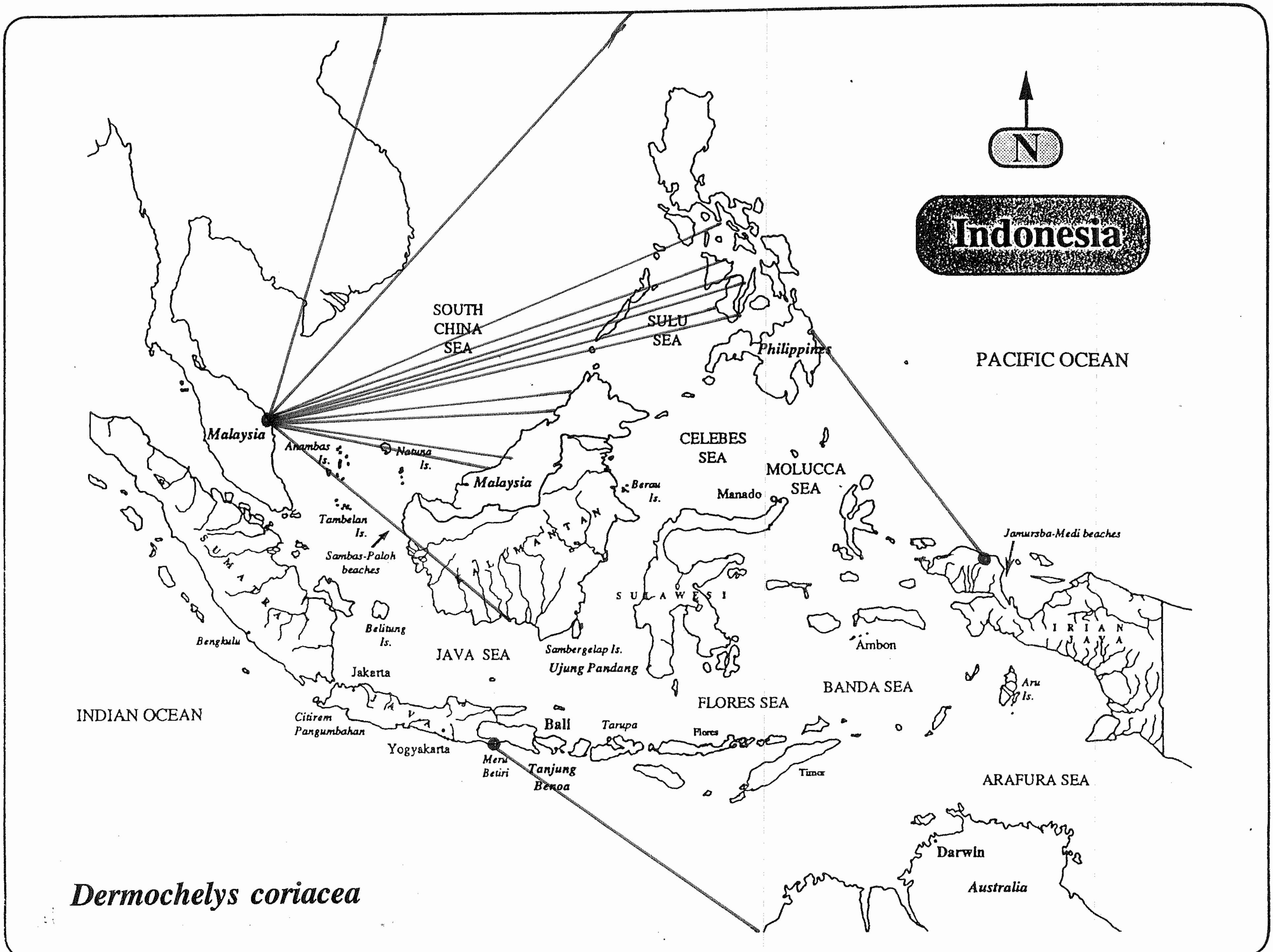
Miller, J. D. and Limpus, C. J. (199* Torres Strauight ******



Dermochelys coriacea

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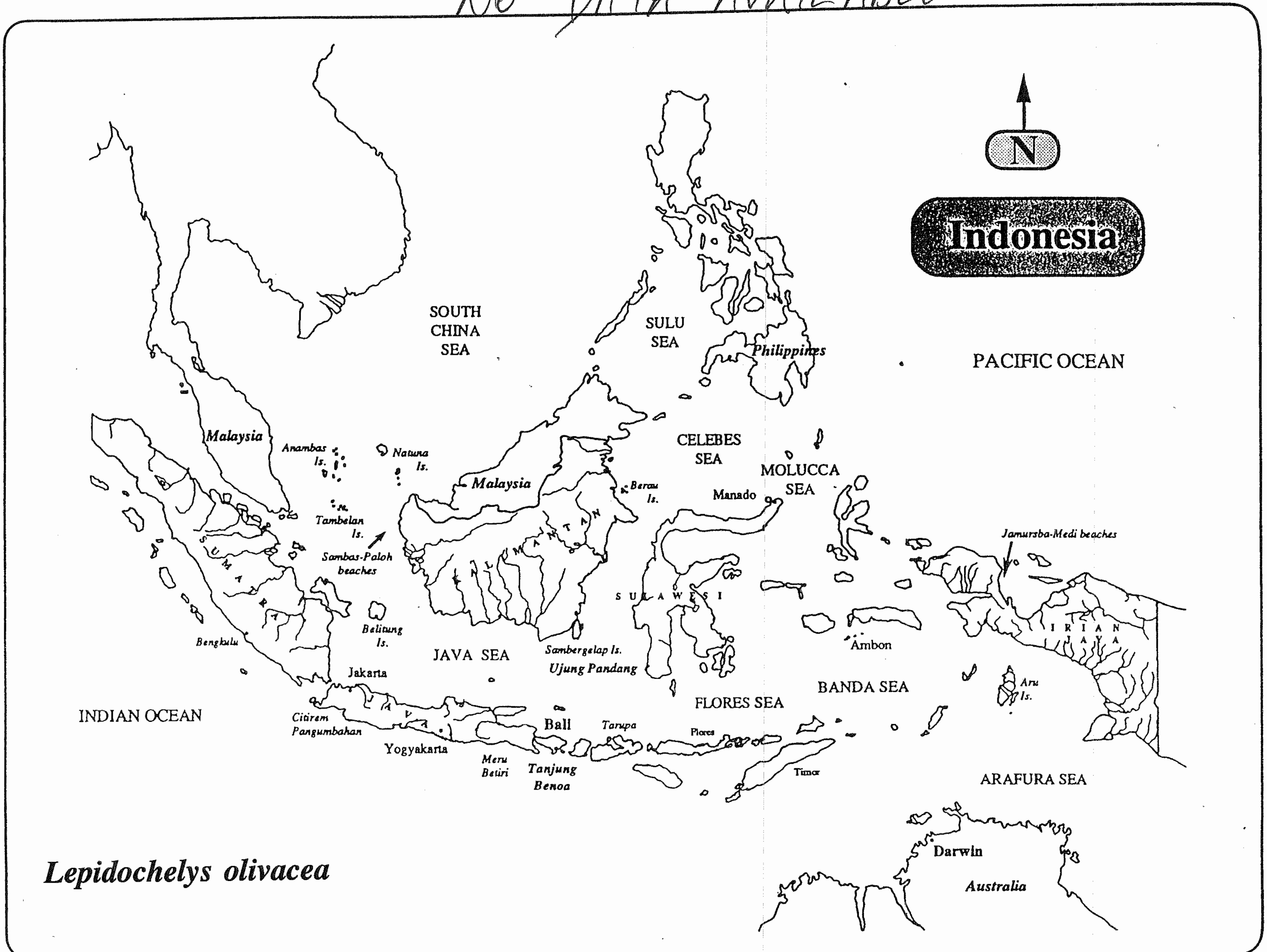
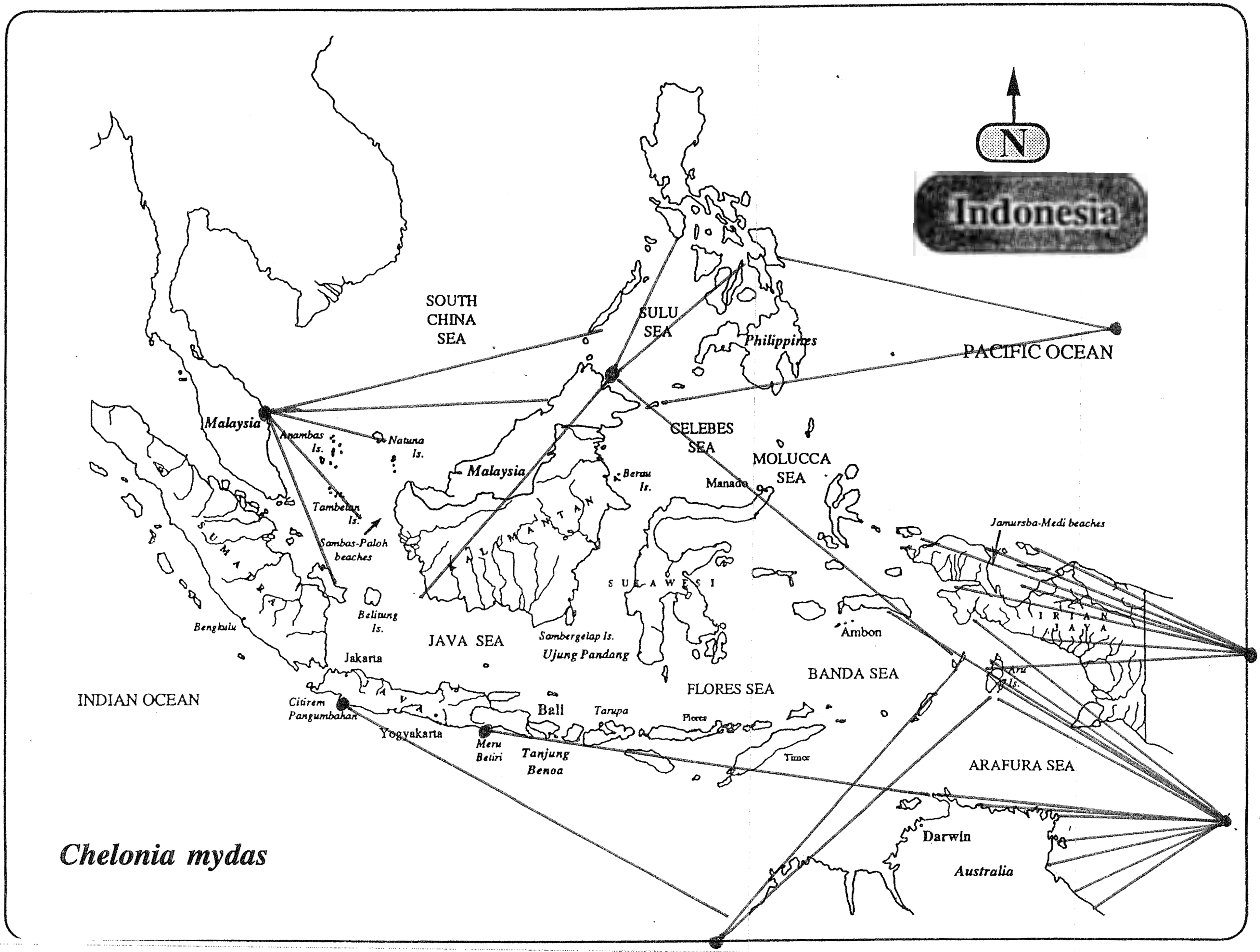


Lepidochelys olivacea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JAVA SEA
Sambergelap Is.
Ujung Pandang
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Jakarta
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Bali
Tarupa
Flores
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Meru
Betiri
Tanjung
Benoa
Timor
ARAFURA SEA
Darwin
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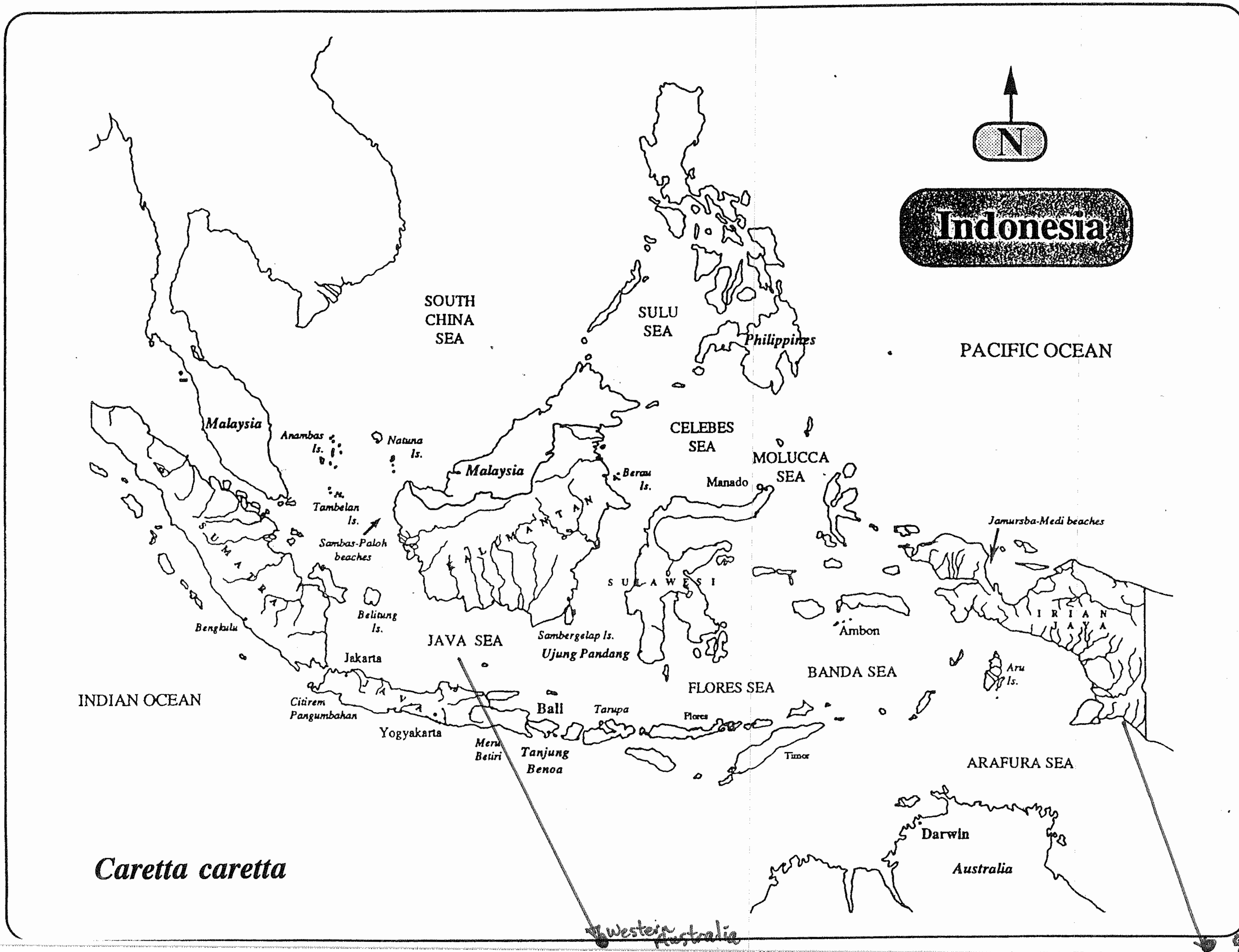
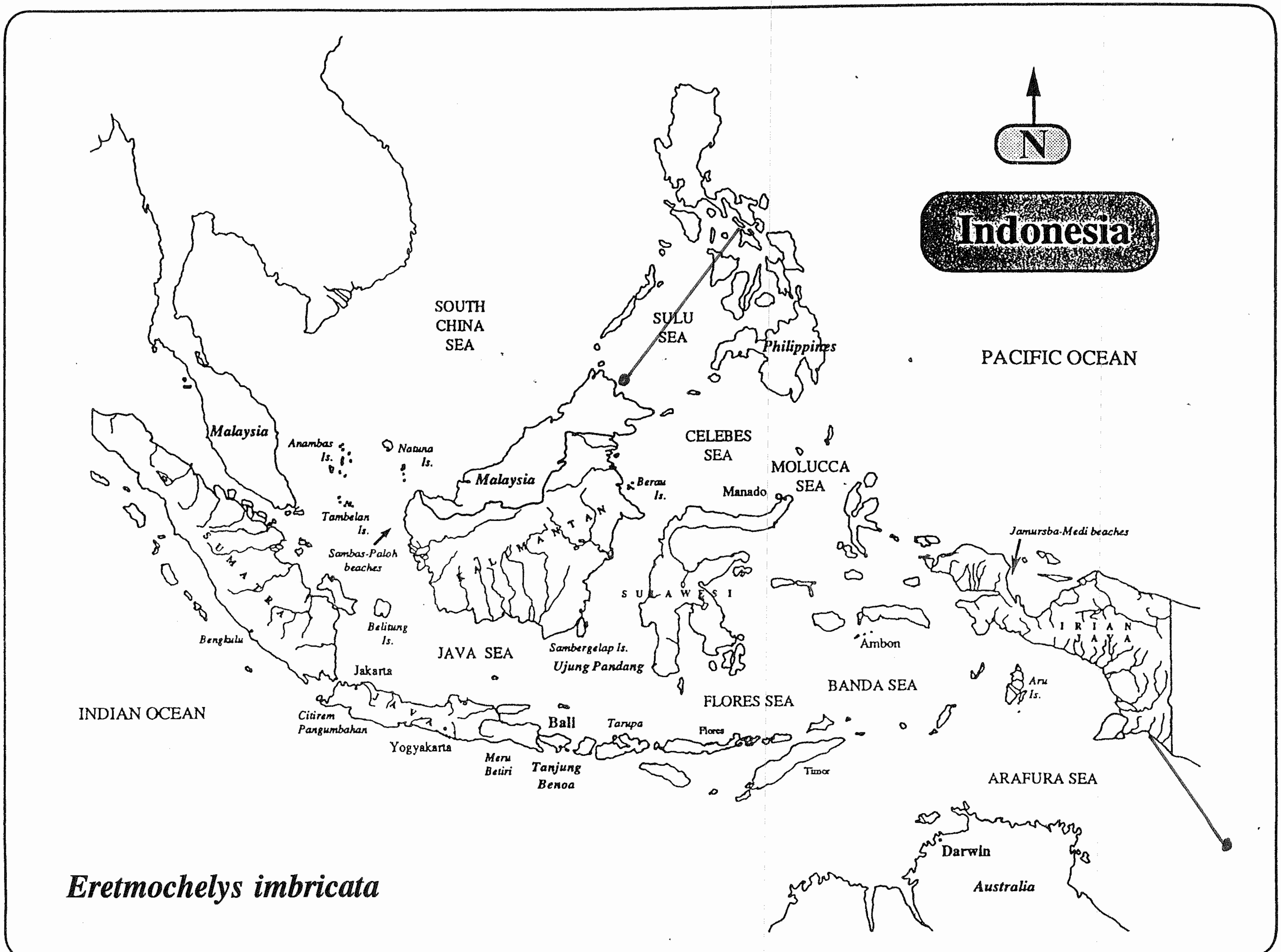
Chelonia mydas



Caretta caretta



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Philippines
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Anambas Is.
Natuna Is.
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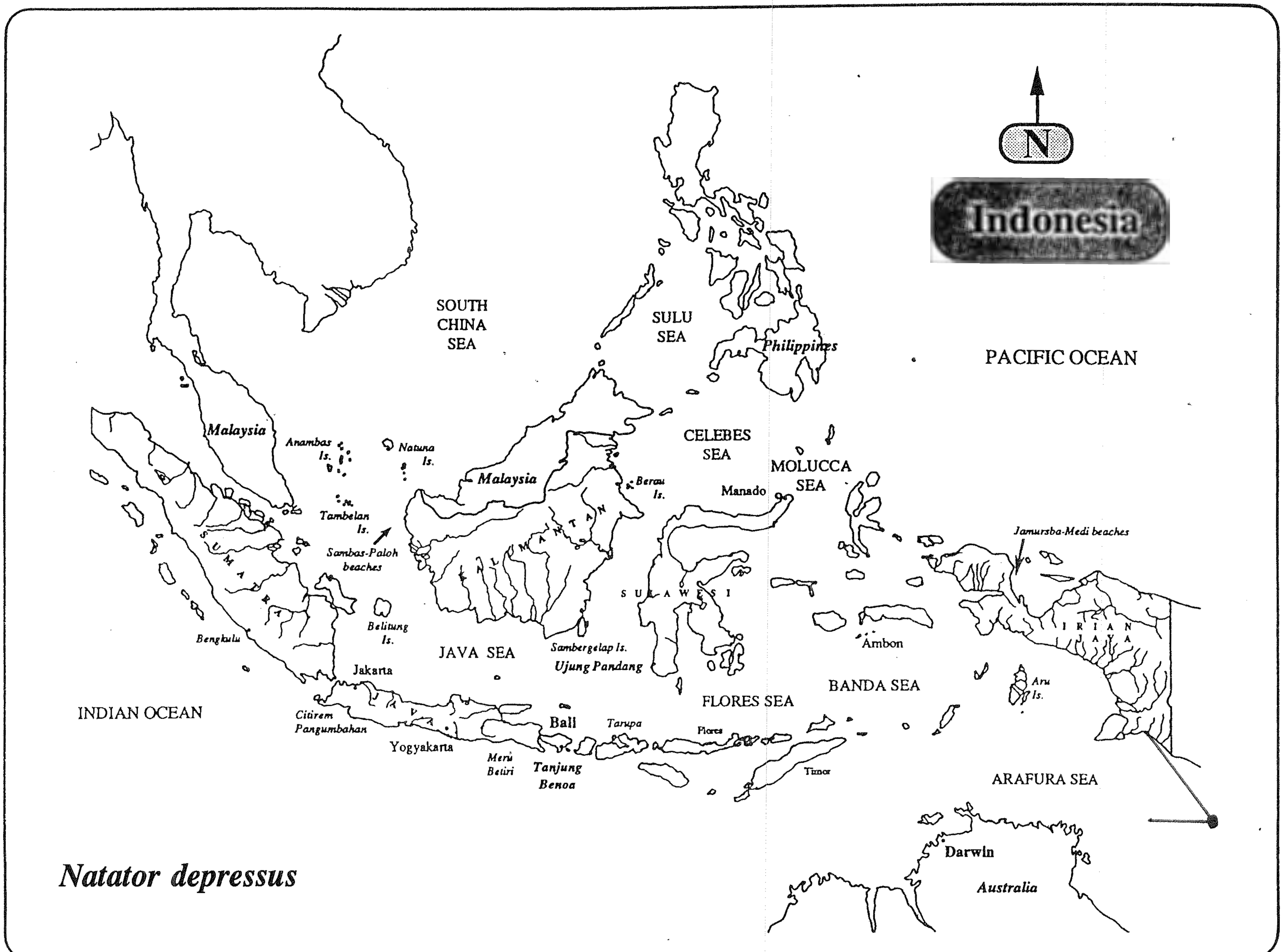
CELEBES SEA
MOLUCCA SEA
Berau Is.
Manado
Tambelan Is.
Sambas-Paloh beaches
KALIMANTAN
SUMATRA
SULAWESI
Jamursba-Medi beaches
IRIAN JAYA
Belitung Is.
Bengkulu
JAVA SEA
Sambergelap Is.
Ujung Pandang
Ambon
Jakarta
BANDA SEA
Aru Is.
INDIAN OCEAN
FLORES SEA
Citirem Pangumbahan
JAVA
Bali
Tarupa
Flores
Yogyakarta
Meru Betiri
Tanjung Benoa
Timor
ARAFURA SEA
Darwin
Australia
Eretmochelys imbricata



Natator depressus

Genetic Analysis of Marine Turtles from Indonesia and Adjacent Nations

C. Moritz, R. Slade and C. Limpus

This research, funded primarily by the Australian Nature Conservation Agency, is examining variation in mitochondrial DNA among green and hawksbill turtle rookeries from SE Asia, Austrlia and the south-west Pacific. This report focuses on the stocks in the SE Asian and western/northern Australian region. Details on stock structure for other Australian and SE Asian rookeries can be found in Norman et al. (1994) for green turtles, and Broderick et al. (1994) for hawksbill turtles. The data summarized below is being prepared for publication including the above authors and staff from relevant regional conservation agencies.

Aims

1. To identify genetically discrete populations (= management units) of marine turtles in South East Asia.

2. To identify any stocks with breeding sites spanning international borders.

3. To define genetic markers unique to different management units and apply these to anaylze the stock composition of turtles in harvests or feeding grounds.

Strategy

Analysis of mitochondrial DNA has proved fruitful for defining genetically distinct populations of marine turtles globally. We are using two methods to investigate mtDNA variation among populations from our region: (I) phylogenetic analysis of DNA sequences to investigate historical associations and dynamics of populations and (ii) analysis of allele frequencies to define current management units. The rationale for this approach is described by Moritz (1994). In situations where mtDNA is uninformative because of lack of variation, we use nuclear microsatellite loci as well, although this has not proved necessary for the SE Asian green turtle populations. Our analysis of mtDNA allele frequencies uses informative restriction sites within a 384bp segment of the control region. The informative sites were defined by a preliminary survey of sequence variation from each rookery (Norman et al., 1994, and unpublished data). RFLP surveys were conducted for between 13 and 40 individuals per rookery. The identity of alleles was then confirmed by sequencing a representative of each allele from each location.

Results

The rookeries addressed in this study are from Australia (Gulf of Carpenteria, GOC; North-West Cape, NWC; Lacepede Islands, LAC), Indonesia (Pangumbahan, Java, JVA), Malaysia (Terrenganu-Paka, Pulau Redang, PEN; Sarawak, SWK; Sabah Turtle Islands, SAB; Sipidan, SIP) and the Philippines (Turtle Islands, PHIL). Sample sizes vary from 13 to 40. Locations of sampling sites are shown in Fig. 1A.

Sequencing of representatives from each rookery revealed 7 different mtDNA sequences that differed by between 1 and 18 base substitutions. The majority of alleles were very closelt related (Fig. 2), differing by between 1 and 2 mutations. These form a widely distributed mtDNA lineage that dominated the rookeries from North-West Australia and the South China Sea. Another highly divergent allele (B, Fig. 2) was found in the Peninsula Malaysia and Sarawak rookeries. On a broader geographic scale, alleles distinct from those found here, but closely related to both the B and the C-F lineages have been found in Japan (see Norman et al., 1994). We devised an RFLP test to diagnose the 7 different sequences and used this to screen all samples from the rookeries, with sample sizes per site varying from 13 to 40 (Table 1). One allele (C3) was very widespread, but varied in frequency. Most other alleles were geographically isolated, occurring either in a single locality or being shared between geographically close rookeries (e.g., B, C1, and D).

Heterogeneity of allele frequencies was tested by comparing observed χ^2 values to those obtained in 1000 randomizations. All but three pair-wise comparisons revealed significant differences in allele frequency (Table 2). The exceptions were (I) the LAC and NWC rookeries from north-west Australia, (ii) the two sampling sites from the Terrenganu coast and (iii) the Philippines and Sabah Turtle Islands. Otherwise, all rookeries were genetically distinct.

Interpretation and Conclusions

(i) Population history. The presence of a widespread clade of very closely related alleles suggests that either these populations occasionally exchange individuals over a long distance or they were founded from a similar stock sometime over the past few thousand years. Given that most sited occurred on the Sunda Shelf that was not inundated until 8-10,000 years ago, the latter interpretation seems likely.

(ii) Current population structure. These data, combined with the geographically broader analysis of Norman et al. (1994), indicate that most rookeries in the region experience little immigration and should be regarded as separate management units. Within this region, we have identified 7 management units: north-west Australia (NWC + LAC), Java, Peninsula Malaysia (Paka + Pulau Redang), Sarawak, the Turtle Islands (SAB + PHIL) and Sipidan. The lack of genetic difference between the Sabah and Philippines Turtle Islands backs up observations of tagged females nesting on islands on either side of the international border in successive nesting seasons (Trono 1993). This is analogous to the situation within the Southern Great Barrier Reef management unit, where different rookeries spread over a similar distance (100km) lack genetic differences and exchange tagged females within and between seasons (Norman et al. 1994; Limpus et al. 1992). This, along with the lack of genetic differences between the two Terrenganu rookeries suggests the generalization that rookeries separated by 100km are likely to function as a single population.

In regard to the Indonesian situation, the Java rookery appears unique relative to the others so far analyzed, bur our sampling is obviously inadequate to define stocks within the country. However, the generalization emerging from our regional studies indicate that (I) rookeries within 100km could be grouped for the purpose of modeling or monitoring, but (ii) rookeries separated by a greater distance should be treated as separate entities.

We urgently need samples for genetic analysis of the remaining substantial Indonesian rookeries to complete the analysis of stock structure. High priority needs to be given to Aru and Berau Islands, but samples from non-sibling hatchlings or nesting females from any other rookeries would be valuable as well. Our ultimate goal is to estimate the contributions from different stocks within Indonesia and from adjacent nations to the Bali harvest. We currently have >200 samples from the harvest for this purpose, but cannot analyze then until potentially contributing stocks in Indonesia have been characterized.

Table 1. Control region haplotypes of Indo-West Pacific green turtles.

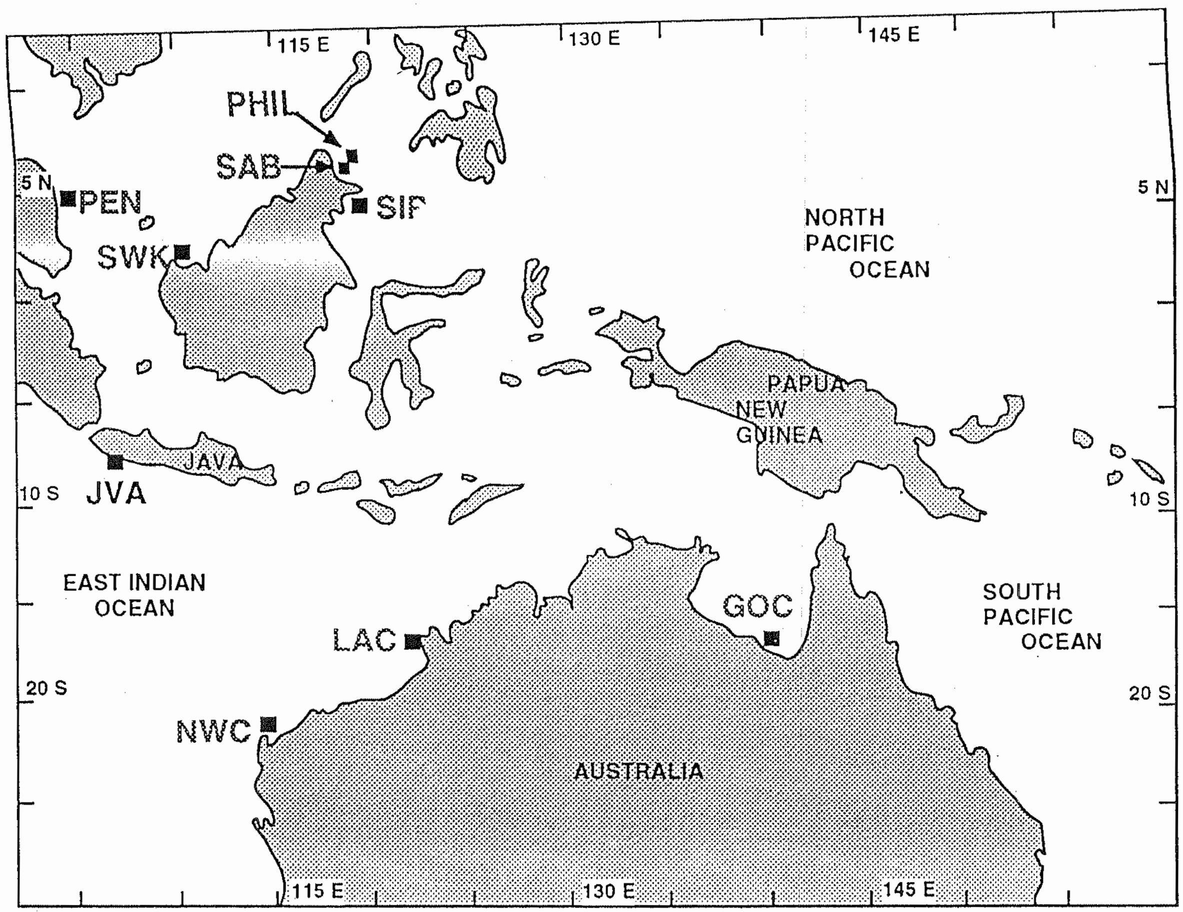
Haplotype	GOC	LAC	NWC	JVA	PEN (Paka)	PEN (Palau)	SWK	SIP	SAB (Turtle Isl)	PHIL (Turtle Isl)
B	-	-	-	-	1	2	2	-	-	-
C1	11	18	16	-	-	-	-	-	-	-
C2	-	-	1	-	-	-	-	-	-	-
C3	7	-	2	8	15	10	2	19	4	5
C4	3	-	-	-	-	1	12	-	-	6
D	-	-	-	-	-	-	-	8	24	29
F	-	-	-	7	-	-	-	3	-	-
TOTAL (216)	21	18	19	15	16	13	16	30	28	40

Table 2. Pairwise comparisons of control region haplotypes of Indo-West Pacific green turtles[1].

	NWC	Lacepedes	GOC	Java	SWK	Peninsula (Paka)	Peninsula (Palau)	Sipidan	Sabah (Turtle Isl)	Phillipines (Turtle Isl)
NWC	-	3.09	7.62	27.51	30.97	27.89	25.09	41.38	41.46	52.46
Lacepedes	**0.105**	-	11.53	33.00	34.00	34.00	31.00	48.00	46.00	58.00
GOC	0.019	< 0.0001	-	20.64	20.88	17.55	13.39	29.88	38.61	39.22
Java	< 0.0001	< 0.0001	< 0.0001	-	24.59	10.11	10.13	10.22	31.26	39.49
SWK	< 0.0001	< 0.0001	< 0.0001	< 0.0001	-	22.27	14.49	38.02	38.24	29.40
Paka	< 0.0001	< 0.0001	< 0.0001	0.003	< 0.0001	-	2.04	9.05	30.35	37.63
Palau	< 0.0001	< 0.0001	0.002	0.005	< 0.0001	**0.222**	-	11.94	27.81	30.36
Sipidan	< 0.0001	< 0.0001	< 0.0001	0.009	< 0.0001	0.014	0.003	-	20.74	28.23
Sabah	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	-	4.61
Phillipines	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	**0.110**	-

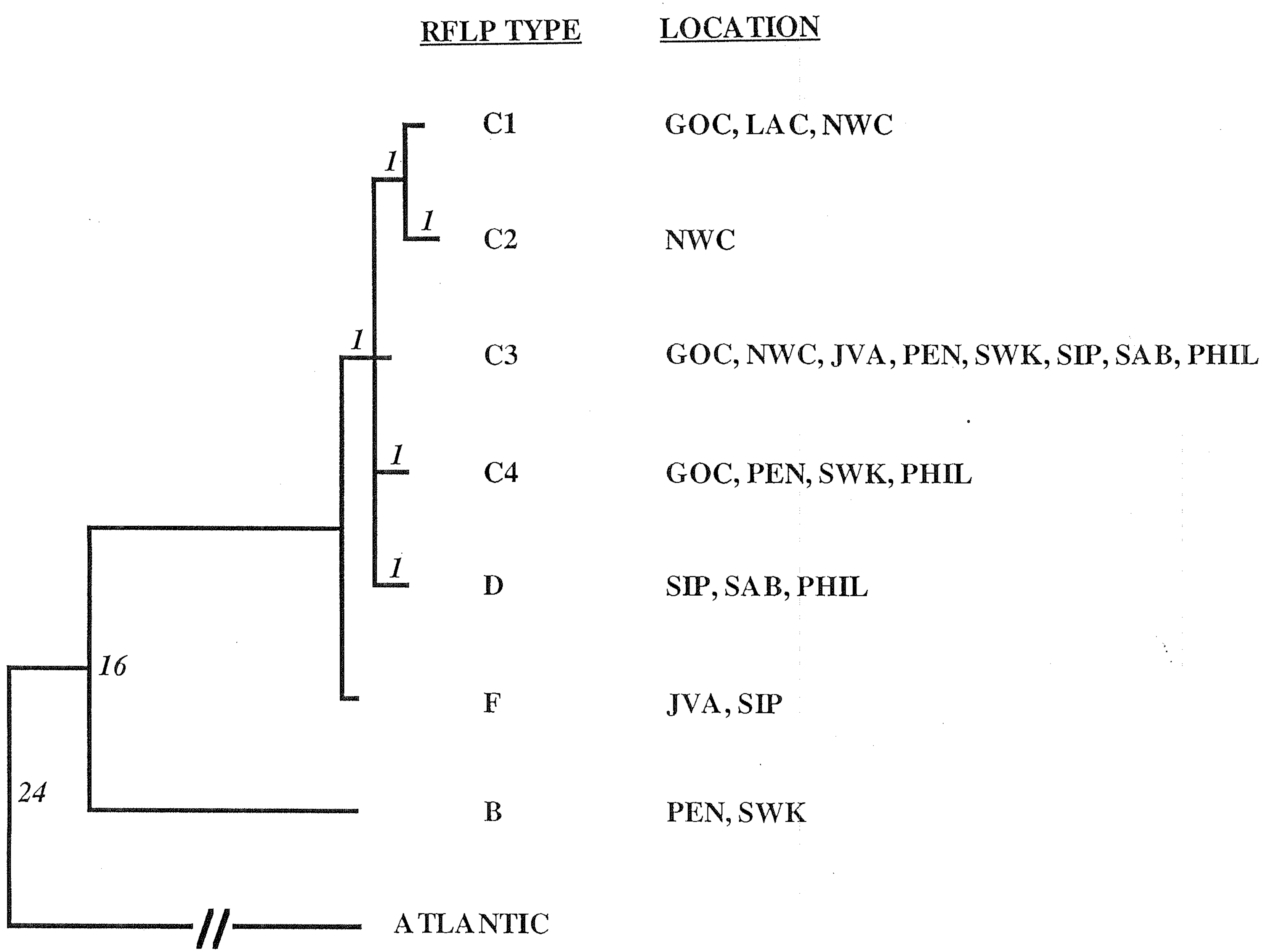
1. X^2 values above diagonal, *p* values below

A.



B.

Basis of grouping	Regions and rookeries								
	AUST			IND	MAL				PHIL
	GOC	LAC	NWC	JVA	PEN	SWK	SIP	SAB	PHIL
Management units	***	*******		***	***	***	***	********	



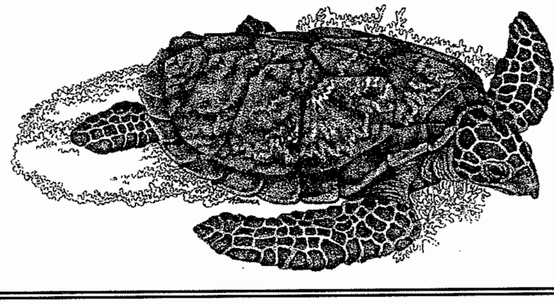
RFLP TYPE
LOCATION
C1
GOC, LAC, NWC
C2
NWC
C3
GOC, NWC, JVA, PEN, SWK, SIP, SAB, PHIL
C4
GOC, PEN, SWK, PHIL
D
SIP, SAB, PHIL
F
JVA, SIP
B
PEN, SWK
ATLANTIC
1
1
1
1
1
16
24

MARINE TURTLES OF INDONESIA

POPULATION VIABILITY AND CONSERVATION ASSESSMENT AND MANAGEMENT WORKSHOP

December 11-14, 1995
Cisarua, Indonesia

Section 4:
Status of Wild Populations of Marine Turtles in Indonesia



Marine Turtle Conservation in Indonesia[1]

Tonny Soehartono

1. Introduction

Six species of marine turtles are known to occur in Indonesian ocean territory: *Dermochelys coriacea* (leatherback), *Eretmochelys imbricata* (hawksbill), *Caretta caretta* (loggerhead), *Natator depressus* (flatback), and *Chelonia mydas* (green). These creatures are widely used for food and ornaments by fishermen and people living along the coastal areas.

Concern about the continuing decline of sea turtle populations and the potential impact of the growing commercial fisheries has prompted the government to develop an action plan for conserving marine turtles. In addition, several efforts on sea turtle conservation particularly on greens and hawksbills, have been undertaken by the government with the help from international agencies such as World Wildlife Fund (WWF) and the Food and Agriculture Organization (FAO).

The overexploitation of marine turtle resources is primarily caused by man. In some areas, they are hunted for meat while in other areas eggs are being harvested.

This report presents a summary of current developments on marine turtle conservation, problems and threats in Indonesia.

2. Management authority

In Indonesia, any species classified as wild flora and fauna falls under the authority of the Directorate General of Forest Protection and Nature Conservation, Ministry of Forestry (PHPA).

Since Marine Turtles are listed as wild fauna, these species have been under the jurisdiction of the PHPA starting from the early 1970s. The authority is recognized by Act No. 5 of 1990 which concerns conservation and ecosystems.

3. Distribution and Abundance

Trading statistics[2] from five major islands[3], show that the most abundant species in Indonesia is the green turtle, followed by hawksbill, loggerhead, olive ridley, flatback and leatherback.

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[1] In: Proceedings of the First ASEAN Symposium-Workshop on Marine Turtle Conservation. Manila, Philippines, 1993.

[2] Trading statistics include information on meat, carcasses, ornaments and stranding on several beaches.

[3] The five islands are Sumatra, Kalimantan, Java, Sulawesi and Irian Jaya.

Results of several surveys conducted by the PHPA indicate that green turtles are widely distributed throughout the Indonesian archipelago.

On the other hand, hawksbills are mostly found along the western and eastern coast of Sumatra, Northern and Southern Java, North of Nusa Tenggara, Southern and North East Sulawesi, Maluku and North of Irian Jaya.

Loggerhead turtles are encountered on the beaches of West Kalimantan, Central and Southern Sulawesi, and Maluku. The three remaining species, i.e., olive ridley, flatback and leatherback have become rare and have only been found in South Sulawesi, Maluku, and Irian Jaya waters. Regular nesting of a sizeable population of leatherbacks have been reported in the northern coast of Irian Jaya.

Appendix 1 enumerates marine turtle nesting areas identified throughout Indonesia.

4. Problems

Major problems concerning the management and conservation of marine turtles in Indonesia are as follows:

- To date, there are no reliable information regarding the population and the extent of utilization of the species in Indonesia;
- Although the government has already declared five of the six species of marine turtles as protected, illegal exploitation, including egg harvests are still going on. This shows that conservation awareness is still a problem;
- Due to the limited number of conservation officers, the control and enforcement of laws against illegal hunting and harvesting of marine turtles is ineffective;
- For certain communities, turtles, particularly the green, are still considered as important source of food and are used in traditional ceremonial practices. A rough record covering the last five years shows approximately 15,000 green turtles consumed per year throughout the country;
- As the demand for and value of the coastal areas increase, particularly for tourism development and settlement purposes, potential conflicts of interest are growing against conserving the nesting beach;
- Local knowledge and expertise on turtle conservation are still inadequate in the country. For some time, Indonesia has been assisted by many international agencies for developing and managing marine turtles.

5. Policy

In essence, local legislation provide that species shall be protected, regulated, and used for the benefit of humankind now and for the future. Specific to marine turtles, conservation efforts are necessary to promote wise and sustainable use of the species to ensure their continued survival.

Legal instruments in Indonesia that provide for the conservation and protection of marine turtles include:

- The Indonesian Constitution of 1945;
- Act No. 5 of 1967 (Basic Provision of Forestry);
- Act No. 4 of 1982 (Basic Provision for the Management for Living Resources);
- Act No. 9 of 1985 (Fishery); and
- Act No. 5 of 1990 (Conservation of Living Resources and their Ecosystems).

In line with the above policies, the government has declared five of the six species of marine turtles as endangered and protected animals. These species are *Dermochelys coriacea, Lepidochelys olivacea, Eretmochelys imbricata, Caretta caretta, and Natator depressus.*

However, due to its relative abundance and its use in traditional Hindu ceremonies in Bali, the green turtle is still legally harvested under a careful quota system. The green turtle quota for 1993 is 5,000 heads. Most of them are allocated for Bali Island.

It is acknowledged that the yearly harvest may exceed the endorsed quota due to difficulties in maintaining control. However, records show that turtle meat consumption outside Bali is still under control.

6. Action Plan

The action programs listed below have been undertaken to save the species. These are aimed to increase conservation efforts to protect turtles and their habitats by:

- Enhancing conservation areas for marine turtles primarily for habitats that are most vulnerable to human disturbance such as nesting beaches and marine areas where juveniles, sub-adults and breeders occur;
- Conservation awareness programs focusing on saving marine turtles;
- Strengthening knowledge, capabilities and facilities for marine turtle conservation;
- Management and control of green turtle utilization including the regulation of egg harvesting; and
- Marine turtle research and development.

Presently, the government is putting emphasis on the first two action plans. Many nesting habitats have been declared as protected areas. Private beach ownership has been abandoned. Fishing zones have already been designated, established and regulated by the Ministry of Agriculture.

7. Programs

The continued threatened status of marine turtles in Indonesia and in the world in general mandates Indonesia to develop aggressive and comprehensive short and long-term programs to accelerate population recovery. The immediate goal of any conservation program is to arrest population decline. The ultimate goal is to provide the conditions that will stabilize the breeding populations to a sustainable level

The following are short-term programs that have been developed and implemented to save the marine turtle:

- Turtle habitat survey and inventory. This activity has already been undertaken for almost five years. As a result of the surveys, 143 nesting beaches throughout the country have been identified (Appendix 1);
- Designation of the nesting beaches as conservation areas. To date, the government has already declared 27 protected areas for marine turtle conservation.
- Conservation awareness campaign. This activity is conducted by conservation officers, NGOs and students. The target communities are fishermen and people who live along and near the beaches.
- Regulation and monitoring of green turtle egg collection. Egg collection is regulated through limited harvest and juvenile restocking system that is usually done by a cooperative owned by the community.

Long-term programs on the other hand consist of the following:

- Research and development on population, migration, and rehabilitation of populations and habitats;
- Regional management and control of marine turtle exploitation (ASEAN and Pacific region);
- Formulation of an educational curriculum for marine turtle conservation;
- Development of an efficient information system and GIS for marine turtle conservation;
- Development of a system that will ensure the sustainability of the resource;
- Establishment of a specific institution mandated to manage and conserve marine turtles in Indonesia; and
- Upgrade the capability of the PHPA for management and conservation of marine turtles.

8. Recommendations

Marine turtle conservation is the responsibility of every man. Any activity adversely affecting the population and their habitat should be discouraged. Since the early 70's, Indonesia has initiated efforts to save and conserve marine turtles. Due to the limited expertise and funds, the results of the activities carried out are by far inadequate. However, these conservation efforts are worthwhile for the development of further conservation strategies.

Knowing that marine turtles regularly migrate within Indonesia and the Pacific Ocean or probably even further, close regional cooperation is urged. Common management strategies among neighboring countries may avert the population decline and strengthen the effort of population rehabilitation. It is also requested that international institutions provide support for: a) the enhancement of technical competence in turtle conservation in the region; and b) the development of necessary facilities.

About the Author

Tonny Soehartono has been Director of the Forest Protection and Nature Conservation Office for West Kalimantan since 1992.

Appendix

Appendix 1 Marine Turtle Nesting Area Throughout Indonesia. (refer to accompanying map)

No.	Province and Location	Species					
		1[3]	2[4]	3[5]	4[6]	5[7]	6[8]
	ACEH						
1	Kepulauan Banyak	+[9]	+	-	-	-	
2	Pulau Beras, P. Nasi	+	-[10]	-	-	-	
	NORTH SUMATRA						
3	Pulau Musala	-	+	-	-	-	
4	Kapulauan Batu	+	+	-	+	+	
	RIAU						
5	Pulau Durai	+	+	-	-	-	
6	Kepulauan Riau, Kep. Lingga	+	+	-	-	-	
7	Kepulauan Anambas	-	+	-	-	-	
8	Kepulauan Natuna Besar	-	+	-	-	-	
9	Kep. Tujuh (South Natuna) ***[11]	-		-	-	-	
10	Pulau Midai	-	+	-	-	-	
11	Kepulauan Tambelan ***	+	+	-	-	-	
	WEST SUMATRA						
12	Pulau Pasanam	+	+	-	-	+	
13	Pulau Siberut	+	+	-	-	+	
14	Pantai Selatan Padang	+	+	-	-	+	
15	Pulau Penyu ***	+	+	-	+	+	
16	Pulau Sipura	-	-	-	-	+	
17	Pulau Kecil sekita Pagai	-	+	-	-	-	
18	Pulau Pagai	-	+	-	-	-	
19	Pulai Sanding	+	-	-	-	-	
	BENGKULU						
20	Pulau Mega	+	-	-	-	-	
21	Bengkulu (Pendek, Sawangkatung, dan pantai antara Muko-Muko Binduhan, dan Pulau Tikus)	+	+	-	+	+	
	SOUTH SUMATRA						
22	Kepulauan lima ***	+	+	-	-	-	
23	Pulau Kalimambang, P. Lengkuas	+	+	-	-	-	
24	Kepulauan Momperang ***	+	+	-	-	-	
25	Tanjung Rusa, Tl. Bolok	+	+	-	-	-	
26	Pulau Plemah - Manggar	+	+	-	-	-	
	LAMPUNG						
27	Keruai	+	-	-	-	-	
28	Tanjung Cina	+	-	-	-	+	
29	Tanjung Rakata,	+	+	-	-	-	
	P. Sertung *[12]	-	+	-	-	-	
30	Pulau Segama	+	+	-	-	-	
	DKI JAKARTA						
31	Kepulauan Seribu *	+	+	-	-	-	
	WEST JAVA						
32	Pulau Panaitan **[13]	+	-	-	-	-	
33	Ujung Kulon **	+	+	-	-	+	
34	Citerem, Cibulakan **	+	-	-	-	-	
35	Pangumbahan ***	+	+	-	-	-	
36	Cipatujah - Sindang Kerta ***	+	+	-	-	-	
37	Cikalong	+	-	-	-	-	
	CENTRAL JAVA						
38	Nusa kambangan **	+	+	-	+	-	-
39	Kepulauan Karimun Jawa *	+	+	-	-	-	-
	EAST JAVA						
40	Pulau Bawean	+	-	-	-	-	
41	Nusa Barung **	+	+	-	-	-	
42	Sukamade **	+	+	-	+	+	
43	Bagian Barat Tl. Blambangan	-	-	-	-	+	
44	Blambangan **	+	-	-	-	+	
45	Pulau Gili Yang	-	+	-	-	-	
46	Pulau Sagubing, P. Saubi **	+	+	-	-	-	
47	Pulau Araan	+	+	-	-	-	
48	Pulau Sepanjang	+	-	-	-	-	

[3] Green turtle
[4] Hawksbill
[5] Loggerhead
[6] Olive ridley
[7] Leatherback
[8] Flatback

[9] + Discovered
[10] - No evidence
[11] *** Proposed priority for protected area
[12] * Protected area
[13] ** Protected area being proposed for extended.

No.	Province and Location	Species					
		1[3]	2[4]	3[5]	4[6]	5[7]	6[8]
	BALI						
49	Bali Barat **	-	+	-	-	-	
50	Nusa Penida dan Lebih	+	-	-	-	-	
51	Bualu	-	+	-	+	-	
	WEST NUSA						
52	Lombok Bagian Tenggara	+	-	-	-	-	
53	Sumbawa Bagian Tenggara	+	+	-	-	-	
54	Ai - Ketapang	+	+	-	-	-	
55	Dara Mata	+	+	-	-	-	
	EAST NUSA TENGGARA						
56	Pulau Komodo **	+	-	-	-	-	
57	Pulau Roti, Pulau Dana	+	+	-	-	-	+
58	Pulau Semau	+	+	-	-	-	
59	Pulau Batek	-	+	-	-	-	
	WEST KALIMANTAN						
60	Paloh - Sambas ***	+	+		+	-	
61	Pulau Lemukutan	+	-	-	-	-	
62	Kepulauan Karimata *	+	-	-	-	-	
	CENTRAL KALIMANTAN						
63	Kumai	+	-	-	-	-	
64	Tanjung Puting	+	-	-	-	-	
	SOUTH KALIMANTAN						
65	Pleihari Tanah Laut **	+	-	-	-	-	
66	Tanjung Selatan	+	+	-	-	-	
67	Kepulauan Marabatua	+	-	-	-	-	
68	Kepulauan laut Kecil ***	+	+	-	-	-	
69	Pulau Birah-Birahan	+	-	-	-	-	
70	Tanjung Layar	+	-	-	-	-	
71	Kepulauan Sambar Gelap ***	+	-	-	-	-	
	EAST KALIMANTAN						
72	Pasir	+	-	-	-	-	
73	Balikpapan	+	-	-	-	-	
74	Pulau Birah-Birahan	+	-	-	-	-	
75	Sankuriang	+	-	-	-	-	
76	Pulau Mataha, P. Bilang-Bilangan	+	-	-	-	-	

No.	Province and Location	Species					
		1[3]	2[4]	3[5]	4[6]	5[7]	6[8]
77	Pulau Semama, P. Sangalaki *	+	+	-	-	-	
78	Pulau Maratua, P. balikukup *	+	+	-	-	-	
79	Pulau, P. Balembangan	+	-	-	-	-	
	NORTH SULAWESI						
80	Pulau Tangkoko - Batuangus **	+	+	-	-	-	
81	Tanjung Flores	+	-	-	-	-	
82	Kepulauan Karkaralong	+	-	-	-	-	
83	Kepulauan Nanusa	+	-	-	-	-	
84	Kepulauan Bunaken *	+	+	-	-	-	
85	Pulau, Popaya, P. Mas **	-	-	-	-	-	
	CENTRAL SULAWESI						
86	Tanjung Arus - Tg. Dako	+	-	-	-	+	
87	Pulau Simatang	+	-	-	-	-	
88	Siraru	+	-	-	-	-	
89	Pulau Pasoso	+	-	-	-	-	
90	Kepulauan Togian	+	+	-	-	-	
91	Kepulauan Banggai	+	-	+	-	-	
	SOUTH SULAWESI						
92	Pulau Lari - Larian	+	-	-	-	-	
93	Pulau Ambo	+	-	-	-	-	
94	Kepulauan Balangan, Kep. Mamuju	+	+	-	-	-	
95	Kepulauan Spermonde	+	+	-	-	-	
96	Kepulauan Masalima	-	+	-	-	-	
97	Kepulauan Kalukalukuang	-	+	-	-	-	
98	Kepulauan Dewakang	-	+	-	-	-	
99	Kepulauan Tengah	+	+	-	-	-	
100	Kepulauan Sabalana	+	+	-	-	-	
101	Tanjung Apatama	-	-	-	-	+	
102	Pulau Kayuadi	-	+	-	-	-	
103	Kepulauan Sembilan	+	+	-	-	-	
104	Taka Bone Rate *	+	+	+	-	-	
105	Pulau kakabia ***	+	-	-	-	-	
106	Pulau Sarege ***	+	-	-	-	-	
107	Pulau Kauna	+	-	-	-	-	
108	Pulau Lalao	+	-	-	-	-	
	SOUTHEAST SULAWESI						
109	Pulau Kabaena, P. Telaga Bsr.	-	+	-	-	-	
110	Padamarang	-	+	-	-	-	
111	Tanjung Kassolamatumbi	+	-	-	-	-	
112	Tanjung Tamponokora	+	-	-	-	-	

No.	Province and Location	Species					
		1[3]	2[4]	3[5]	4[6]	5[7]	6[8]
113	Pulau Manui	+	-	-	-	-	
114	Pulau Wowoni	-	+	-	-	-	
115	Pulau Saponda	-	+	-	-	-	
116	Lintea Tiwolu	+	-	-	-	-	
117	Binongko	+	-	-	-	-	
118	Pulau Batuata	-	+	-	-	-	
	<u>MALUKU</u>						
119	Pulau Weter	-	+	-	-	-	
120	Seira	-	+	-	-	-	
121	Kepulauan Aru Tenggara (P. Enu, P. Jeh, P. Karang) * Kep. Penyu-Kep. Lucipara ***	+	+	-	-	-	
122	Pulau Ambon	+	+	+	-	-	
123	Latuhalat P. Pombo *	+	-	-	-	-	
124	Pulau Kasa	-	+	-	-	-	
125	Pulau Seram Timur	-	+	-	-	-	
126	Pulau Parang	-	+	-	-	-	
127	Wahai	+	+	-	-	-	
128	Kayoa	-	+	-	-	-	
129	Morotai Utara	-	+	-	-	-	
130		-	-	-	-	+	
	<u>IRIAN JAYA</u>						
131	Pulau Sayang	+	+	-	-	+	
132	Kepulauan Ayu	+	+	-	-	+	
133	Kepulauan Asia	+	+	-	-	+	
134	Kepulauan Dua	+	+	-	-	+	
135	Pantai Utara Kepala Burung Irian Jaya (Vogelkop)	+	-	-	+	+	
136	Kepulauan Mapia	+	+	-	-	-	
137	Pulau Ayawi	+	+	-	-	-	
138	Kepuluan Auri-Tl. Cendrawasih *	+	+	-	-	-	
138	Inggresau	-	-	-	-	+	
140	Kepulauan Raja Ampat	+	+	-	+	-	
141	Pulau Tataruga, P. Sabuda	+	-	-	-	-	
142	Pulau Adi	+	-	-	-	-	
143	Pulau Dolok - Marauke	+	-	-	-	-	

Figure

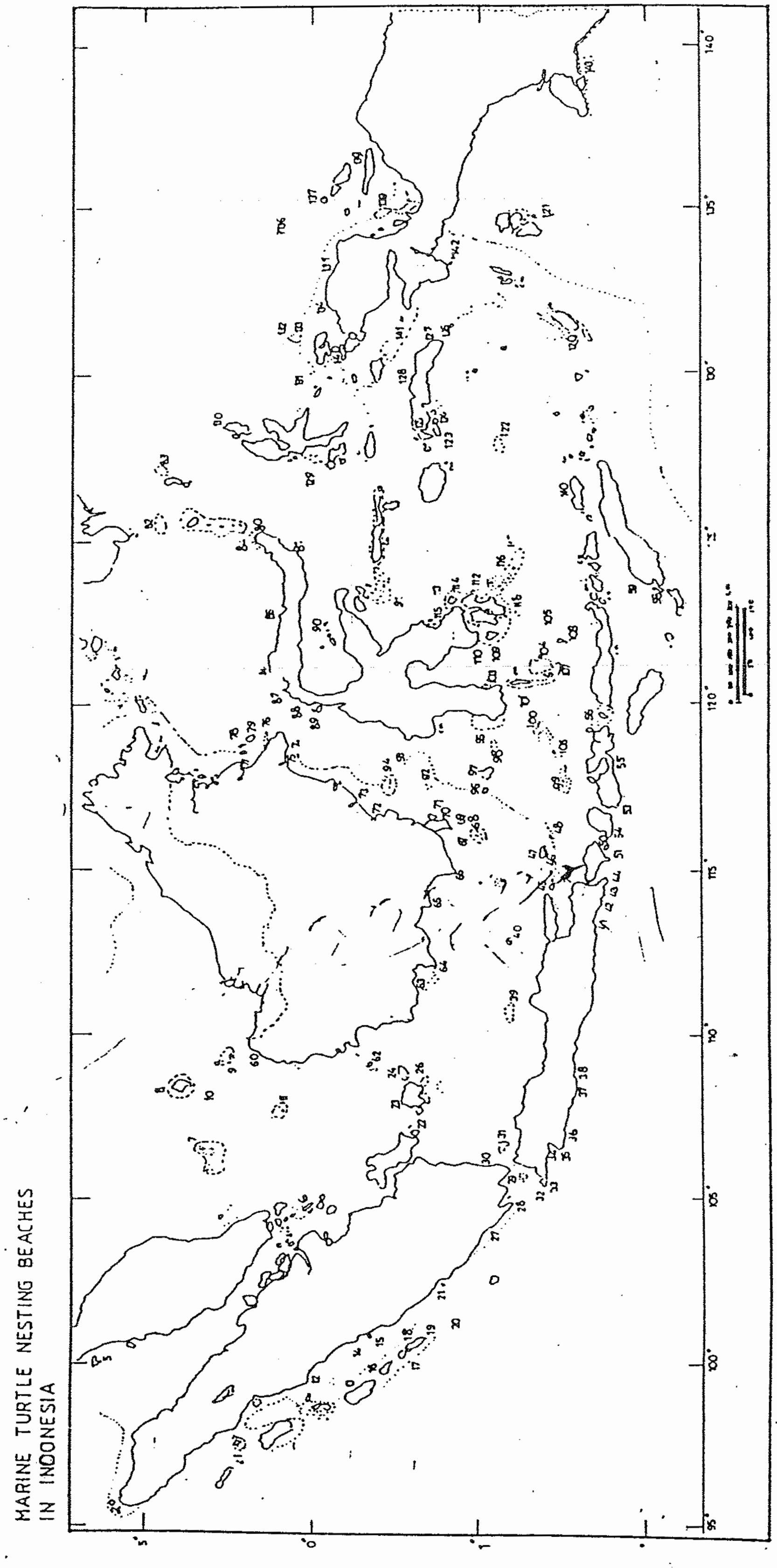


Figure 1. Nesting sites in Indonesia

Recommendations for Java + Bali Region

1. Survey area for turtle (Bali, Java) feeding grounds.

2. Improve habitat conditions in relation to feeding grounds.

3. Create a pilot project to monitor the behavior of turtles in selected locations which can be used to guide for management in the entire region.

4. Build facilities needed for monitoring and observation.

5. Initiate a turtle conservation campaign to encourage awareness of people at the local, regional, and national levels.

6. Develop the information network to local, regional, national, and international levels.

Bali: Develop rearing at this area so the consumption for food or religious ceremony will not exploit natural stock.

Alas Purwo: Do a tagging program and add to the existing facilities (especially for the research program).

Jember: Increase exchange of information with international experts and institutions.

Cipatujah: Add to the existing facilities.

All of this area is protected and has data which can be found at the local office.

Information from Sumatra

Based on information gathered at the meeting, marine turtle species are also found in Aceh Province and the distribution was identified to include P. Weh, P. Breuh, P. Rubiah (north of Banda Aceh). During peak season (July-August) large numbers of turtles land and lay eggs. The people who live in the surrounding area collect some of the turtle eggs and then sell them in Banda Aceh.

Another location with turtles is Pulau Banyak which consists of several islands (Tuangku, Bah, Bangkam, Tepe, Ujung Batu, Pagg, etc.). The total number of turtles nesting as well as the number of eggs laid are still unknown. According to information from the fishermen the species are recognized as the hawksbill and the green turtles.

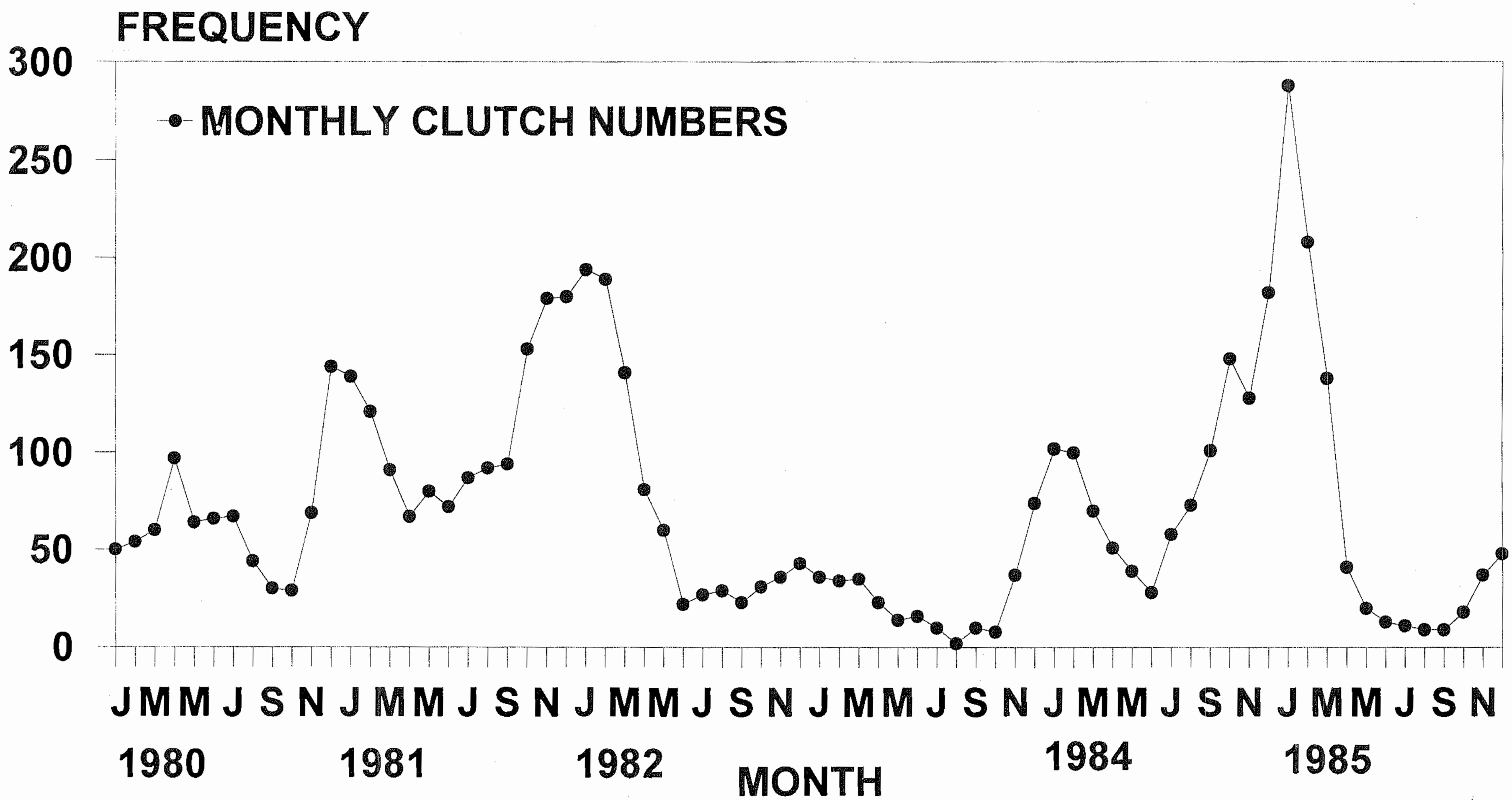
Recommendation for Sumatra

Based on these rough data, we strongly recommend that those islands should be surveyed as part of the potential assessment of these turtles.

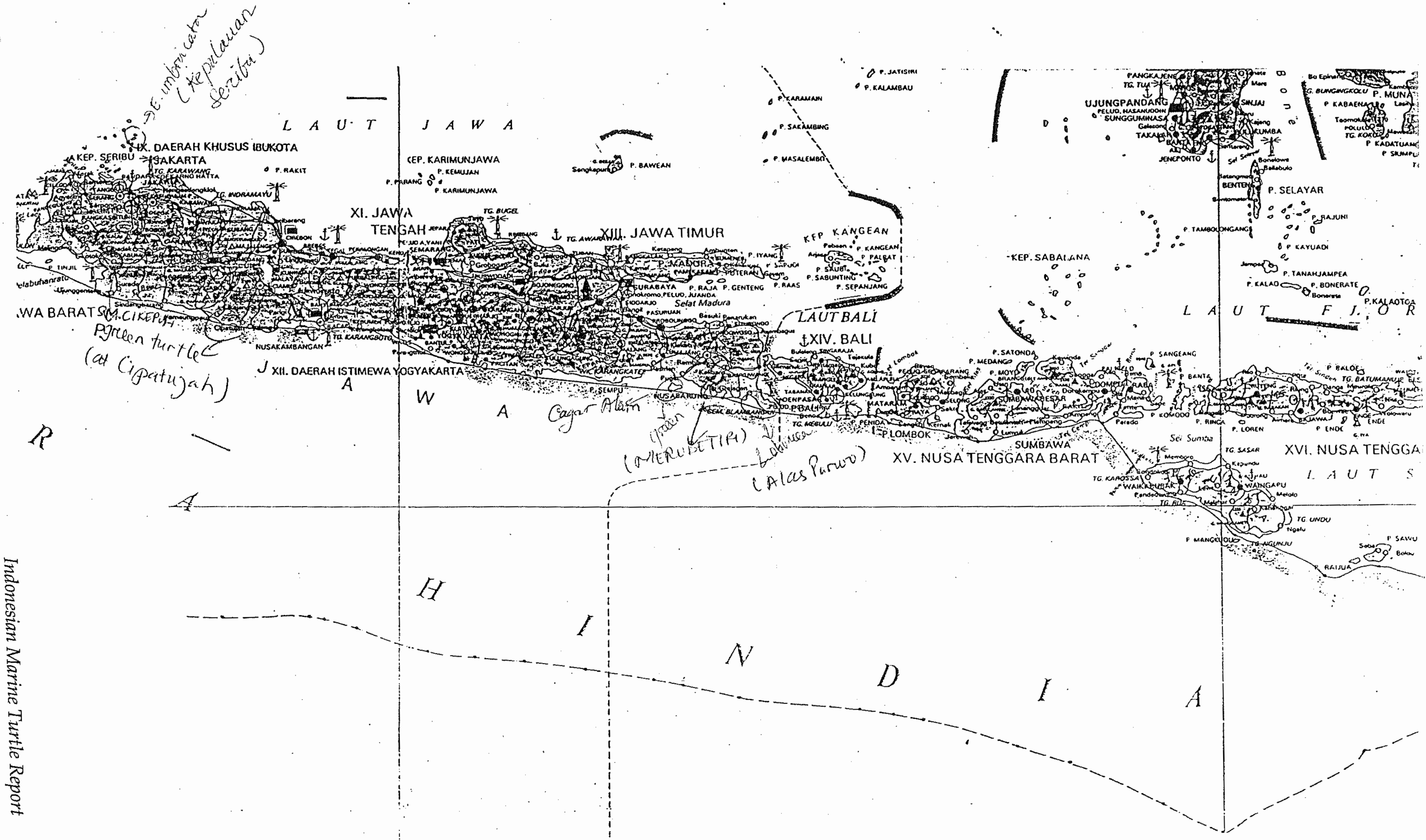
Location	Species	Trend	Breeding ♀ (1995)	# Loc's	Field Study	Threats	Law Enforcement	Management	Problems
Bali	Leatherback Hawksbill	± ?	493 ?	1 Pantai Padang Galik 1 Panti Bali Baret NP	? ?		Some at several art shops and restaurant	Hatching, eggs from Pangumbahan	Too many gates for illegal trade; Lack of: Enforcement Monitoring
Taman Nasional Alas Purwo	Olive Leatherback Hawksbill Green	↑ ± ↓ ↓	110 10 0 4	2 2 1 3	Habitat and Hatchery	Poaching on land and sea, Natural predator,	Yes	Rearing + Releasing, Guard house Research house being built	Lack of field personnel to turtle monitor, Difficult to access the location
Meru Betiri (Jember)	Green Olive Leatherback Hawksbill	↓ ↓ ↓ ↓	317 3 0 0	1 1 1 1	Hatchery and Tagging	*Varanus salvator*, Ants	Yes	Rearing + Releasing, Laboratory	Lack of professional officer
Cipatujah (West Java)	Green turtle	↓	47	1	habitat	Human and Natural predator	Yes	Rearing + Releasing, Guard house	Lack of facility and professional officer
Kepulauan Seribu Nasional Park (North Jakarta)	Hawksbill turtle Green turtle	? ↓	50 (1994) 3	8 Islands: Gosong rengat, Peteloran Timur, Dua Timur, Rengit, Satu, Belanda, Kuburan Cina, Semak Daun	Hatching and Habitat	Humans and *Varanus salvator*, Habitat loss	Yes	Guard house, Rearing + Releasing Hatchery	Lack of transportation and monitoring
Suoha Margasatwa Cikepuh (West Jawa)	Green turtle	?	507	3: Wayjungan, Citirem Cibulakan	Hatching and Habitat	Human *Varanus* Habitat	Yes	Hatchery, Guard house, Habitat loss, Development	Lack of: Enforcement Monitoring Professionals

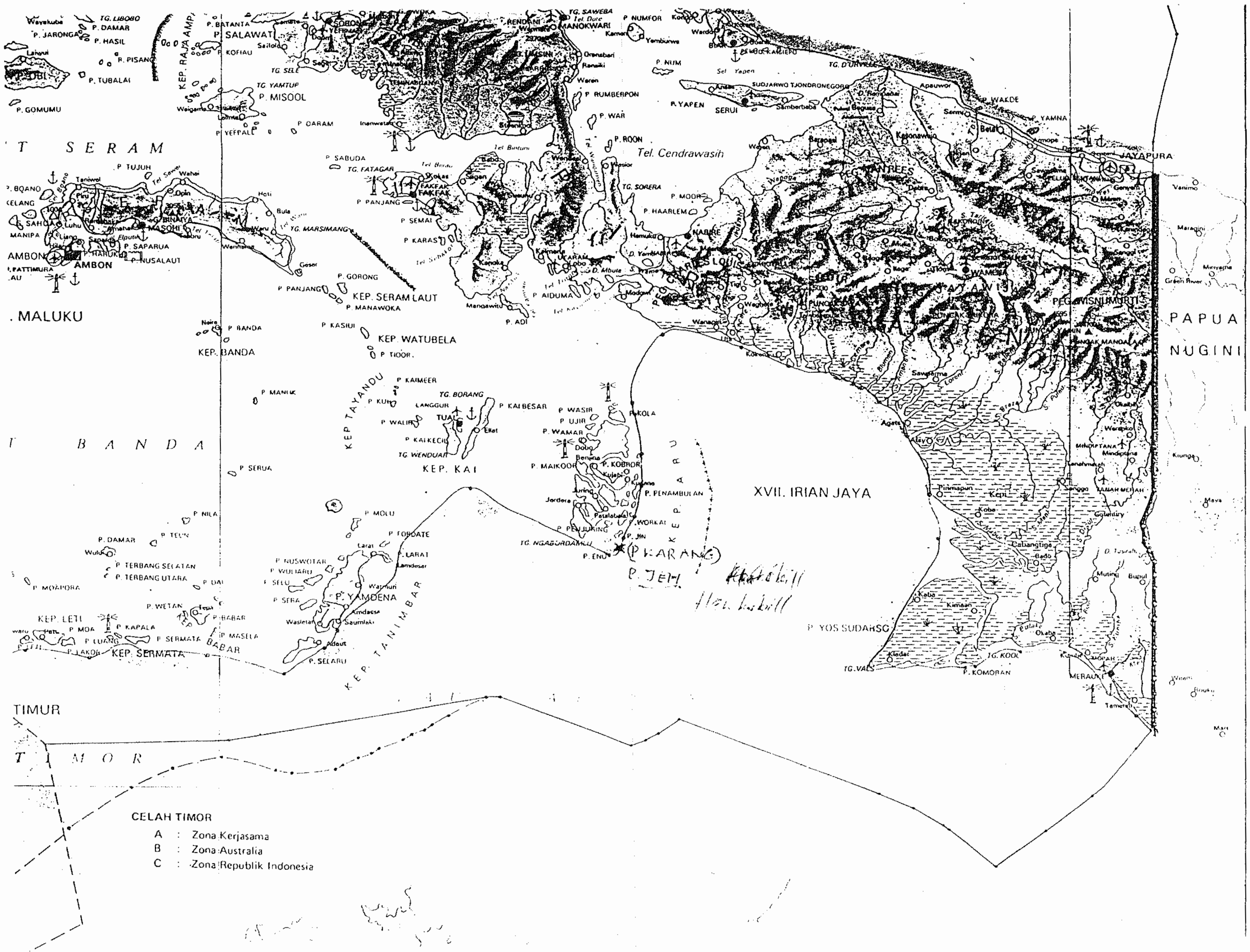
Suka Made, Meru Betiri National Park, East Java

PENYU HIJAU (Chelonia mydas) : 1980-1985



Nesting season peak = December - February


LAUT JAWA
IX. DAERAH KHUSUS IBUKOTA JAKARTA
KEP. SERIBU
KEP. KARIMUNJAWA
P. BAWEAN
XI. JAWA TENGAH
XIII. JAWA TIMUR
XII. DAERAH ISTIMEWA YOGYAKARTA
KEP. KANGEAN
KEP. SABALANA
LAUT BALI
XIV. BALI
P. LOMBOK
SUMBAWA
XV. NUSA TENGGARA BARAT
XVI. NUSA TENGGA
UJUNGPANDANG
P. SELAYAR
NUSAKAMBANGAN
Selat Madura
LAUT FLOR
SAMUDRA HINDIA



SERAM
MALUKU
AMBON
P. MISOOL
P. SALAWATI
MANOKWARI
Tel. Cendrawasih
P. YAPEN
JAYAPURA
KEP. SERAM LAUT
KEP. BANDA
KEP. WATUBELA
BANDA
KEP. KAI
KEP. TAYANDU
KEP. ARU
XVII. IRIAN JAYA
PAPUA
NUGINI
P. KARANG
P. YAMDENA
KEP. TANIMBAR
KEP. LETI
KEP. SERMATA
P. YOS SUDARSO
P. KOMORAN
MERAUKE
TIMUR
TIMOR
CELAH TIMOR
A : Zona Kerjasama
B : Zona Australia
C : Zona Republik Indonesia

Kalimantan

Recommendations

1. Tagging some turtles landed on some major turtle nesting sites.

2. Provide certain facilities for law enforcement.

3. Developed community participation in and around the turtle conservation and non-conservation areas.

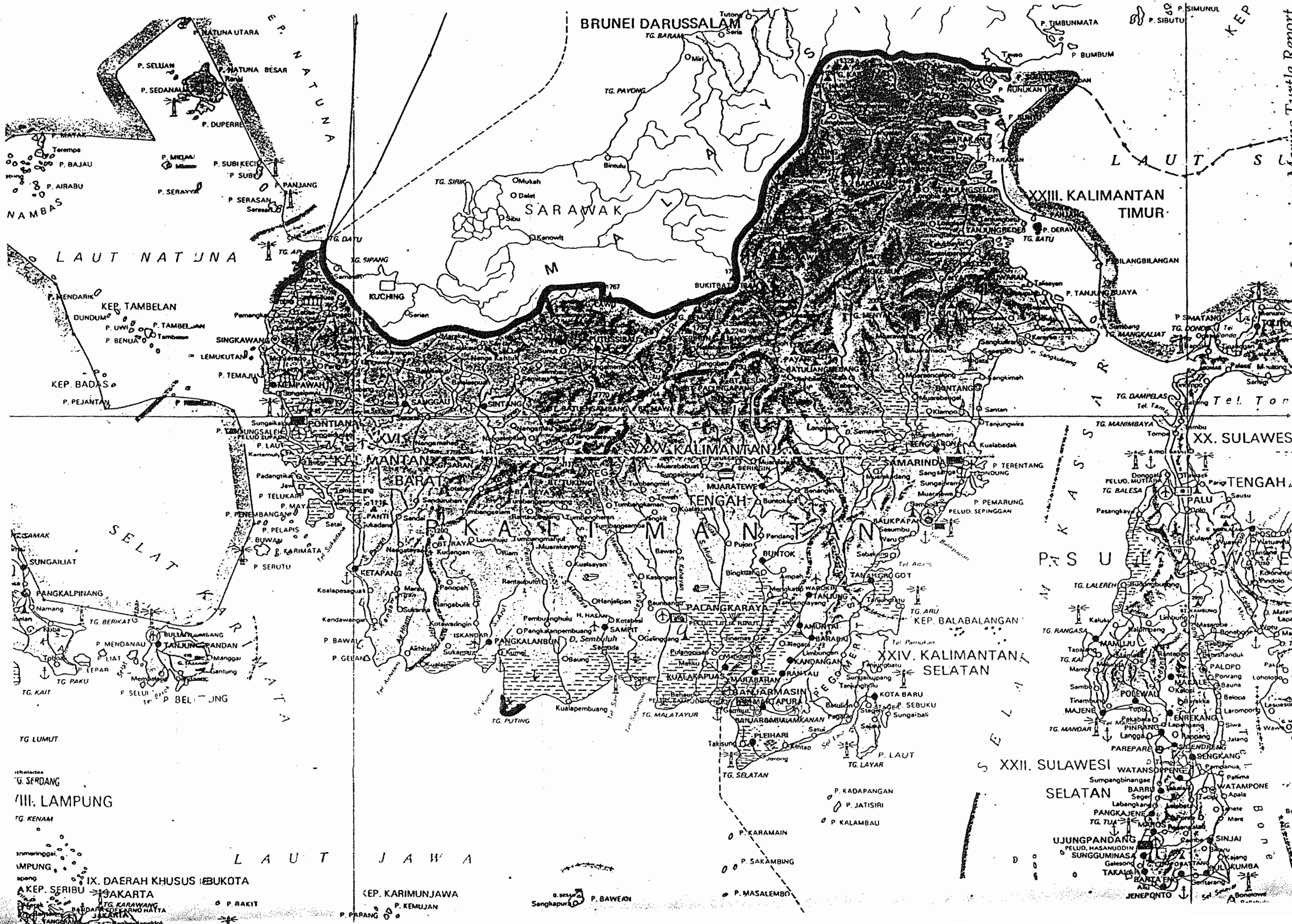
4. Conduct collaborative research activities with institutions which have an advanced capabilities regarding turtle research.

5. Develop awareness and extension activities.

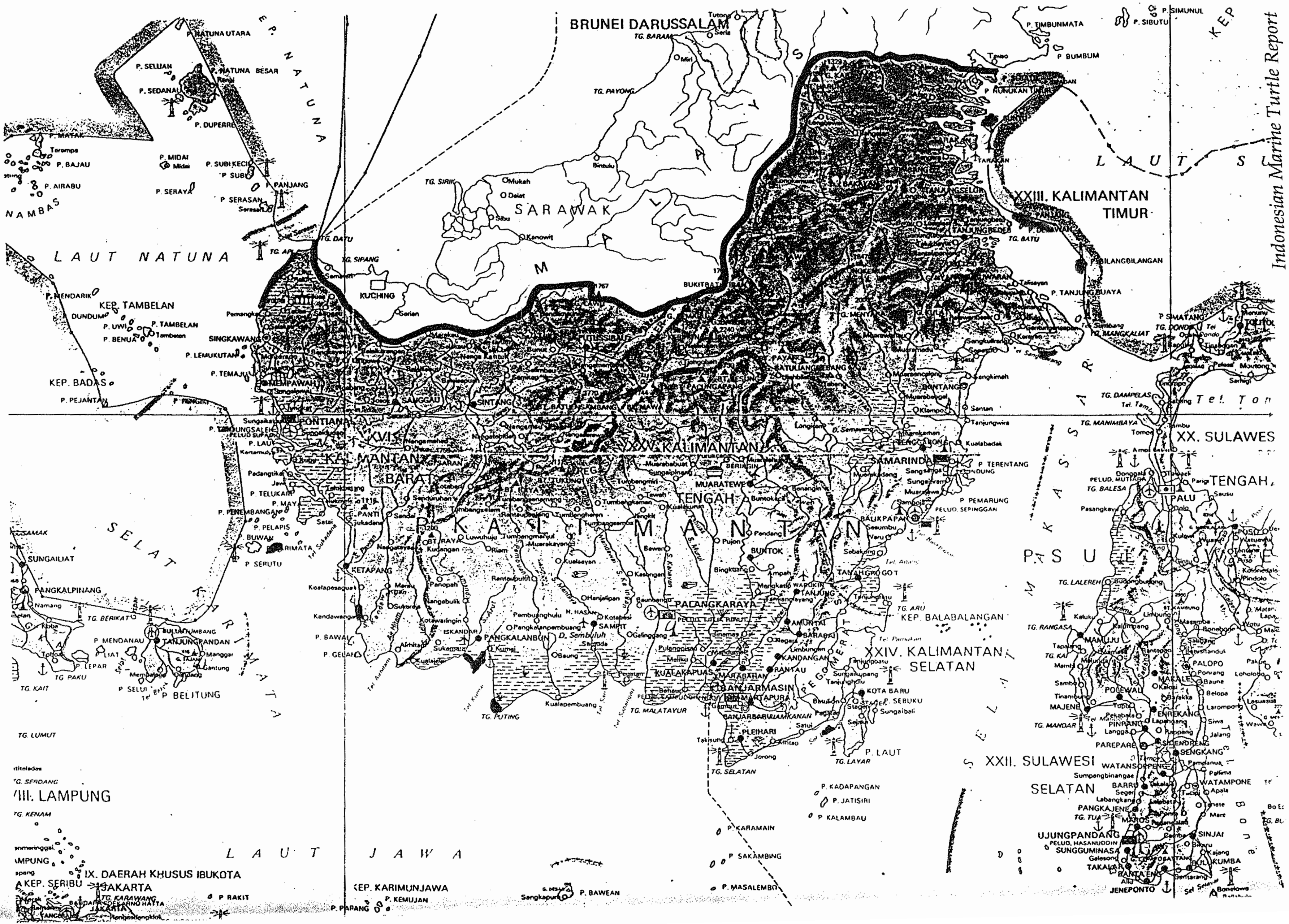
6. Develop protection staff and their skill for turtle conservation activities.

Location	Species	Trends	Breeding Female	Location Number	Field Study	Threats	Laws Enforcement	Management Activities	Constraints
East Kalimantan	Penyu Hijau (Green turtle)	↓	80 - 100 nesting ♀ per night in season. 3-10 nesting ♀ per night in & out season	Sangalaki Recreation Area Semama Nature Reserve	Conservation Area Conservation area	Egg harvests, concession to a local company Poaching	Little law enforcement	Management of areas by 1 person each with few facilities.	Staff in the area has limited knowledge and skills.
	Penyu hijau (Green)	↓	Turtles are found in rookeries No population	Bilang-bilangan; Maratua; Balembangan	Outside protected areas	Poaching of turtles & eggs. Harvesting	Very little	Patrolling not done in area due to status outside conservation area. Head rearing since 1960's by local people and sold to agriculture department	No information on protected species caught in this area.
	Penyu sisik (Hawksbill)	↓	Found in rookeries	Maratua island; and P. Panjang	Outside protected areas	poaching of turtles and eggs collection	Very little	Management: Limited extension and awareness programs conducted in limited number.	Limited material for extension or funds for conducting such activities.
West Kalimantan	Penyu hijau (Green) dan Penyu sisik (Hawksbill)	↓	Nesting turtle have not been counted	Paloh, Karimata, Kendawangan Lemukutan	Proposed as protected area. Protected areas. Area not protected. Area not protected.	Poaching of turtles and eggs. Collection done by local people	None Low law enforcement No law enforcement	Head rearing and turtle releasing done since 85's in Paloh. Facilities such as boat available only in Paloh and Kendawangan Extension activities done only in Kendawangan.	Few facilities for law enforcement. No extension activities or community program. Difficult to reach this area. Limited staff available
Central Kalimantan	Penyu hijau (Green)	↓	Unknown # of breeding females.	Pantai Kubu; Tanjung Keluang Tanjung Puting	Unprotected area Protected area Protected area	Eggs collected and poaching of turtles	No law enforcement Patrolling is not done regularly. No turtle data collection.	Little management of turtle because focus is the orang utan.	Little understanding of turtles so it as a second priority. No facilities for turtle conservation

HAWKSBILL TURTLE



Green Turtle



Maluku Area

Green Turtles, Chelonia mydas

Current status

Wild population has dramatically declined in many major nesting beaches in the Maluku areas, such as in Enu island in Aru Tenggara Marine Reserve, due to unsustainable exploitation to supply the increasing demand of green turtle meat at major markets in Bali and other part of Indonesia. Illegal hunting continues through the capture of the adult females that nest on the beaches. According to Schultz, in 1988 about 4,000 green turtles were taken from the Aru Strict Nature Reserve (esp. Pulau Karang and Enu) and usually between 200-300 eggs (2-4 nests) are collected per group of people (fishermen). Some nests are lost due to natural factors such as beach abrasion. Many conservationists are worried that the habitats, feeding and foraging areas of the green turtles in the areas are now seriously affected by the trawl operation.

Actual Management

1. The most important nesting areas for green turtles, like Aru Tenggara, have been declared and managed as strict nature reserves.

2. Management activities were effective in the period of 1991-1993 when intense conservation programs conducted jointly by PHPA, IUCN, WWF/NL, WWF/IP, local univeristies and other conservation organizations. There was no illegal hunting observed during the time of this project. However, illegal activities started again since 1994 because there has been no interest and commitment of PHPA to follow up the previous activity (including patroling that is so expensive). This may be due to a lack of budget and trained staffs.

3. Law enforcement is still ineffective, since the green turtles are not yet given a nation wide protection by Indonesian law.

4. Tagging programs were done during 1991-1993 when more than 500 female green turtles were tagged in Enu island; however there has been no follow up activity taken to keep track of the tagged turtles.

5. There are no definite boundaries or marks established for the important green turtle nesting beaches (the Aru Reserve and other sites).

6. With collaboration between WWF/IP and PHPA and local NGOs, extension programs were conducted to increase the awareness of local communities who live in areas surrounding the reserve to support and become directly involved in the protection and management of sea turtles in the region. The activities were through conservation cadre programs.

What Management is needed?

1. Long-term improved management activities need to be conducted by PHPA at the major green turtle nesting areas and reserves in the region. This will include the need to provide an appropriate number of trained staff.

2. Totally stop the hunting of green turtles from the Aru Tenggara Strict Nature Reserve and other declared turtle reserves.

3. The local government, with the full support of the national government (PHPA), should act as soon as possible to set zonation for the protection of turtle nesting sites in the Molluccas.

4. The trawl operation must be totally put away from the nesting areas (nature reserve) as the trawl operation clearly has been affecting the quality of feeding areas and disturbing the female coming to nest.

5. Conservation management-oriented research must be conducted to fulfill data needs regarding population status, feeding and nesting condition, migratory routes and the level of threats (trade, habitat degradation etc.).

Hawksbill Turtles, Eretmochelys imbricata

Current status

The population of hawksbill turtle has declined due to over exploitation but no census data are available. Hawksbill turtles are hunted ilegally for their flesh and shells, especially in Aru island.

Their distribution are Kasa isl, Wetar isl, Jeh isl., Karang isl, Enu isl, North Morotai, Kayoa Isl, East and North Seram, North and South Tanimbar, and Lucipara isl. Their population size is unknown.

Actual Management

1. Some important nesting habitats are managed and declared as Strict Nature Reserves.

2. Incidental patrolling is done by Jagawana (PHPA's field ranger).

3. Hawksbill turtle is given a nation wide protection by Indonesian law no. 5 thn 1992

Management needed

1. More funds are needed to achieve the objectives of conservation in the areas.

2. Improve conservation management.

3. Routine patrolling and law enforcement effort should be done to stop illegal hunting, particulary in the Aru area.

4. Encourage local community participation to be involved in the protection effort.

Information needed

1. Evaluation and monitoring of nesting sites.

2. Population status, nesting beach viability, foraging areas and migration route.

3. Turtle captive breeding technique.

General Recommendations

1. Provide an appropriate number of trained staff to manage the important turtle nesting areas (the Reserve in the region).

2. Secure long-term budget allocation to enhance the support of the management and protection of turtles in Reserve areas.

3. Develop alternative income-generating sources as initiative for local communities surrounding nesting areas in Aru.

4. Develop an extension and deucation program to empower the local community for support of turtle management.

5. Construct a turtle conservation database for the region.

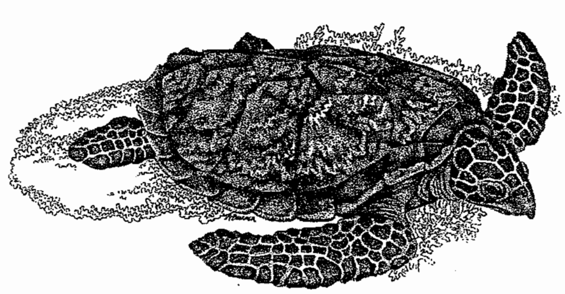
6. Trade monitoring is needed.

MARINE TURTLES OF INDONESIA

POPULATION VIABILITY AND CONSERVATION ASSESSMENT AND MANAGEMENT WORKSHOP

December 11-14, 1995
Cisarua, Indonesia

Section 5: Marine Turtle Population Biology and Preliminary Modeling



POPULATION BIOLOGY AND MODELLING OF GREEN TURTLES IN INDONESIA

Introduction

Currently listed on Appendix I of CITES, the six species of marine turtles currently nesting in Indonesian waters are under severe threat from both the harvesting of eggs from nesting beaches for food and the hunting of subadult and adult animals for meat and other products. As many as 20,000 green turtles are taken in and around Indonesian waters every year to support the Bali market, and millions of eggs have been removed annually from nesting beaches throughout the Indonesian islands. These levels of harvest undoubtedly contribute to the considerable decline in global population numbers.

The need for and effects of intensive management strategies can be modelled to suggest which practices may be the most effective in conserving the green turtle, as well as other marine turtle species, in Indonesia. VORTEX, a simulation modelling package written by Robert Lacy and Kim Hughes, was used as a tool to study the interaction of multiple stochastic variables on marine turtle population dynamics.

The VORTEX package is a Monte Carlo simulation of the effects of deterministic forces as well as demographic, environmental, and genetic stochastic events on wild populations. VORTEX models population dynamics as discrete, sequential events (e.g., births, deaths, sex ratios, catastrophes, etc.) that occur according to defined probability distributions. The probabilities of events are modelled as constants or as random variables that follow specified distributions. The package simulates a population by stepping through the series of events that describe the typical life cycle of sexually reproducing, diploid organisms.

VORTEX is not intended to give absolute answers, since it is projecting stochastically the interactions of the many parameters which enter into the model and because of the random processes involved in nature. Interpretation of the output depends upon our knowledge of the biology of marine turtles, the conditions affecting population dynamics, and possible changes in the future. When data specific to Indonesian marine turtle populations were not available, studies on western Pacific turtle populations were consulted in order to provide a best guess for a particular demographic or environmental parameter. It is important to keep in mind that these estimates for the purposes of population modeling are by nature imprecise and preliminary; by the same token, even initial guesstimates can provide insight into the dynamics of marine turtle populations that can lead to the prioritization of future research directions concerning the demographics and genetics of these elusive creatures.

Input Parameters for Simulations

Mating System: Polygynous. In addition to males mating with more than one female, data suggest that females often mate with multiple males in a given breeding season and store sperm during egg development.

Average Age of First Reproduction: VORTEX precisely defines breeding as the time when young are born, not the age of sexual maturity. The age of first breeding in marine turtles is currently unknown; indirect size data for green turtles suggests that the age of first breeding is at least 35 years and probably higher. For the following models, this parameter was initialized at 35 years. Subsequent models were constructed with the age of first breeding set at 40 years to investigate the sensitivity of the population dynamics to this aspect of turtle life history.

Age of Reproductive Senescence: VORTEX assumes that animals can breed (at the normal rate) throughout their adult life. There is currently no evidence for reproductive senescence in marine turtles; in other words, marine turtles appear to be able to reproduce throughout their adult lives. Because of the difficulties inherent in aging marine turtles, no precise estimate of longevity exists for this species group. We estimated that an adult marine turtle could live as long as 130 years if conditions were favorable. It should be remembered, however, that the number of individuals living to such an old age is unlikely because of annual mortality.

Offspring Production: For the purposes of modelling green turtle population dynamics, we defined "reproduction" for a given female not as the production of eggs, but instead as the production of hatchlings that reach the water and make it through the so-called "swimming frenzy" (up to about three days after hatching on the nesting beach) and begin to drift and feed on plankton. This definition is necessary if we are to successfully model highly fecund, long-lived species like marine turtles using VORTEX.

Available data from Australia indicate that the mean remigration interval in green turtles is approximately five years. This translates into approximately 20% of all adult females reproducing in a given year. To calculate the number of offspring produced per nesting female, the following scheme was developed:

Eggs per clutch: 110
Clutches per nesting season: 5 ± 2
Proportion of nests that produce hatchlings: 0.9
Hatching success of surviving nests: 0.65
Proportion of hatchlings reaching the water: 0.85
Proportion of hatchlings in water that survive the swimming frenzy: 0.5

Therefore, from an initial average number of 550 eggs per female, a total of 137 hatchlings survive to the plankton feeding stage, here defined as age 0. To facilitate the modelling of such high fecundity in VORTEX, which can only deal with a maximum of 100 offspring per female, we modelled each nesting female as producing 100 offspring. These offspring were then spared from annual mortality for the first three years of life. This is equivalent to the production of 137 offspring that are each subject to a given level of annual mortality described later in this section. Further thought is required to more accurately simulate the reproductive output of a green turtle using VORTEX; this will be incorporated in later sets of models investigating green turtle population dynamics.

Environmental variation in reproduction is modelled in VORTEX by entering a standard deviation (SD) for the proportion of adult females failing to reproduce in a given year. Because empirical data for this variable were lacking, we assumed that such variation (due to fluctuations in food abundance and variability in the age at which females reach sexual maturity) was 10-15% of the mean value. VORTEX then determines the percent of females breeding each year of the simulation by sampling from a binomial distribution with the specified mean (20%) and SD (10%). The number of offspring produced per female, however, remains constant.

Male Breeding Pool: Available data for green turtles off the coast of Australia indicate that only about 40% of adult males engage in spermatogenesis preceding the breeding season. Consequently, we designated that 40% of the adult males were available for breeding in all models, a process whose consequences are primarily genetic, not demographic given the nature of the breeding system.

Offspring Sex Ratio: Best guesses for nesting beaches in Indonesia indicate that about 30% of offspring produced are male.

Mortality: Essentially no data exist on annual mortality rates for green turtles from the time they enter the water to when they reach adulthood. Consequently, the modelling process forces an educated guess to be developed with respect to these parameters. General logic dictates that only a small proportion of juveniles survive to adulthood. Given this assumption, we can derive an annual mortality rate that fits this pattern. If the age of first reproduction is set at 35 years, an annual mortality rate of 10% results in about 2.5% survival to adulthod. While even this level of mortality may be conservative (perhaps only 0.1% of juveniles survive to adulthood), the baseline models were constructed using this mortality.

Additionally, very little data exist on adult mortality rates. What data do exist suggest that annual mortality rates are likely to be less than 5%. Moreover, it was suggested that because of the additional burden of nesting and the accompanying risk of increased predation, annual mortality rates of females may slightly exceed that of males. Baseline models were constructed that used 2% annual mortality in males and 3% annual mortality in females.

To investigate the impact of the harvest of subadult and adult turtles in Indonesia, mortality rates for this age class (designated as from 25 years of age to adulthood) were systematically increased in subsequent models. The initial mortality schedule has been termed the "low mortality" scenario, while the final mortality schedule, with all adult and subadult mortality schedules increased by 100%, has been termed the "high mortality" schedule.

Initial Population Size: Because it is an individual-based simulation model, VORTEX is limited in its ability to model large populations, i.e., those numbering in the tens of thousands. Consequently, we chose to model a green turtle population initially numbering 5000 individuals, encompassing all age classes. A population of this size is undoubtedly smaller than most green turtle nesting populations in Indonesia; however, the nature of the dynamics of green turtle populations modelled in VORTEX will be essentially identical irrespective of the initial population size entered into the model. It should be noted, however, that it is in most cases inappropriate to discuss the risk of extinction in simulated populations that are smaller than the actual populations they are intending to model. We will therefore be limited to discussing general growth trends and the impacts of different management strategies on those trends.

In addition, the simulated marine turtle populations discussed in this section were initialized according to a stable age structure (for a complete definition of this concept, refer to Caughley, 1977: Analysis of Vertebrate Populations). If many of these turtle populations are declining like that at Meru Betiri, it is likely that the population's age structure is not stable, perhaps with a strong decline in the younger age classes. Future modeling efforts need to investigate this modification and its potential impact in greater detail.

Carrying Capacity: The carrying capacity (K) defines an upper limit for population size, above which additional mortality is imposed equally across age and sex classes in order to return the population to this value.

The concensus reached among the workshop participants was that green turtle populations nesting in Indonesia are considerably below their ecological carrying capacity. This is substantiated by the historical observations of green turtle populations that were substantially larger than those extant today. We therefore set the carrying capacity at 30,000 individuals. It may be possible for certain simulated populations to reach this size and be prohibited from further growth. While artificial, this event will still allow us to gain insight into green turtle population dynamics and the effects of alternative management options.

Catastrophes: Catastrophes are singular events outside the bounds of normal environmental variation affecting reproduction and/or survival. They can be tornadoes, floods, droughts, fire, disesase, or other similar circumstances. Catastrophes are modelled by assigning an annual probability of occurrence and a severity factor ranging from 0.0 (maximum or absolute effect) to 1.0 (no effect).

The Indo-Pacific is a tectonically active area, subjected to seismic activity that may result in high waves and similar phenomena. A tsunami-like catastrophe was identified that occurs about every five years in Indonesia. While not affecting survival of individuals across all age classes, the event can have considerable impact on the nesting beaches affected by the waves. Virtually all the nests on beaches that are inundated by these waves are drowned. We therefore modelled the impact of these events as a 50% reduction in the reproductive output of the adult female population. In the language of VORTEX, this translates into a 50% reduction in the number of females successfully breeding in a catastrophe year. Because only some of these events occur during the actual nesting season, their impact was reduced from 100% average severity (complete elimination of reproduction) to 50%.

Iterations and Years of Projection: All scenarios were simulated 100 times, with population projections extending for 100 years. The large population sizes and time constraints during the workshop prohibited us from conducting a larger number of iterations for each scenario. Output results were summarized at 10-year intervals for use in some of the figures that follow. All simulations were conducted using the VORTEX 7.0 software package.

Results from Simulation Modelling

Before the results of the VORTEX simulation models for Indonesian nesting populations of green turtles are discussed, it is very important to keep in mind that these models are preliminary and are intended to give us some initial insight into the nature of interactions among key demographic parameters affecting the viability of marine turtle populations. The **absolute** values of, for example, final population size and population growth rate given by the model are not as instructive as are the **relative** differences between these values under different conditions relating to alternative management strategies or basic marine turtle population biology variables. Continued data collection and refinement of the VORTEX models are needed in order to build a more accurate picture of green turtle population dynamics in Indonesia.

Figure 1 gives the results for population growth rate (r) under different conditions of subadult and adult mortality and for alternative ages of first reproduction. Moreover, there is no egg harvest included in this set of models; in other words, each nesting female produces her full complement of 137 offspring each time she nests. Positive population growth rates indicate population growth, whereas negative population growth rates indicate population decline. A population growth rate of 0.0 represents a population that is stable, or neither growing nor declining.

Under conditions of low mortality and age to first reproduction of 35 years, the population shows the capacity for considerable growth ($r = 0.047$). As subadult and adult mortality increases to its maximum level (adult mortality = 20%), the growth rate of the population decreases by more than 50% to $r = 0.016$. In other words, the removal of older turtles through harvests like that on Bali has a dramatic negative effect on the ability of the green turtles populations to grow in size through time. This effect is even more pronounced if the age of first reproduction is increased from 35 years to 40 years of age. Population growth rates are consistently reduced, and the proportional reduction becomes greater as mortality among subadults and adults increases. In fact, under the "high mortality" scenario, increasing the age of first reproduction to 40 years results in a declining population ($r = -0.010$) as compared to a population subject to the same mortality schedule but with the age of first reproduction set at 35 years ($r = 0.016$). These models demonstrate that the age of first reproduction in female green turtles is a very important variable in shaping green turtle population dynamics.

Figures 2 through 4 present results from models that are similar to those presented in Figure 1. However, these models include egg harvests of increasing intensity and the figures attempt to display the consequences of this practice. Under a 25% egg harvest (Figure 2), growth rates are reduced by about 20%-50% for both values of age of first reproduction. Again, these differences become more pronounced as the mortality of adults and subadults increases (harvesting of these animals increases). As in the results presented in Figure 1, the consequences of a relatively slight change in the age of first reproduction in this species can have considerable impact on the viability of populations. As the intensity of egg harvest increases further to 50% and 75% (Figures 3 and 4), a wider range of harvesting of subadults and adults leads to general population decline. For example, a 13.3% annual adult mortality and an age of first reproduction of 40 years leads to a growth rate of $r = -0.002$. In contrast, under a 25% egg harvest, the growth rate of the population is $r = 0.015$. Under higher levels of subadult and adult mortality, high levels of egg harvest lead to strong population decline. These levels of egg harvest and adult mortality are likely to be reasonably accurate estimates of actual removal rates for some (or perhaps many) populations in the wild. As a result, it is imperative that these sources of mortality be curtailed to every extent possible in order to improve the chances of successful recovery of green turtle populations in Indonesia.

On some Indonesian nesting beaches, egg harvests approach 90%. To begin a specific detailed investigation on the consequences of such intense egg harvests, a small set of models was developed with a 90% annual reduction in offspring production under low and high subadult and adult mortality and the alternative ages of first reproduction. The results of these models are shown at the bottom of Table 1 and Figures 5 and 6. The solid line in each of the two figures is a time series of the baseline population size (File #001) without an egg harvest. As the figures show, these populations experience rapid growth and, in our models, are prohibited from further growth by the imposition of the carrying capacity, here set at 30,000 individuals. What is important to observe, however, is the strong growth rate in this population. Under a 90% egg harvest, the populations are dramatically affected and, in all but one case, show negative population growth. An egg harvest of this intensity clearly has a very significant effect. In the most severe case, namely a high subadult/adult mortality coupled with a later age of reproductive maturity, the population shows a growth rate of -0.047.

It is highly unlikely that a real marine turtle population suffering a 90% egg harvest on the nesting beaches would show positive growth over time like we see in selected simulated populations graphed in Figure 5. This suggests that the demographic parameters used as input to these model are overly optimistic with respect to their impact on the growth dynamics of the simulated population. Indeed, when the age of first reproduction is increased from 35 years to 40 years, population growth under low-mortality conditions flips from positive (Figure 5) to negative (Figure 6). This preliminary modeling exercise should make clear the vital need for refinement of demographic parameters used in further population modelling.

Summary and Recommendations

1. Preliminary VORTEX simulation models were developed in an initial attempt to investigate the nature of green turtle population dynamics and to assess the impacts of various human-mediated actions on the continued persistence of populations nesting on the beaches of Indonesia.

2. Modelled populations were sensitive to changes in the age at which both males and females reach reproductive maturity. Because of the sensitivity of the populations to this important parameter, and because of the general lack of detailed information regarding its precise value, it is vital that detailed data collection programs be devised and implemented in order to more precisely determine the age of first reproduction for green turtles. Comprehensive research programs designed to better understand the relationships between size and age in this species

must be coupled with intensive tagging efforts if our knowledge of this aspect of gren turtle population biology is to be advanced.

3. The simulation models clearly show the severe consequences of increased harvesting of both eggs and subadult/adult individuals for Indonesian nesting populations of green turtles. Egg harvests of up to 90% can push a once-healthy population into serious decline and perhaps even into a reasonable risk of local extinction. Furthermore, increased mortality of adults and subadults through the regional trade for turtle meat and other products also greatly destabilizes the populations.

4. Continued work on the use of an individal-based simulation modelling program like VORTEX will be necessary in order to better deal with long-lived, high-fecundity organisms such as marine turtles. Studies are currently underway with CBSG to refine the use of VORTEX with marine turtles and these refinements will be implemented more effectively in future conservation management workshops for these species.

Sample VORTEX Input File

```
GREEN036.OUT     ***Output Filename***
Y     ***Graphing Files?***
N     ***Each Iteration?***
Y      ***Screen display of graphs?***
100     ***Simulations***
100     ***Years***
10     ***Reporting Interval***
1     ***Populations***
N     ***Inbreeding Depression?***
N     ***EV correlation?***
1     ***Types Of Catastrophes***
P     ***Monogamous, Polygynous, or Hermaphroditic***
40     ***Female Breeding Age***
40     ***Male Breeding Age***
130     ***Maximum Age***
0.300000     ***Sex Ratio***
10     ***Maximum Litter Size***
N     ***Density Dependent Breeding?***
80.000000     ***Population 1: Percent Litter Size 0***
0.000000     ***Population 1: Percent Litter Size 1***
0.000000     ***Population 1: Percent Litter Size 2***
0.000000     ***Population 1: Percent Litter Size 3***
0.000000     ***Population 1: Percent Litter Size 4***
0.000000     ***Population 1: Percent Litter Size 5***
0.000000     ***Population 1: Percent Litter Size 6***
0.000000     ***Population 1: Percent Litter Size 7***
0.000000     ***Population 1: Percent Litter Size 8***
0.000000     ***Population 1: Percent Litter Size 9***
20.000000     ***Population 1: Percent Litter Size 10***
10.000000     ***EV--Reproduction***
0.000000     ***Female Mortality At Age 0***
0.000000     ***EV--FemaleMortality***
0.000000     ***Female Mortality At Age 1***
0.000000     ***EV--FemaleMortality***
0.000000     ***Female Mortality At Age 2***
0.000000     ***EV--FemaleMortality***
10.000000     ***Female Mortality At Age 3***
3.000000     ***EV--FemaleMortality***
10.000000     ***Female Mortality At Age 4***
3.000000     ***EV--FemaleMortality***
10.000000     ***Female Mortality At Age 5***
3.000000     ***EV--FemaleMortality***
10.000000     ***Female Mortality At Age 6***
3.000000     ***EV--FemaleMortality***
10.000000     ***Female Mortality At Age 7***
3.000000     ***EV--FemaleMortality***
10.000000     ***Female Mortality At Age 8***
3.000000     ***EV--FemaleMortality***
10.000000     ***Female Mortality At Age 9***
3.000000     ***EV--FemaleMortality***
10.000000     ***Female Mortality At Age 10***
3.000000     ***EV--FemaleMortality***
10.000000     ***Female Mortality At Age 11***
3.000000     ***EV--FemaleMortality***
10.000000     ***Female Mortality At Age 12***
3.000000     ***EV--FemaleMortality***
10.000000     ***Female Mortality At Age 13***
3.000000     ***EV--FemaleMortality***
10.000000     ***Female Mortality At Age 14***
3.000000     ***EV--FemaleMortality***
10.000000     ***Female Mortality At Age 15***
3.000000     ***EV--FemaleMortality***
10.000000     ***Female Mortality At Age 16***
```

Sample VORTEX Input File (Cont'd.)

```
3.000000       ***EV--FemaleMortality***
10.000000       ***Female Mortality At Age 17***
3.000000       ***EV--FemaleMortality***
10.000000       ***Female Mortality At Age 18***
3.000000       ***EV--FemaleMortality***
10.000000       ***Female Mortality At Age 19***
3.000000       ***EV--FemaleMortality***
10.000000       ***Female Mortality At Age 20***
3.000000       ***EV--FemaleMortality***
10.000000       ***Female Mortality At Age 21***
3.000000       ***EV--FemaleMortality***
10.000000       ***Female Mortality At Age 22***
3.000000       ***EV--FemaleMortality***
10.000000       ***Female Mortality At Age 23***
3.000000       ***EV--FemaleMortality***
10.000000       ***Female Mortality At Age 24***
3.000000       ***EV--FemaleMortality***
20.000000       ***Female Mortality At Age 25***
6.000000       ***EV--FemaleMortality***
20.000000       ***Female Mortality At Age 26***
6.000000       ***EV--FemaleMortality***
20.000000       ***Female Mortality At Age 27***
6.000000       ***EV--FemaleMortality***
20.000000       ***Female Mortality At Age 28***
6.000000       ***EV--FemaleMortality***
20.000000       ***Female Mortality At Age 29***
6.000000       ***EV--FemaleMortality***
20.000000       ***Female Mortality At Age 30***
6.000000       ***EV--FemaleMortality***
20.000000       ***Female Mortality At Age 31***
6.000000       ***EV--FemaleMortality***
20.000000       ***Female Mortality At Age 32***
6.000000       ***EV--FemaleMortality***
20.000000       ***Female Mortality At Age 33***
6.000000       ***EV--FemaleMortality***
20.000000       ***Female Mortality At Age 34***
6.000000       ***EV--FemaleMortality***
20.000000       ***Female Mortality At Age 35***
6.000000       ***EV--FemaleMortality***
20.000000       ***Female Mortality At Age 36***
6.000000       ***EV--FemaleMortality***
20.000000       ***Female Mortality At Age 37***
6.000000       ***EV--FemaleMortality***
20.000000       ***Female Mortality At Age 38***
6.000000       ***EV--FemaleMortality***
20.000000       ***Female Mortality At Age 39***
6.000000       ***EV--FemaleMortality***
6.000000       ***Adult Female Mortality***
2.000000       ***EV--AdultFemaleMortality***
0.000000       ***Male Mortality At Age 0***
0.000000       ***EV--MaleMortality***
0.000000       ***Male Mortality At Age 1***
0.000000       ***EV--MaleMortality***
0.000000       ***Male Mortality At Age 2***
0.000000       ***EV--MaleMortality***
10.000000       ***Male Mortality At Age 3***
3.000000       ***EV--MaleMortality***
10.000000       ***Male Mortality At Age 4***
3.000000       ***EV--MaleMortality***
10.000000       ***Male Mortality At Age 5***
3.000000       ***EV--MaleMortality***
10.000000       ***Male Mortality At Age 6***
3.000000       ***EV--MaleMortality***
10.000000       ***Male Mortality At Age 7***
```

Sample VORTEX Input File (Cont'd.)

```
3.000000        ***EV--MaleMortality***
10.000000        ***Male Mortality At Age 8***
3.000000        ***EV--MaleMortality***
10.000000        ***Male Mortality At Age 9***
3.000000        ***EV--MaleMortality***
10.000000        ***Male Mortality At Age 10***
3.000000        ***EV--MaleMortality***
10.000000        ***Male Mortality At Age 11***
3.000000        ***EV--MaleMortality***
10.000000        ***Male Mortality At Age 12***
3.000000        ***EV--MaleMortality***
10.000000        ***Male Mortality At Age 13***
3.000000        ***EV--MaleMortality***
10.000000        ***Male Mortality At Age 14***
3.000000        ***EV--MaleMortality***
10.000000        ***Male Mortality At Age 15***
3.000000        ***EV--MaleMortality***
10.000000        ***Male Mortality At Age 16***
3.000000        ***EV--MaleMortality***
10.000000        ***Male Mortality At Age 17***
3.000000        ***EV--MaleMortality***
10.000000        ***Male Mortality At Age 18***
3.000000        ***EV--MaleMortality***
10.000000        ***Male Mortality At Age 19***
3.000000        ***EV--MaleMortality***
10.000000        ***Male Mortality At Age 20***
3.000000        ***EV--MaleMortality***
10.000000        ***Male Mortality At Age 21***
3.000000        ***EV--MaleMortality***
10.000000        ***Male Mortality At Age 22***
3.000000        ***EV--MaleMortality***
10.000000        ***Male Mortality At Age 23***
3.000000        ***EV--MaleMortality***
10.000000        ***Male Mortality At Age 24***
3.000000        ***EV--MaleMortality***
20.000000        ***Male Mortality At Age 25***
6.000000        ***EV--MaleMortality***
20.000000        ***Male Mortality At Age 26***
6.000000        ***EV--MaleMortality***
20.000000        ***Male Mortality At Age 27***
6.000000        ***EV--MaleMortality***
20.000000        ***Male Mortality At Age 28***
6.000000        ***EV--MaleMortality***
20.000000        ***Male Mortality At Age 29***
6.000000        ***EV--MaleMortality***
20.000000        ***Male Mortality At Age 30***
6.000000        ***EV--MaleMortality***
20.000000        ***Male Mortality At Age 31***
6.000000        ***EV--MaleMortality***
20.000000        ***Male Mortality At Age 32***
6.000000        ***EV--MaleMortality***
20.000000        ***Male Mortality At Age 33***
6.000000        ***EV--MaleMortality***
20.000000        ***Male Mortality At Age 34***
6.000000        ***EV--MaleMortality***
20.000000        ***Male Mortality At Age 35***
6.000000        ***EV--MaleMortality***
20.000000        ***Male Mortality At Age 36***
6.000000        ***EV--MaleMortality***
20.000000        ***Male Mortality At Age 37***
6.000000        ***EV--MaleMortality***
20.000000        ***Male Mortality At Age 38***
6.000000        ***EV--MaleMortality***
20.000000        ***Male Mortality At Age 39***
```

Sample VORTEX Input File (Cont'd.)

```
6.000000      ***EV--MaleMortality***
4.000000      ***Adult Male Mortality***
2.000000      ***EV--AdultMaleMortality***
20.000000     ***Probability Of Catastrophe 1***
0.500000      ***Severity--Reproduction***
1.000000      ***Severity--Survival***
N       ***All Males Breeders?***
Y       ***Answer--A--Known?***
40.000000     ***Percent Males In Breeding Pool***
Y       ***Start At Stable Age Distribution?***
5000    ***Initial Population Size***
30000   ***K***
0.000000      ***EV--K***
N       ***Trend In K?***
N       ***Harvest?***
N       ***Supplement?***
N       ***AnotherSimulation?***
```

Sample VORTEX Output File

```
VORTEX -- simulation of genetic and demographic stochasticity

GREEN036.OUT
Thu Dec 14 08:13:54 1995


  1 population(s) simulated for 100 years, 100 iterations

  No inbreeding depression

  First age of reproduction for females: 40   for males: 40
  Age of senescence (death): 130
  Sex ratio at birth (proportion males): 0.30000


Population 1:

  Polygynous mating;
 40.00 percent of adult males in the breeding pool.

  Reproduction is assumed to be density independent.

    80.00 (EV = 10.00 SD) percent of adult females produce litters of size 0
     0.00 percent of adult females produce litters of size 1
     0.00 percent of adult females produce litters of size 2
     0.00 percent of adult females produce litters of size 3
     0.00 percent of adult females produce litters of size 4
     0.00 percent of adult females produce litters of size 5
     0.00 percent of adult females produce litters of size 6
     0.00 percent of adult females produce litters of size 7
     0.00 percent of adult females produce litters of size 8
     0.00 percent of adult females produce litters of size 9
    20.00 percent of adult females produce litters of size 10

    0.00 (EV = 0.00 SD) percent mortality of females between ages 0 and 1
    0.00 (EV = 0.00 SD) percent mortality of females between ages 1 and 2
    0.00 (EV = 0.00 SD) percent mortality of females between ages 2 and 3
   10.00 (EV = 3.00 SD) percent mortality of females between ages 3 and 4
   10.00 (EV = 3.00 SD) percent mortality of females between ages 4 and 5
   10.00 (EV = 3.00 SD) percent mortality of females between ages 5 and 6
   10.00 (EV = 3.00 SD) percent mortality of females between ages 6 and 7
   10.00 (EV = 3.00 SD) percent mortality of females between ages 7 and 8
   10.00 (EV = 3.00 SD) percent mortality of females between ages 8 and 9
   10.00 (EV = 3.00 SD) percent mortality of females between ages 9 and 10
   10.00 (EV = 3.00 SD) percent mortality of females between ages 10 and 11
   10.00 (EV = 3.00 SD) percent mortality of females between ages 11 and 12
   10.00 (EV = 3.00 SD) percent mortality of females between ages 12 and 13
   10.00 (EV = 3.00 SD) percent mortality of females between ages 13 and 14
   10.00 (EV = 3.00 SD) percent mortality of females between ages 14 and 15
   10.00 (EV = 3.00 SD) percent mortality of females between ages 15 and 16
   10.00 (EV = 3.00 SD) percent mortality of females between ages 16 and 17
   10.00 (EV = 3.00 SD) percent mortality of females between ages 17 and 18
   10.00 (EV = 3.00 SD) percent mortality of females between ages 18 and 19
   10.00 (EV = 3.00 SD) percent mortality of females between ages 19 and 20
   10.00 (EV = 3.00 SD) percent mortality of females between ages 20 and 21
   10.00 (EV = 3.00 SD) percent mortality of females between ages 21 and 22
   10.00 (EV = 3.00 SD) percent mortality of females between ages 22 and 23
   10.00 (EV = 3.00 SD) percent mortality of females between ages 23 and 24
   10.00 (EV = 3.00 SD) percent mortality of females between ages 24 and 25
   20.00 (EV = 6.00 SD) percent mortality of females between ages 25 and 26
   20.00 (EV = 6.00 SD) percent mortality of females between ages 26 and 27
   20.00 (EV = 6.00 SD) percent mortality of females between ages 27 and 28
   20.00 (EV = 6.00 SD) percent mortality of females between ages 28 and 29
```

Sample VORTEX Output File (Cont'd.)

```
20.00 (EV = 6.00 SD) percent mortality of females between ages 29 and 30
20.00 (EV = 6.00 SD) percent mortality of females between ages 30 and 31
20.00 (EV = 6.00 SD) percent mortality of females between ages 31 and 32
20.00 (EV = 6.00 SD) percent mortality of females between ages 32 and 33
20.00 (EV = 6.00 SD) percent mortality of females between ages 33 and 34
20.00 (EV = 6.00 SD) percent mortality of females between ages 34 and 35
20.00 (EV = 6.00 SD) percent mortality of females between ages 35 and 36
20.00 (EV = 6.00 SD) percent mortality of females between ages 36 and 37
20.00 (EV = 6.00 SD) percent mortality of females between ages 37 and 38
20.00 (EV = 6.00 SD) percent mortality of females between ages 38 and 39
20.00 (EV = 6.00 SD) percent mortality of females between ages 39 and 40
 6.00 (EV = 2.00 SD) percent annual mortality of adult females (40<=age<=130)
 0.00 (EV = 0.00 SD) percent mortality of males between ages 0 and 1
 0.00 (EV = 0.00 SD) percent mortality of males between ages 1 and 2
 0.00 (EV = 0.00 SD) percent mortality of males between ages 2 and 3
10.00 (EV = 3.00 SD) percent mortality of males between ages 3 and 4
10.00 (EV = 3.00 SD) percent mortality of males between ages 4 and 5
10.00 (EV = 3.00 SD) percent mortality of males between ages 5 and 6
10.00 (EV = 3.00 SD) percent mortality of males between ages 6 and 7
10.00 (EV = 3.00 SD) percent mortality of males between ages 7 and 8
10.00 (EV = 3.00 SD) percent mortality of males between ages 8 and 9
10.00 (EV = 3.00 SD) percent mortality of males between ages 9 and 10
10.00 (EV = 3.00 SD) percent mortality of males between ages 10 and 11
10.00 (EV = 3.00 SD) percent mortality of males between ages 11 and 12
10.00 (EV = 3.00 SD) percent mortality of males between ages 12 and 13
10.00 (EV = 3.00 SD) percent mortality of males between ages 13 and 14
10.00 (EV = 3.00 SD) percent mortality of males between ages 14 and 15
10.00 (EV = 3.00 SD) percent mortality of males between ages 15 and 16
10.00 (EV = 3.00 SD) percent mortality of males between ages 16 and 17
10.00 (EV = 3.00 SD) percent mortality of males between ages 17 and 18
10.00 (EV = 3.00 SD) percent mortality of males between ages 18 and 19
10.00 (EV = 3.00 SD) percent mortality of males between ages 19 and 20
10.00 (EV = 3.00 SD) percent mortality of males between ages 20 and 21
10.00 (EV = 3.00 SD) percent mortality of males between ages 21 and 22
10.00 (EV = 3.00 SD) percent mortality of males between ages 22 and 23
10.00 (EV = 3.00 SD) percent mortality of males between ages 23 and 24
10.00 (EV = 3.00 SD) percent mortality of males between ages 24 and 25
20.00 (EV = 6.00 SD) percent mortality of males between ages 25 and 26
20.00 (EV = 6.00 SD) percent mortality of males between ages 26 and 27
20.00 (EV = 6.00 SD) percent mortality of males between ages 27 and 28
20.00 (EV = 6.00 SD) percent mortality of males between ages 28 and 29
20.00 (EV = 6.00 SD) percent mortality of males between ages 29 and 30
20.00 (EV = 6.00 SD) percent mortality of males between ages 30 and 31
20.00 (EV = 6.00 SD) percent mortality of males between ages 31 and 32
20.00 (EV = 6.00 SD) percent mortality of males between ages 32 and 33
20.00 (EV = 6.00 SD) percent mortality of males between ages 33 and 34
20.00 (EV = 6.00 SD) percent mortality of males between ages 34 and 35
20.00 (EV = 6.00 SD) percent mortality of males between ages 35 and 36
20.00 (EV = 6.00 SD) percent mortality of males between ages 36 and 37
20.00 (EV = 6.00 SD) percent mortality of males between ages 37 and 38
20.00 (EV = 6.00 SD) percent mortality of males between ages 38 and 39
20.00 (EV = 6.00 SD) percent mortality of males between ages 39 and 40
 4.00 (EV = 2.00 SD) percent annual mortality of adult males (40<=age<=130)
 EVs may have been adjusted to closest values
     possible for binomial distribution.
 EV in mortality will be correlated among age-sex classes
    but independent from EV in reproduction.

Frequency of type 1 catastrophes: 20.000 percent
  with 0.500 multiplicative effect on reproduction
   and 1.000 multiplicative effect on survival
```

Sample VORTEX Output File (Cont'd.)

```
    Initial size of Population 1:
      (set to reflect stable age distribution)
   Age 1     2     3     4     5     6     7     8     9    10    11    12    13    14
15     16    17    18    19    20    21    22    23    24    25    26    27    28    29
    30    31    32    33    34    35    36    37    38    39    40    41    42    43
44     45    46    47    48    49    50    51    52    53    54    55    56    57    58
    59    60    61    62    63    64    65    66    67    68    69    70    71    72
73     74    75    76    77    78    79    80    81    82    83    84    85    86    87
    88    89    90    91    92    93    94    95    96    97    98    99   100   101
102    103    104    105    106    107    108    109    110    111    112    113
114    115    116    117    118    119    120    121    122    123    124    125
126    127    128    129    130    Total
     84    87    91    85    80    75    71    66    62    59    55    51    48    46
42     40    38    35    33    31    29    27    26    24    23    18    16    13    11
     9     8     6     6     4     4     3     2     3     1     2     1     2     1
2      1     2     1     2     1     2     1     2     1     2     1     2     1     2
  2      1     2     1     2     1     2     1     2     1     2     2     1     2
1      2     1     2     1     2     2     1     2     1     2     1     2     2     1
  2      1     2     2     1     2     1     2     2     1     2     1     2     2
1      2     1     2     2     1     2     2     1     2     1     2     2     1     2
  2      1     2     2     1     2     2     1     2     1     2     2     1     2
1556 Males
    195   203   213   199   187   175   165   155   145   136   128   120   112   106
99     94    87    82    77    73    67    64    60    56    53    44    37    30    26
  21     18    15    12    10     9     7     6     5     4     4     3     4     3
3      3     3     3     3     3     3     3     3     2     3     3     2     3     2
  3      2     2     2     3     2     2     2     2     2     2     2     2     2
2      1     2     2     1     2     2     1     2     1     2     1     2     1     1
  2      1     1     2     1     1     1     2     1     1     1     1     1     1
1      1     1     1     1     1     1     1     1     0     1     1     1     1     0
  1      1     1     0     1     1     0     1     1     0     1     1     0     1
3444  Females

  Carrying capacity = 30000 (EV = 0.00 SD)

Deterministic population growth rate (based on females, with assumptions of
  no limitation of mates, no density dependence, and no inbreeding depression):

      r =  -0.042      lambda = 0.959      R0 =      0.073
    Generation time for:   females = 62.38     males = 72.64

Stable age distribution:  Age class     females      males
                               0        0.036       0.015
                               1        0.037       0.016
                               2        0.039       0.017
                               3        0.040       0.017
                               4        0.038       0.016
                               5        0.035       0.015
                               6        0.033       0.014
                               7        0.031       0.013
                               8        0.029       0.013
                               9        0.028       0.012
                              10        0.026       0.011
                              11        0.024       0.010
                              12        0.023       0.010
                              13        0.021       0.009
                              14        0.020       0.009
                              15        0.019       0.008
                              16        0.018       0.008
                              17        0.017       0.007
                              18        0.016       0.007
                              19        0.015       0.006
                              20        0.014       0.006
                              21        0.013       0.006
```

Sample VORTEX Output File (Cont'd.)

22	0.012	0.005
23	0.011	0.005
24	0.011	0.005
25	0.010	0.004
26	0.008	0.004
27	0.007	0.003
28	0.006	0.002
29	0.005	0.002
30	0.004	0.002
31	0.003	0.001
32	0.003	0.001
33	0.002	0.001
34	0.002	0.001
35	0.002	0.001
36	0.001	0.001
37	0.001	0.000
38	0.001	0.000
39	0.001	0.000
40	0.001	0.000
41	0.001	0.000
42	0.001	0.000
43	0.001	0.000
44	0.001	0.000
45	0.001	0.000
46	0.001	0.000
47	0.001	0.000
48	0.001	0.000
49	0.001	0.000
50	0.001	0.000
51	0.001	0.000
52	0.001	0.000
53	0.001	0.000
54	0.001	0.000
55	0.000	0.000
56	0.000	0.000
57	0.000	0.000
58	0.000	0.000
59	0.000	0.000
60	0.000	0.000
61	0.000	0.000
62	0.000	0.000
63	0.000	0.000
64	0.000	0.000
65	0.000	0.000
66	0.000	0.000
67	0.000	0.000
68	0.000	0.000
69	0.000	0.000
70	0.000	0.000
71	0.000	0.000
72	0.000	0.000
73	0.000	0.000
74	0.000	0.000
75	0.000	0.000
76	0.000	0.000
77	0.000	0.000

Ratio of adult (>= 40) males to adult (>= 40) females: 0.969

Sample VORTEX Output File (Cont'd.)

```
Population 1

Year 10
       N[Extinct] =        0, P[E] = 0.000
       N[Surviving] =    100, P[S] = 1.000
       Population size =         3278.18 (  41.89 SE,  418.92 SD)
       Expected heterozygosity =   0.999 (  0.000 SE,   0.000 SD)
       Observed heterozygosity =   1.000 (  0.000 SE,   0.000 SD)
       Number of extant alleles = 3409.49 (  35.50 SE,  355.01 SD)

Year 20
       N[Extinct] =        0, P[E] = 0.000
       N[Surviving] =    100, P[S] = 1.000
       Population size =         2159.35 (  37.35 SE,  373.49 SD)
       Expected heterozygosity =   0.998 (  0.000 SE,   0.000 SD)
       Observed heterozygosity =   1.000 (  0.000 SE,   0.000 SD)
       Number of extant alleles = 1193.81 (  14.75 SE,  147.51 SD)

Year 30
       N[Extinct] =        0, P[E] = 0.000
       N[Surviving] =    100, P[S] = 1.000
       Population size =         1423.18 (  30.05 SE,  300.47 SD)
       Expected heterozygosity =   0.996 (  0.000 SE,   0.001 SD)
       Observed heterozygosity =   1.000 (  0.000 SE,   0.000 SD)
       Number of extant alleles =  519.36 (   7.04 SE,   70.42 SD)

Year 40
       N[Extinct] =        0, P[E] = 0.000
       N[Surviving] =    100, P[S] = 1.000
       Population size =          933.48 (  25.31 SE,  253.08 SD)
       Expected heterozygosity =   0.994 (  0.000 SE,   0.001 SD)
       Observed heterozygosity =   1.000 (  0.000 SE,   0.000 SD)
       Number of extant alleles =  316.39 (   5.17 SE,   51.66 SD)

Year 50
       N[Extinct] =        0, P[E] = 0.000
       N[Surviving] =    100, P[S] = 1.000
       Population size =          607.70 (  20.38 SE,  203.81 SD)
       Expected heterozygosity =   0.990 (  0.000 SE,   0.003 SD)
       Observed heterozygosity =   1.000 (  0.000 SE,   0.000 SD)
       Number of extant alleles =  204.73 (   4.10 SE,   41.04 SD)

Year 60
       N[Extinct] =        0, P[E] = 0.000
       N[Surviving] =    100, P[S] = 1.000
       Population size =          394.12 (  15.46 SE,  154.63 SD)
       Expected heterozygosity =   0.984 (  0.001 SE,   0.006 SD)
       Observed heterozygosity =   1.000 (  0.000 SE,   0.001 SD)
       Number of extant alleles =  132.80 (   3.16 SE,   31.60 SD)

Year 70
       N[Extinct] =        0, P[E] = 0.000
       N[Surviving] =    100, P[S] = 1.000
       Population size =          260.70 (  11.41 SE,  114.13 SD)
       Expected heterozygosity =   0.973 (  0.001 SE,   0.010 SD)
       Observed heterozygosity =   0.999 (  0.000 SE,   0.003 SD)
       Number of extant alleles =   83.81 (   2.38 SE,   23.77 SD)
```

Sample VORTEX Output File (Cont'd.)

```
Year 80
      N[Extinct] =        0, P[E] = 0.000
      N[Surviving] =    100, P[S] = 1.000
      Population size =           176.03 (   8.79 SE,    87.87 SD)
      Expected heterozygosity =    0.958 (  0.002 SE,    0.017 SD)
      Observed heterozygosity =    0.999 (  0.000 SE,    0.005 SD)
      Number of extant alleles =   53.64 (   1.78 SE,    17.78 SD)

Year 90
      N[Extinct] =        0, P[E] = 0.000
      N[Surviving] =    100, P[S] = 1.000
      Population size =           107.82 (   6.58 SE,    65.80 SD)
      Expected heterozygosity =    0.936 (  0.003 SE,    0.028 SD)
      Observed heterozygosity =    0.998 (  0.001 SE,    0.007 SD)
      Number of extant alleles =   35.33 (   1.35 SE,    13.51 SD)

Year 100
      N[Extinct] =        4, P[E] = 0.040
      N[Surviving] =     96, P[S] = 0.960
      Population size =            71.10 (   4.96 SE,    48.56 SD)
      Expected heterozygosity =    0.902 (  0.005 SE,    0.046 SD)
      Observed heterozygosity =    0.998 (  0.001 SE,    0.007 SD)
      Number of extant alleles =   23.27 (   1.03 SE,    10.04 SD)

In 100 simulations of Population 1 for 100 years:
   4 went extinct and 96 survived.

This gives a probability of extinction of 0.0400 (0.0196 SE),
   or a probability of success of         0.9600 (0.0196 SE).

4 simulations went extinct at least once.
Of those going extinct,
    mean time to first extinction was 97.75 years (0.63 SE, 1.26 SD).

Mean final population for successful cases was 71.10 (4.96 SE, 48.56 SD)

   Age 1        2        3        4        5        6        7        8        9       10
11       12       13       14       15       16       17       18       19       20       21
22       23       24       25       26       27       28       29       30       31       32
33       34       35       36       37       38       39    Adults    Total
     0.98     1.04     1.27     1.17     0.97     1.19     0.83     0.91     1.11     0.75
0.82     0.61     0.83     0.67     0.60     0.46     0.54     0.56     0.51     0.36     0.56
0.44     0.57     0.54     0.39     0.35     0.27     0.27     0.15     0.16     0.21     0.07
0.10     0.08     0.08     0.06     0.05     0.03     0.03     1.89     22.51  Males
     2.67     2.29     2.79     2.55     2.33     2.86     2.30     2.29     2.22     1.58
2.05     1.52     1.46     1.42     1.46     1.32     1.18     1.19     1.17     0.82     1.16
1.10     1.21     1.02     0.75     0.76     0.53     0.52     0.31     0.39     0.25     0.27
0.16     0.18     0.16     0.11     0.09     0.04     0.06     2.04     48.59  Females

Without harvest/supplementation, prior to carrying capacity truncation,
  mean growth rate (r) was -0.0467 (0.0007 SE, 0.0690 SD)

Final expected heterozygosity was      0.9021 ( 0.0047 SE,  0.0462 SD)
Final observed heterozygosity was      0.9978 ( 0.0008 SE,  0.0074 SD)
Final number of alleles was             23.27 (   1.03 SE,   10.04 SD)
*************************************************************************
```

Table 1. Growth rates for green turtle populations modelled using VORTEX. Descriptions of the input parameters and the interpretations of the results are discussed further in the text.

	Mortality (%)			
File Number	Subadult	Adult (M,F)	First Breeding	Growth Rate (r)
001	10	2,3	35	0.049
002	13.3	2.7,4	35	0.038
003	16.7	3.4,5	35	0.027
004	20	4,6	35	0.015
005	10	2,3	40	0.034
006	13.3	2.7,4	40	0.021
007	16.7	3.4,5	40	0.007
008	20	4,6	40	-0.006
25% Annual Egg Harvest				
009	10	2,3	35	0.042
010	13.3	2.7,4	35	0.032
011	16.7	3.4,5	35	0.021
012	20	4,6	35	0.010
013	10	2,3	40	0.029
014	13.3	2.7,4	40	0.015
015	16.7	3.4,5	40	0.002
016	20	4,6	40	-0.013

Table 1 (Continued).

	Mortality (%)			
File Number	Subadult	Adult (M,F)	First Breeding	Growth Rate (r)
50% Annual Egg Harvest				
017	10	2,3	35	0.034
018	13.3	2.7,4	35	0.024
019	16.7	3.4,5	35	0.013
020	20	4,6	35	0.001
021	10	2,3	40	0.022
022	13.3	2.7,4	40	0.009
023	16.7	3.4,5	40	-0.005
024	20	4,6	40	-0.019
75% Annual Egg Harvest				
025	10	2,3	35	0.021
026	13.3	2.7,4	35	0.010
027	16.7	3.4,5	35	-0.002
028	20	4,6	35	-0.016
029	10	2,3	40	0.010
030	13.3	2.7,4	40	-0.002
031	16.7	3.4,5	40	-0.016
032	20	4,6	40	-0.031
90% Annual Egg Harvest				
033	10	2,3	35	0.005
034	10	2,3	40	-0.004
035	20	4,6	35	-0.028
036	20	4,6	40	-0.047

Figure Legends

Figure 1. Stochastic population growth rate (r_s) as a function of subadult and adult mortality and age of first reproduction in green turtles nesting in Indonesia modelled using VORTEX. The stochastic population growth rate is a measure of the average annual proportional growth of the population; positive values indicate population growth while negative values indicate population decline. The mortality rates are shown in the form *X*/*Y*,*Z* where *X* is the annual mortality rate of subadults (age 25-adult), *Y* is the annual mortality rate of adult males, and *Z* is the annual mortality rate of adult females. Open bars show results for models in which the age of first reproduction was set at 35 years, while filled bars show results for the age of first reproduction set at 40 years.

Figure 2. Stochastic population growth rate (r_s) as a function of subadult and adult mortality and age of first reproduction in green turtles nesting in Indonesia modelled using VORTEX. Results shown here are for models incorporating a 25% reduction in the number of offspring produced per female, thereby simulating a 25% harvest of eggs on nesting beaches. See legend for Figure 1 for additional details.

Figure 3. Stochastic population growth rate (r_s) as a function of subadult and adult mortality and age of first reproduction in green turtles nesting in Indonesia modelled using VORTEX. Results shown here are for models incorporating a 50% reduction in the number of offspring produced per female, thereby simulating a 50% harvest of eggs on nesting beaches. See legend for Figure 1 for additional details.

Figure 4. Stochastic population growth rate (r_s) as a function of subadult and adult mortality and age of first reproduction in green turtles nesting in Indonesia modelled using VORTEX. Results shown here are for models incorporating a 75% reduction in the number of offspring produced per female, thereby simulating a 75% harvest of eggs on nesting beaches. See legend for Figure 1 for additional details.

Figure 5. Time series plot of population size for green turtles nesting in Indonesia modelled using VORTEX. Egg harvest is set at 90%, thereby reducing the number of offspring produced per female by the same amount. The age of first reproduction in each scenario is 35 years. The "low mortality" scenario has an annual subadult mortality of 10% and an adult male/female annual mortality of 2%/3%. The annual mortalities in the "high mortality" scenario are doubled to 20%/4%,6%. In the scenario with no egg harvest (solid line), the carrying capacity of 30,000 individuals artificially limits population growth beyond this size.

Figure 6. Time series plot of population size for green turtles nesting in Indonesia modelled using VORTEX. The plot is very similar to that shown in Figure 5, with the only exception being the change in the age of first reproduction from 35 years to 40 years.

Figure 1.
Green Turtles in Indonesia: Subadult / Adult Mortality and Age of First Reproduction

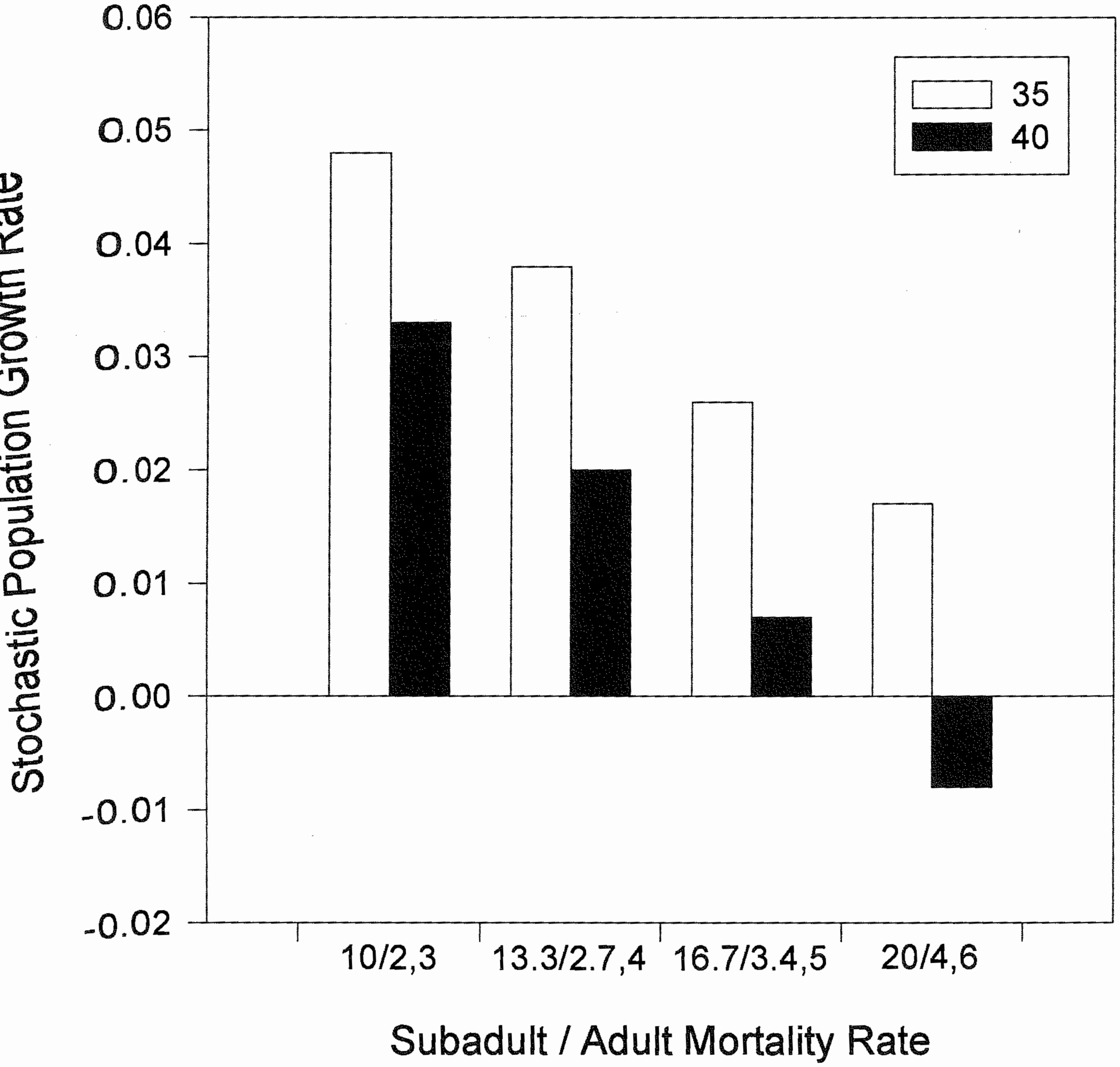


Figure 2.
Green Turtles in Indonesia:
Subadult / Adult Mortality and
Age of First Reproduction

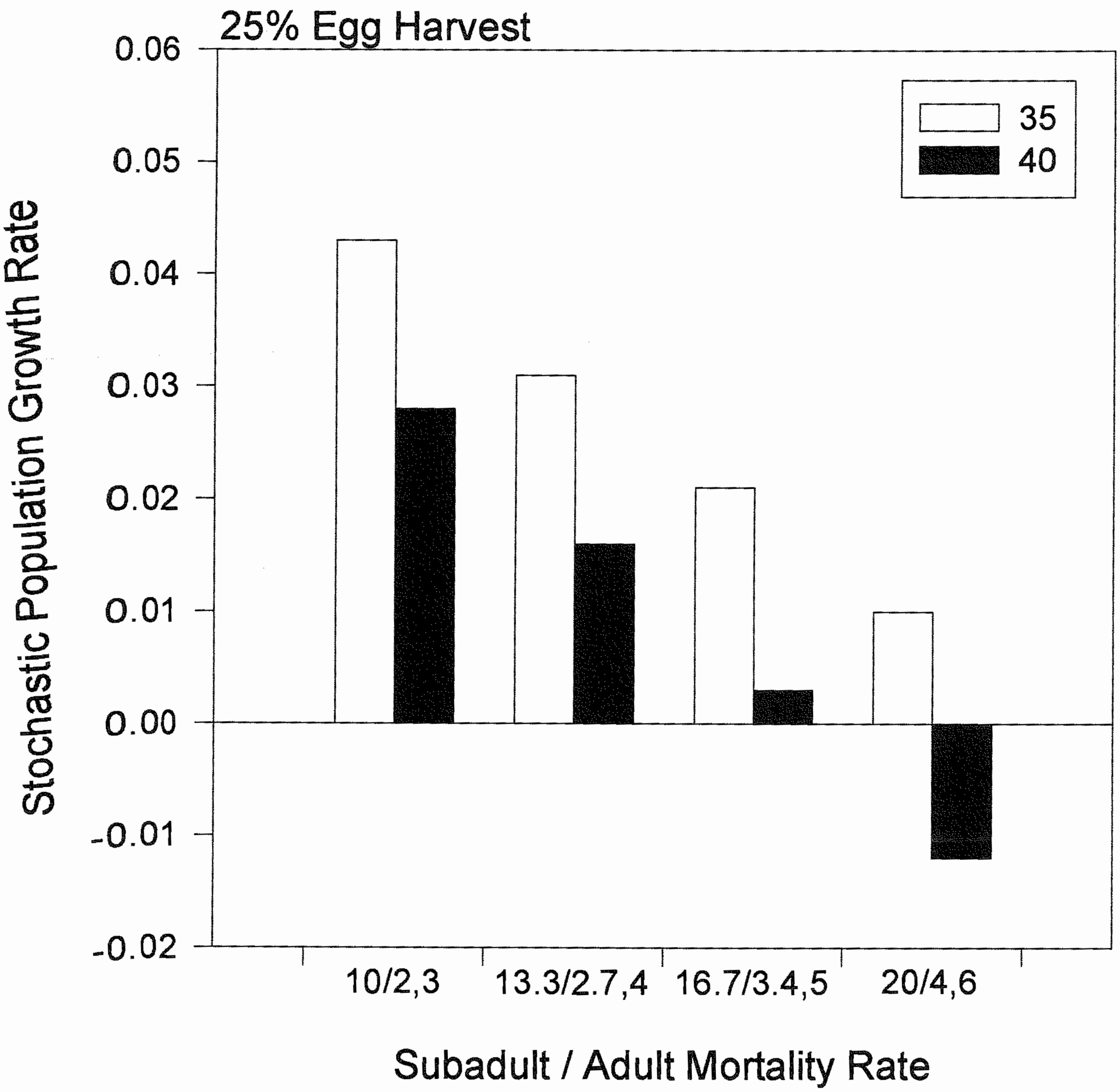


Figure 3.
Green Turtles in Indonesia: Subadult / Adult Mortality and Age of First Reproduction

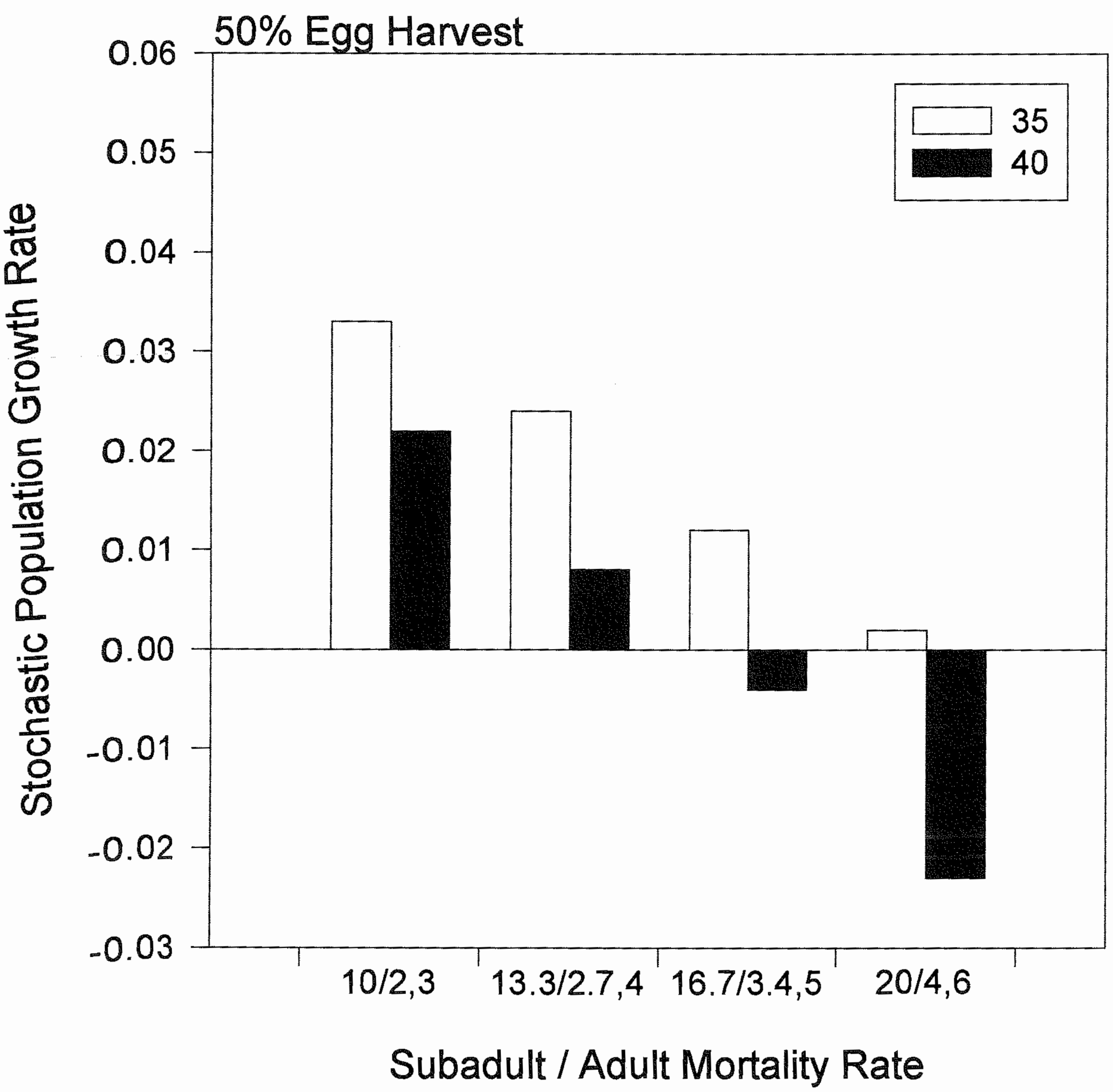


Figure 4.
Green Turtles in Indonesia:
Subadult / Adult Mortality and
Age of First Reproduction

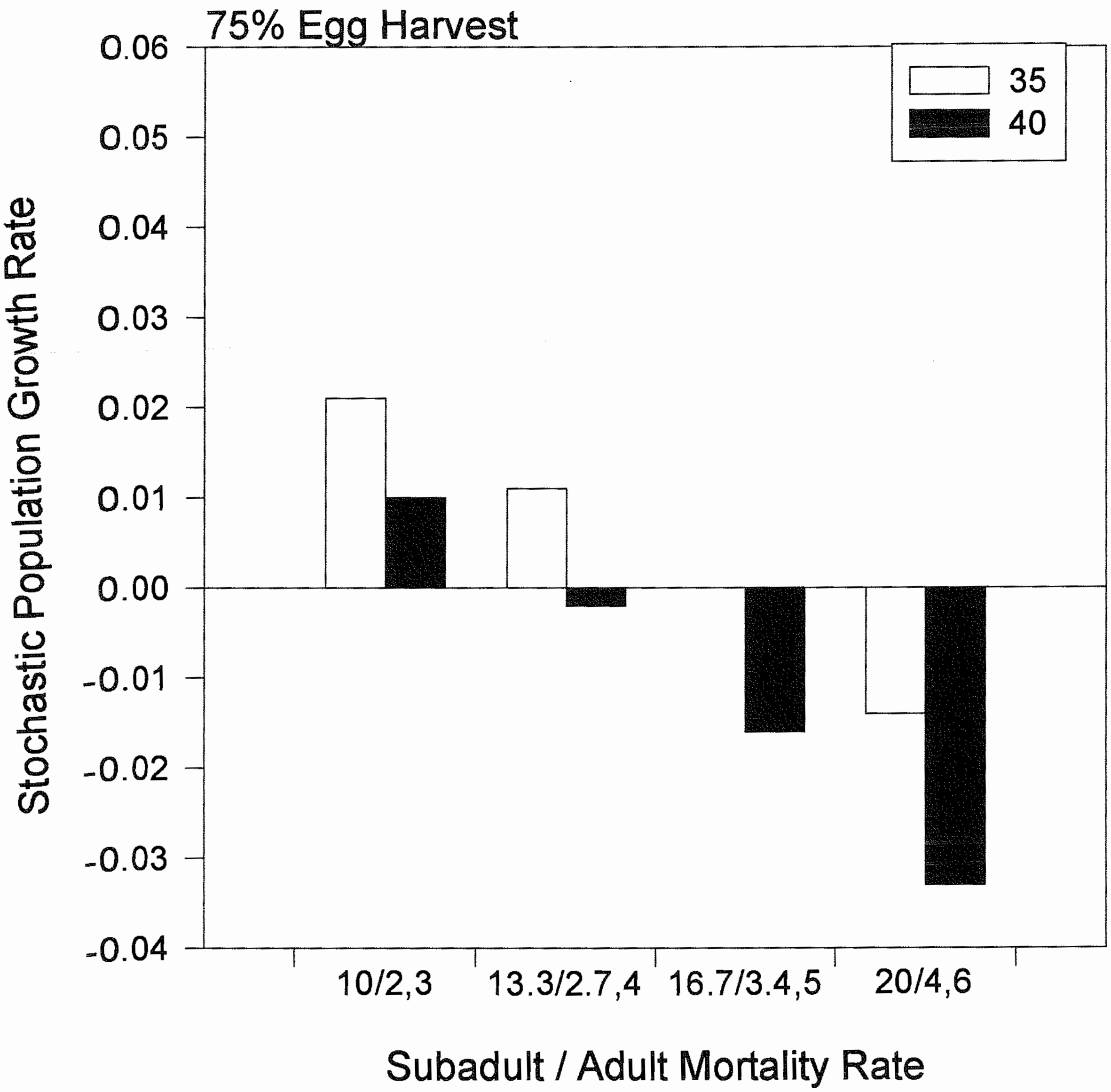


Figure 5.
Green Turtles in Indonesia:
90% Egg Harvest and Mortality

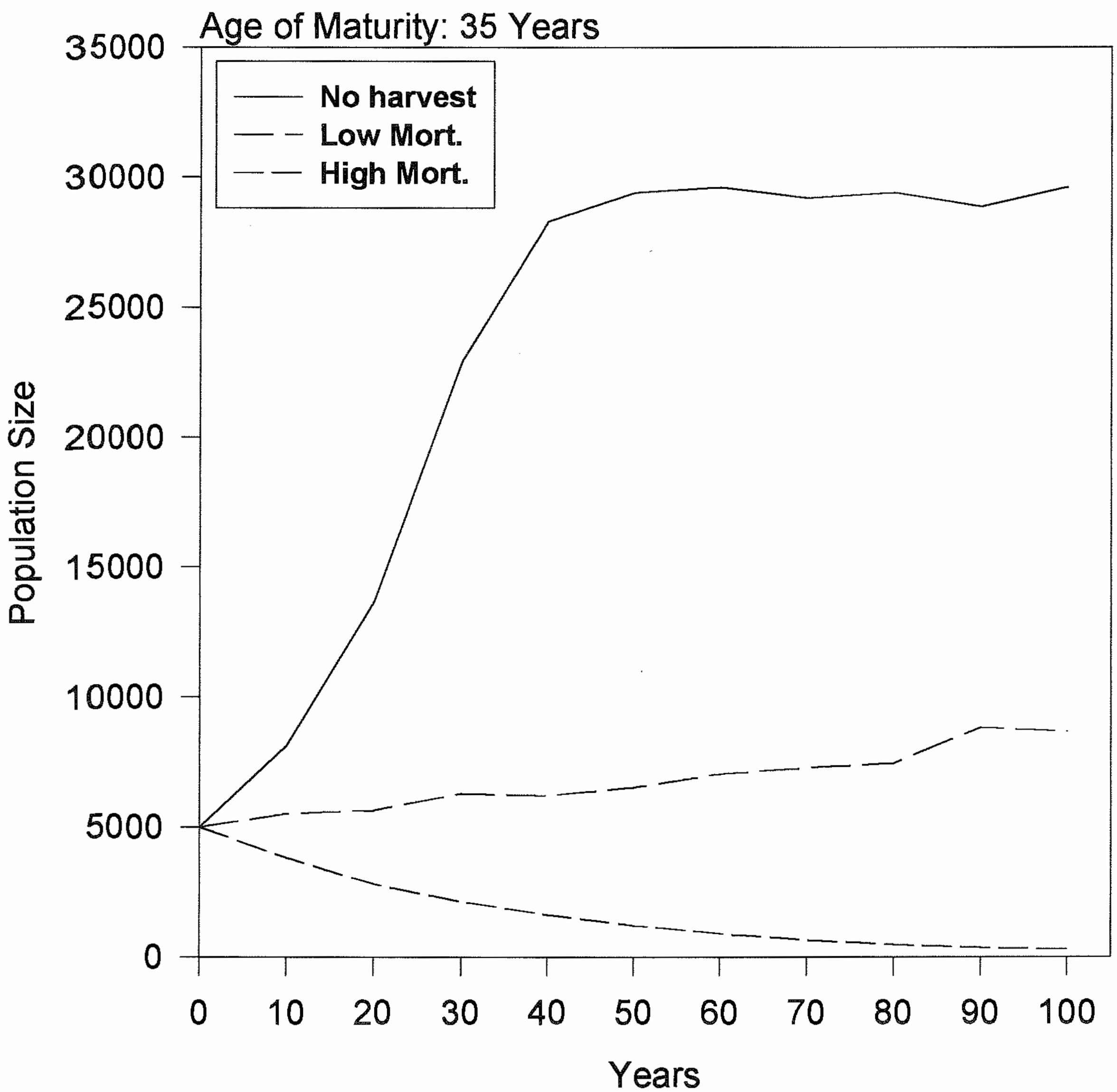
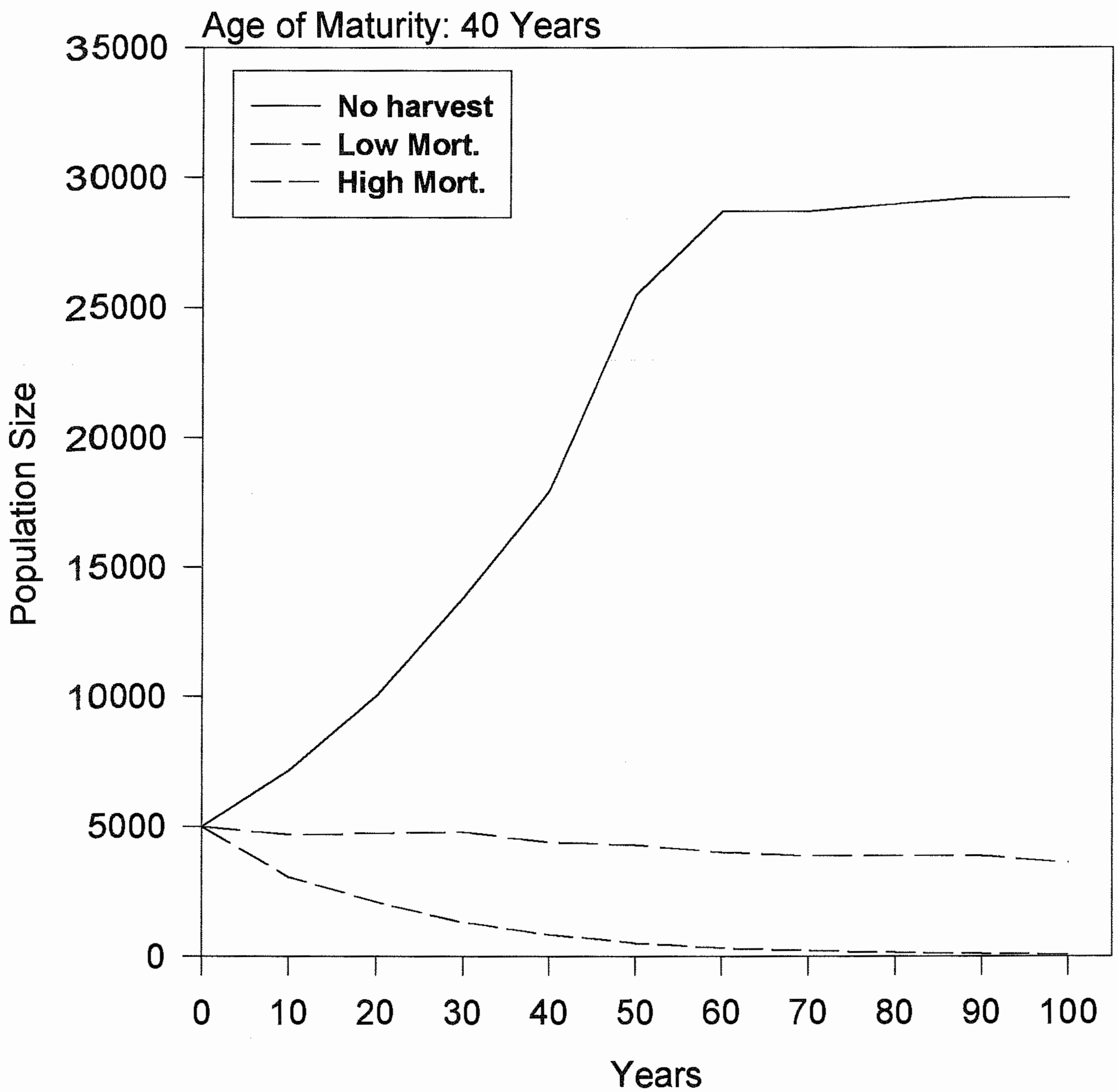


Figure 6.
Green Turtles in Indonesia:
90% Egg Harvest and Mortality

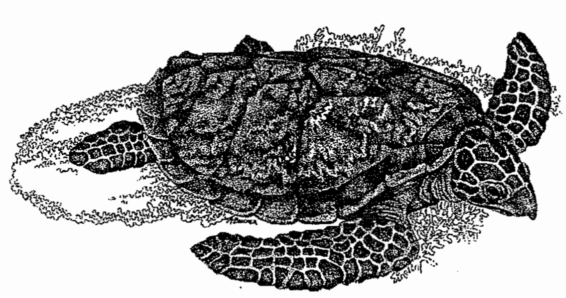


MARINE TURTLES OF INDONESIA

POPULATION VIABILITY AND CONSERVATION ASSESSMENT AND MANAGEMENT WORKSHOP

December 11-14, 1995
Cisarua, Indonesia

Section 6:
Research Needs and Protocols



INDONESIAN MARINE TURTLE RESEARCH NEEDS AND PROTOCOLS

Introduction

The materials presented in this section were developed by workshop participants in an attempt to stimulate an international collaborative effort aimed at collecting data to assist in the identification of management units molecular genetics techniques. In addition, drawing upon the considerable experience of Australian colleagues concerning marine turtle hatchery management, hatchery information summary sheets were constructed so Indonesian managers can better monitor their hatchery stocks. These reports are also included for review in this section.

Conservation Breeding Specialist Group

Species Survival Commission
IUCN -- The World Conservation Union
U.S. Seal, CBSG Chairman

Ir. Soemarsono, Director General
Perlindungan Hutan dan Pelestarian, Depart. Kehutanaian
Gd. Manggala Wanabaki, Blok. I Lt. *, Jl.
Gatot Subroto
Jakarta 10270, INDONESIA Fax: 62-21-573-4818

Dear sir,

The Indonesia government conservation agency, PHPA, is invited to collaborate in the current INDO-PACIFIC MARINE TURTLE POPULATION GENETICS RESEARCH PROJECT.

The aims of this study are:
1. To identify genetically discrette populations (= management units) of marine turtles in South East Asia.

2. To identify any stock with breeding sites spanning international borders.

3. To define genetic markers unique to different management units and apply these to analyse the stock composition of turtles in harvest or feeding grounds.

If it is your wish for your staff to participate in this study, please notify Dr. Colin Limpus, Queensland Department of Environment and Hertitage, Brisbane, Australia (FAX: 61 7 32276386) of the contact name and address.

This study is being coordinated by Dr. Craig Moritz, Director, Centre for Conservation Biology, University of Queensland and Dr. Colin Limpus, Manager Maritime Research and Monitoring, Queensland Department of Environment and Heritage. The study is a collaborative study that has had active participation of scientists and conservation managers from eight countries in designing the experiment for their respective country's turtle stocks and participation in collection of turtle tissue samples for genetics analysis. Most of the genetics analysis is conducted at the University of Queensland. Some samples are forewarded to other laboratories as required.

Until the end of 1996, the cost of genetic analysis of turtle tissue samples from the Southeast Asian region can be covered by grant monies from the Australian Government.

C Limpus
13 Dec 1995

12101 Johnny Cake Ridge Road, Apple Valley, MN 55124-8151, USA
tel: 1-612-431-9325 fax: 1-612-432-2757 e-mail: cbsg@epx.cis.umn.edu

MARINE TURTLE POPULATION GENETIC RESEARCH IN INDONESIA

SIGNIFICANT ROOKERIES TO BE SAMPLED

To complete the regional assessment/identification of marine turtle management units (genetic stocks) that occur in the southeastern Asian region, turtles from the following sites from Indonesia should be included in the genetic assessment:

Penyu hijau

1. Berau Islands:
   Palau Semama & P. Sangalaki & P. Birabitahan (any one of these islands)

2. Natuna Islands:
   P. Tambelan

3. Aru Islands:
   P. Ebu

4. South Kalimantan
   Sambergelap

5. East Java
   Meru Betiri

Penyu sisik

1. **Belitung area**

2. **Natuna Islands:**
   P. Tambelan

Penyu belimbing

1. Northwest Irian Jaya
   Jamursba-Medi beaches

PREPARATION OF TISSUE SAMPLES FOR GENETICS RESEARCH

Should you wish to collaborate in this regional study (the Indo-Pacific marine turtle population genetics study based out of the University of Queensland in collaboration with the Queensland Turtle Research Project) then the following instructions apply for collection of the tissue samples:

SAMPLE SIZE: 20 - **30** individuals per site

(If 30 samples are not available, then what ever can be collected can be used but confidence limits are large with small samples.)

TISSUE TYPE: Several types of tissue are suitable for analysis.

1. nesting adults femeles: skin from neck or shoulder

   Do not sample the same female twice. Sample females at the nesting beach. It is best to identify the females by a turtle tag number.

2. hatchling or advanced embryo: liver or heart muscle

   CAUTION:

   Because all hatchlings in the same clutch have identical mtDNA, which is also identical to that of their mother, **ONLY ONE HATCHLING/EMBRYO SHOULD BE SAMPLED FROM ANY ONE CLUTCH.**

To avoid collecting hatchlings from successive clutches by the same nesting female, either:

SAMPLE ONLY ONE CLUTCH FROM EACH OF 30 DIFFERENT NESTING FEMALES (if turtles are identified by tags),

or

SAMPLE FROM UP TO THIRTY DIFFERENT CLUTCHES LAID WITH IN A 12 DAY INTERVAL AT THE ONE ROOKERY (e.g. from clutches in a hatchery)

TISSUE PRESERVATION:

I am supplying you with numbered tubes containing 20% dimethyl sulfoxide (DSMO) in saturated sodium chloride solution. These tubes are individually identified with numbers prefixed with a "J".

1. **WITH ADULTS:**

   Pinch up skin at the base of the neck/shoulder of turtle and with a sharp blade cut off a piece of skin less than 1.0cm in diameter and approximately 1-2mm thick.

   . place skin sample in vial of DMSO and tightly seal the tube.

   . record on the data sheet::

   vial number, species, age class of turtle, date ,tissue type, rookery.

2. WITH HATCHLINGS:

   Remove ~0.5ml of heart/liver tissue from the hatchling/embryo.

   . finely chop the liver/heart tissue.

   . place in vial of DMSO and tightly seal the tube.

   . record on a data sheet:

   vial number, species, rookery, date laid, date sampled, tissue type

This preserved tissue can be safely stored at room temperature for months. Avoid overheating in the sun.

CITES PERMITS AND POSTAGE:

1. When you have the specimens contact :
   Dr. Colin Limpus,
   Queensland Department of Environment and Heritage,
   P.O. Box 155,
   Brisbane (Albert Street), 4002,
   AUSTRALIA.. Phone : 61 7 32277718; Fax: 61 7 32276386.

2. Dr. Limpus will send you a CITES import permit for our receiving the specimens into Australia.

3. Obtain a CITES export permit from your country.

4. Send specimens + Indonesian CITES export permit + Australian CITES permit
   by AIRMAIL to:

   Dr. Colin Limpus (see above address.)

[SPECIMEN TUBES TAKEN TO INDONESIA 10-14 DECEMBER 1995

J3765 - 3974 : 210 TUBES (DMSO/salt)]

Dr. Col Limpus
Manager, Research and Monitoring (Maritime)
Queensland Department of Environment and Heritage

INDO-PACIFIC MARINE TURTLE POPULATION GENETICS RESEARCH PROJECT

RECORD OF COLLECTED SPECIMENS

Return completed data sheets with the specimens samples.

Specimen number	Species H=hijau S=sisik L=lekang B=belimbing	Ageclass A=nesting adult H=hatchling	Tissue type S=skin L=liver	Date	Tag number of turtle	Location
SAMPLE						
J						
J						
J						
J						
J						
J						
J						
J						
J						
J						
J						
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NESTING TURTLES & THEIR EGGS J.D. Miller

Sea turtles typically nest in large numbers on a few selected beaches and in low numbers on many wide spread beaches. No one can say why a sea turtle or a species of turtle selects a specific beach; however, the beaches used by sea turtles can be characterised in four generalised aspects.

1. The beach must have a suitable temperature range to facilitate development; temperatures in the range of 23 C and 33 C are within the limits for embryonic development.
2. The beach must be relatively stable during the nesting season and through time; turtles do not typically nest on unstable shifting beaches which do not provide an adequate environment for embryonic development.
3. The near shore and off shore currents must assist in the dispersal of hatchlings to their oceanic, pelagic habitat.
4. Off shore habitat must be suitable for the adult females during the internesting period.

Among the biological characteristics of sea turtles that are particularly important to understanding and management of reproductive success of sea turtles, their eggs and nesting sites, there are several fundamental attributes: (1) sea turtles return the a nesting beach that they have used in previous years, (2) each turtle will nest several times within a nesting season, (3) individual sea turtles do not nest every year, (4) an individual sea turtle may have a renesting interval of 3, 4, 5 or more years, (5) the sex of the hatchlings is determined by the temperature during incubation, (6) hatchlings quickly disperse into oceanic currents.

Each species of sea turtle lays eggs of specific size (Table 1). Normal eggs of all sea turtle species are round and contain proportional amounts of yolk (≈48%), albumen (≈48%), and shell (≈4%), regardless of the egg diameter or weight.

Some clutches contain eggs of different sizes and ones that are not round. These eggs may be grouped into two general groups: Yolkless Eggs and Malformed Eggs. The small yolkless eggs are usually 1/3 small in diameter than normal eggs in the clutch; when candled immediately after being laid, yolkless eggs appear white rather than yellowish like normal eggs. A yolkless egg cannot produce hatchling because a yolkless does not contain an embryo. Malformed eggs exhibit several shapes. Usually, two or more eggs joined together into strings or chains such that they are encased in a single, continuous shell; these chain-form eggs seldom produce hatchlings. Occasionally a turtle lays a very large egg by comparison to normal; these extra large eggs usually contain two yolks inside a single, round shell; although these eggs contain embryos, no hatchlings are produced.

Table 1. Reproductive characteristics of marine turtles: sizes of eggs and hatchlings. Values are means of means of populations, (standard deviation), number of populations included.

Species	Clutch Count (# of eggs)	Egg Weight (g)	Egg Diameter (mm)	Hatchling Weight (g)
D. coriacea	81.5 (3.6) 12	75.9 (4.2) 4	53.4 (0.5) 9	44.4 (4.16) 5
Ch. mydas	112.8 (3.7) 24	46.1 (1.6) 10	44.9 (0.7) 17	24.6 (0.91) 11
Ca. caretta	112.4 (2.2) 19	32.7 (2.8) 7	40.9 (0.4) 14	19.9 (0.68) 7
L. olivacea	109.9 (1.8) 11	35.7 (----) 1	39.3 (0.4) 6	17 (------) 1
E. imbricata	130.0 (6.8) 17	26.6 (0.9) 5	37.8 (0.5) 1	14.8 (0.61) 5
N. depressus	52.8 (0.9) 6	51.4 (0.4) 3	51.5 (0.3) 6	39.3 (2.42) 3

The nest environment is subject to a variety of external factors (rainfall, erosion, sand grain size, etc.) which have an impact on the developing embryo through their impact on the temperature, moisture and/or atmosphere in the nest at the level of the eggs. Temperature has three major impacts. If the temperature is outside the embryonic tolerance limits (≈ 23-33°C) for very long, the embryo will die. Within the embryonic tolerance limits, temperature also lengthens (cooler temperatures) or shortens (warmer temperatures) the duration of incubation. Further, the temperature during the middle third of the incubation period determines the sex of the hatchlings; above about 29.5°C hatchlings will be female; below 28.5°C hatchlings will be male. Between these values the sex ratio within the clutch is difficult to estimate.

The moisture contained in the sand during incubation influences the weight of the hatchlings. If eggs are in very dry sand they will loose weight and may not hatch; if eggs are in sand that is 3-12% moisture by weight the embryos will develop normally. If the sand is saturated with water, even for relatively short periods, the water replaces the atmosphere around the eggs and they die. The atmosphere within the sand of a beach is usually adequate to support normal development; however, flooding of the nesting area by storms reduces the amount of air that reaches the eggs. If the oxygen demand of the eggs is not fulfilled, the eggs die.

The goal of the turtle's nesting effort is to produce healthy hatchlings that form the basis of the next generation; one of the goals of conservation management is to assist in the process. Occasionally, as the result of threats in the local situation the management decision is made to remove eggs from their natural nests to an area of greater safety.

When ever the decision is made to move a clutch of eggs, records must be kept of the number of clutches and eggs moved (plus: date, time started, time finished, type of transport, place collected, place reburied). The size and shape of artificial nest should be a replica of the natural nest. In a hatchery nests should be spaced so that each nest is at least 1m from any other nest. Eggs must be collected and reburied within 2 hours of being laid; if reburial takes longer than 4 hours the movement of the eggs will increase the mortality of the embryos. Whenever eggs are moved, they should be treated as if they are extremely delicate; they should not be turned up-side-down, dropped or twisted quickly during the process of excavating the nest, transportation, and reburial.

HATCHERY INFORMATION SHEET

Species:

HATCHERY RECORDS

Location:

Year/months/season:

When was the hatchery started:

Do you have records for each nest? (Y/N)

Do you have annual records for the total hatchery? (Y?N)

- Total # of clutches moved to the hatchery each year?
- Total # of eggs incubated per year?
- Total # of hatchlings released per year?

From where are eggs obtained?

Describe how are eggs moved.

HATCHERY ENVIRONMENT

Are temperature data available:

- By nest?
- By day/week for the incubation season?
- Are sand moisture data available?
- Are rainfall and air temperature data available?

Are hatchlings released on beach or in surf?

Are records kept of the size and shape of unhatched embryos?

Have you observed disease problems (Y/N):

- fungus:
- insects in nest:
- other:

NEEDS & PROBLEMS

Identifiable needs:

Operational:

Staff:

Identifiable problems:

Poachers:
Predators:
Flooding:
Other:

Other comments:

Your Name and Address:

Thank you for taking the time to complete this questionnaire.
Please mail or fax completed forms to:

Mr. Jansen Manansang
Taman Safari Park Indonesia
J1. Raya Puncak No. 601
Cibeurem Cisarua
Bogor, Java Barat
Indonesia
FAX 62-251-253-555

or

IUCN/SSC Conservation Breeding Specialist Group
12101 Johnny Cake Ridge Road
Apple Valley, MN 55124 USA
FAX 1-612-432-2757

Hatchery Information Summary Sheet

Hatchery Name & Location: Species:	Female Tag #	Female Tag #	Female Tag #	Female Tag #	Female Tag #	Female Tag #	Female Tag #	Female Tag #	Female Tag #
Date clutch laid									
# of eggs in clutch									
Original nest location Below high water? (BHW) Beach slope? (BS) Nesting area? (NA)									
How far moved?									
Elapsed time from laying to reburying?									
Depth eggs re-buried									
Original nest temperature									
Re-buried nest temperature									
Depth temperature measured									
Moisture (%)									
Nest shaded during part of day?									
Date hatched									
# hatchlings									
# dead hatchlings in nest									
# unhatched eggs									
Identified causes of non-hatching									
Interval between emergence of hatchlings and release									

DAFTAR HARJAN #1

BULAN ____________________

PENYI YANG BERTELUR + SARANG² YANG DIPINDAH

TAHUN ____________________

PANTAI PELLELURAN ____________________

PENANGGUNG JAWAB ____________________

tanggal	jenis penyu	dibiarkan di tempat	ke atas di pantai	ke tempat penetasan	butir telur	tanda ('tag') # + kode	panjang karapas (cm)	________ karapas (cm)	seksie (pos/blok) pantai	keterangan (sarang² yang dirusakkan oleh predator, dll.)

DAFTAR HARIAN # 2

PENETASAN TELUR

BULAN / TAHUN ______________________

PANTAI PERTEJURAN ______________________

PENANGGUNG JAWAB ______________________

tanggal penetasan	tanggal ditanam	jenis penyu	alamiah (= sarang yang dibiarkan)				semi-alamiah (= dipindah ke atas)				sarang^2 di tempat penetasan				keterangan (predator, dll.)
			# sarang	jumlah tukik	tebur yang tidak menetas # sarang	%	# sarang	jumlah telur	jumlah tulak	%	# sarang	butir telur	jumlah tukik	%	

DAFTAR BULANAN

JENIS PENYU ______________________

BULAN / TAHUN ______________________

PANTAI PERTELURAN ______________________

PENANGUNG JAWAB ______________________

SEKSI / POS / BLOK ______________________

tanggal	jumlah ekor yang bertelur	sarang^2			penetasan telur				jumlahbutir telor yang dipindah	jumlah tukik dilepaskan ke laut	sarang^2 dirusakkan oleh		keterangan
		alamiah	dipindah		semi-alamia		tempat penetaian				predator	air laut	
			semi-alamiah	ke tempat penelasan	jumlah sarang^2	jumlah tukik^2	jumlah sarang^2	jumlah tukik^2					

DAILY FORM # 1
MONTH ____________________

YEAR ____________________

NESTING BEACH ____________________

TURTLES THAT HAVE NESTED & NESTS TRANSPLANTED

RESPONSIBLE ____________________

Date	Species	Nest left *in situ*	Moved higher up on beach platform	Moved to hatchery	# of eggs	Female Tag #	Carapace length	Carapace width	Section of the Beach	Remarks (predation, flooding, other disturbances, etc.)

DAILY FORM # 2
MONTH ____________________

MONTH AND YEAR ____________________

NESTING BEACH ____________________

HATCHING RESULTS

RESPONSIBLE ____________________

Hatching date	Date of transplant	Species	Nests left *in situ*					Nests transplanted higher up				Nests moved to hatchery				Remarks (predation, etc.)
			Nest #	Total # hatchlings	Eggs not hatched #	Eggs not hatched %		Nest #	Total #eggs	Total # hatched	%	Nest #	# of eggs	# hatched	%	

MONTHLY FORM

SPECIES ______________________

MONTH AND YEAR ________________

NESTING BEACH _________________

RESPONSIBLE __________________

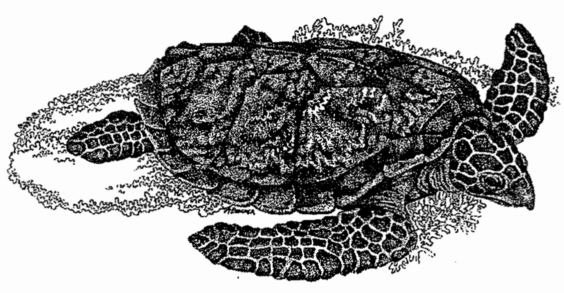
Date	Total # of females nesting	Nests			Hatching				Total # of eggs transplanted	Total # of hatchlings released to sea	Nest damaged by		Remarks
		Left *In situ*	Transplanted		Moved higher up on beach		Moved to hatchery				Predator (kind)	Sea (high water)	
			Moved higher up on beach	Moved to hatchery	Total # of nests	Total # of hatchlings	Total # of nests	Total # of hatchlings					

MARINE TURTLES OF INDONESIA

POPULATION VIABILITY AND
CONSERVATION ASSESSMENT AND MANAGEMENT WORKSHOP

December 11-14, 1995
Cisarua, Indonesia

Section 7:
Appendix I



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Burning the Candle at Both Ends

Joop Schulz

The situation facing sea turtles in Indonesia today is comparable to burning a candle at both ends, an extremely wasteful form of lighting. The similarity between both forms of wasteful consumption is obvious: virtually every clutch of sea turtle eggs is collected and the purveyors of the eggs are killed exclusively for their meat and shell.

At the invitation of the Indonesia authorities, over the last two decades, five sea turtle biologists, in collaboration with Indonesian PHPA officials, have examined the situation in Indonesia: Polunin (1974); Salm (1983-1984); Schulz (1984); Limpus (1984); Schulz and Canin (1989). They expressed deep concern at the unregulated exploitation and decline of the sea turtle populations in Indonesia.

Two management plans were presented. The first by Schulz in 1985 was called Sea Turtle Strategy in Indonesia. The second plan was developed in 1991, A Sea Turtle Strategy Plan (*Pembahasan Strategi Nasional Dan Action Plan Konservasi Dan Pengelolaan Penyu*), drafted by an assembly of high staff members of "Kantor Mentri Negara Kependudukan Dan Lingkungan Hidup", Departemen Kehutanan, WWF Indonesia Programme, and "Environmental Development in Indonesia" (EMDI-3). Most of these recommendations and suggestions have been ignored, although they had been included in a detailed Green Turtle Management Action Plan offered by Indonesia at the 1985 CITES meeting of the parties. This action plan, however, was never implemented.

The recommendations and action plans come down to the following four main points, three of which were included in the official Indonesia Green Turtle Action Plan.

1. Reduction of harvest of turtle eggs on all beaches to 30% of the eggs laid.
2. Implementation of the decline of turtles landed in Bali to a maximum of 2,000 animals per annum.
3. Identification and protection of sea turtle foraging grounds, of which nothing is known.
4. Vigorous enforcement of all regulations.

At the first point:

Eggs of all species, including those of the species protected by Ministerial decree, are harvested throughout Indonesia. On all major nesting beaches I visited in six years, the egg harvest is granted by the local government (usually the 'Pemba Tingkat II') to the highest bidder. This tender system provides the government with quite substantial incomes.

The contractors are usually bound to hatch a small percentage of the eggs, but quite often the hatchery is a fake and where a few hatchlings are released to the sea it is done in the naive belief that this would compensate for the hundreds of thousands of eggs taken. The conservation authorities, PHPA and KSDA, are not involved in this form of exploitation over which they have not the slightest control.

In 1989, I estimated from records of a total annual harvest of 7-8 million eggs (95% of green turtles) on the beaches of: The Natuna and Anambas Islands (South China Sea); the Tambelan islands Sambas-Paloh (East Kalimantan); Birah-Birahan, Sambergelap and other islands of South Kalimantan, Berau Islands of East Kalimantan Bengkulu Coast, Pangumbahan (West Java) and Tarupa on Sumbawa.

Eggs also are heavily collected - often on an opportunistic basis - on all other smaller nesting beaches by local people and non-resident fishermen. Surveys made in 1984-1988 in various regions (South China Sea, around Belitung, in the Makassar Straights, in the Flores and the Banda Seas and in the South Moluccas (including Maluku Tenggara Jahu) gave us the strong impression that scarcely any clutch of sea turtle eggs escapes the egg collectors. Even on the remotest uninhabited islands in the South China Sea and the Arafura Sea, the collectors seldom miss a turtle nest, except during periods of adverse weather when it is impossible to reach the beaches.

The few programs aimed at protecting eggs from poaching and animal predators, while well intentioned, achieve very little. Current beach management techniques often are inadequate and little effort is made for improvement. These efforts on some of the 21 nesting beaches designated as nature reserves, are used as justification for allowing the exploitation to continue and create a false sense of security that something is done to offset the massive over exploitation. There is no need to dwell on the second point; the notorious green turtle harvest far in excess of sustainable levels is common knowledge within and outside the country. It is also generally understood that a crashing nesting population is inevitable if the killing on feeding grounds and in front of and on the nesting beaches remains at the prevailing intensity. Populations are to some extent buffered against over-exploitation because a still-unknown proportion of the turtles caught at sea are turtles that forage in Indonesia waters but use nesting beaches outside Indonesian territory.

It is also general knowledge that since the last three decades a network of green turtle hunters has arisen throughout the archipelago to supply the Bali market. In 27 years (1969-1995), two million green turtles were landed at Tanjung Benoa, Bali. To this number should be added some 20% for the turtles that succumb during the often long voyage back to Bali. The consumption of sea turtle meat in Indonesia is not just limited to Bali. Turtle meat also has a tradition of consumption in Ujung Pdandang, Menado, Ambon, Nias, Tanimbar, and many other communities. None of the provisions Indonesia submitted in its Green Turtle Management Action Plan in 1985 have been implemented. These provisions include:

(a) the green turtle quota for traditional ceremonial purposes on Bali would be brought down to a maximum of 2,000 per annum;
(b) all turtle boats and traders would be required to purchase licenses from PHPA on a quota basis;
(c) the capture and sale of green turtles smaller than 60 cm curved carapace length or larger than 85 cm curved carapace length would be banned.

In the ten years since, not one of these provisions notified in 1985 has been implemented and Bali is still the largest sea turtle slaughterhouse in the world.

In contrast to the other species, commercial exploitation of Hawksbill turtles dates back centuries. As early as the 17th century, ship's journals of the European traders listed tortoiseshell as trade goods from the Indo-Malaysian Archipelago.

There is no need to dwell on the generally known, notoriously disastrous effects on the Indonesian Hawksbill populations of the very high levels of exploitation of the hawksbill stocks during the seventies and eighties, to fulfill the demands of trade to Japan, Hong Kong, and Singapore. While it is certainly true that the illegal, uncontrolled export of sea turtle products is still continuing at an unknown rate, there have been very encouraging signs that attempts to control the export trade are effective; this is largely the result to measures taken by PHPA to tighten export controls. Since 1992, Hawksbill turtles are protected Ministerial decree, but in spite of this, stuffed Hawksbill and tortoiseshell ornaments are still for sale in many shops. Hawksbill flesh is even sold at the Bali markets.

Although knowledge of the sizes of the populations of sea turtles in Indonesian waters is poor, Indonesia certainly still has large populations of green turtles and the largest breeding population of leatherback turtles in Asia, and perhaps the world. Appreciable numbers of Hawksbill turtles are still nesting in the western part of the Archipelago (and perhaps in Nusa Tenggara). Working back from the egg production figures available for six of the major green turtle rookeries (7-8 million eggs per-annum), it could be estimated that at least 10,000,000 green turtle females are nesting every year on Indonesian beaches.

Therefore, there is still a basis for conservation which makes it possible to solve the turtle problem. This would imply, I may repeat again, urgent attention through legislative action and subsequent enforcement at both ends of the candle. First: drastic reduction of the taking of eggs on the leatherback rookeries (NW Irian Jaya) and the harvest of some 7 million eggs of green turtles and Hawksbills rented out under a tender system on the major nesting beaches. Second: the crushing of the flame at the other end of the candle by vigorous curtailment of the green turtle slaughter in Bali.

This strategy, Indonesia announced already ten years ago, has the great advantage that implementation and enforcement could be concentrated on approximately eight key rookeries and on one center of consumption, the Badung district of Bali. Success can be expected only from an integrated approach by PHPA/KSDA in collaboration with other agencies and institutions, such as: a) with local governments at all three levels and with local coastal communities, b) with the Directorate General of Fisheries and the Provincial Fisheries Services, c) with Lipi, d) with the Ministry of the Environment, e) with NGOs and f) with the police and the navy and the coordinating body of the latter two, the Bakorkamla. The links of academia need to be forged more strongly. The operationalization of the new coastal guard system, Siskamla, should be promoted.

One last remark: in my opinion the basic principle of an Indonesia Conservation Plan ought to be that sustainable harvest of marine turtles should not benefit a few wealthy merchants, but primarily the coastal communities. Many of the coastal people traditionally rely on turtles for food and income.

Media Informasi Pelestarian Satwa

BERITA No 5 Th I Oktober - Nopember 1995

BERITA TAMAN SAFARI INDONESIA

DARI REDAKSI
Satwa yang menjadi [illegible]

FOKUS BERITA
Mengenal Kehidupan Penyu dan Kura-kura
Penyu Daging Paling Banyak Dikonsumsi
Gaya Hidup Penyu

DARI KANDANG SATWA
Lebih Dekat Dengan Singa Laut
13 Ekor Kadal Panama Lahir
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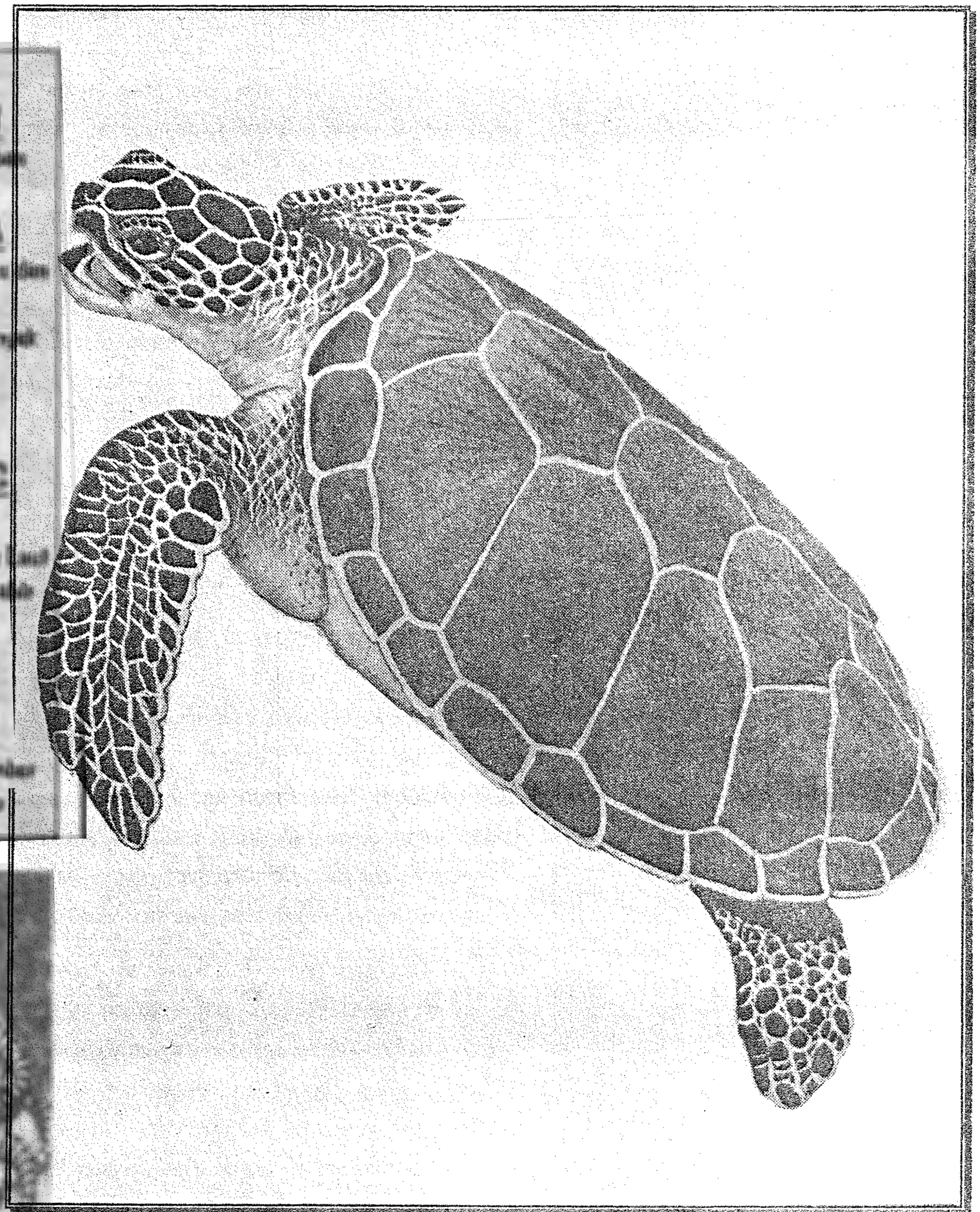
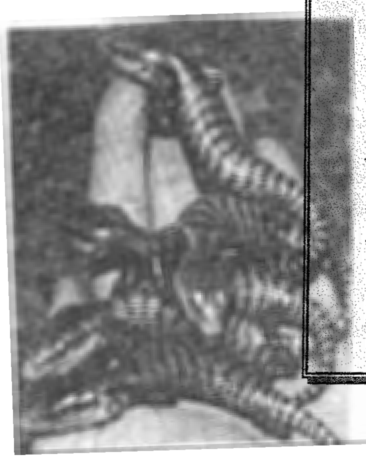
BERITA
Lokakarya Jalak Bali
Workshop di Bulan Desember
Pemenang Lomba Foto





Penyu Hijau (*Chelonia mydas*)

BERITA TAMAN SAFARI INDONESIA

Diterbitkan oleh Taman Safari Indonesia setiap dua bulan secara terbatas. Buletin ini merupakan media informasi pelestarian satwa. Redaksi menerima tulisan dari luar, yang sesuai dengan usaha pelestarian satwa.

Alamat
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Tilp 62-251-253222/28
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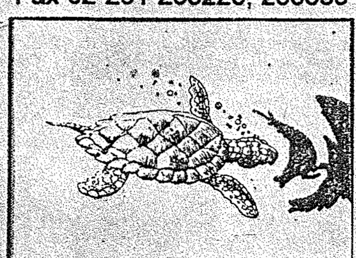


SATWA YANG MENJADI KORBAN

Indonesia, yang mempunyai ratusan suku bangsa dan adat istiadat, mempunyai berbagai macam acara didalam menghormati hari-hari penting. Misalnya masyarakat pribumi Kalimantan, Dayak, dalam melakukan upacara tewah, yaitu acara penggalian dan pembersihan mayat kemudian disimpan pada suatu tempat atau dibakar dan abunya baru disimpan, jaman dahulu, mereka harus menyediakan kepala manusia atau istilahnya mengayau. Namun jaman sudah berubah, kepala manusia diganti dengan kepala kerbau atau sapi atau satwa lainnya, kadang kadang babi, tergantung kemampuan yang mempunyai hajat. Ada juga bila daerah lain, acara tidak "afdol" bila tidak memotong monyet atau penyu.

Upacara ini sudah turun temurun, dan telah dilakukan ratusan atau bahkan ribuan tahun yang lalu, dikala satwa-satwa yang dimaksud atau kehidupan sosial manusia masih primitif. Namun kini pada jaman yang telah moderen dan keadaan satwa dihutan dan di laut semakin menipis, tentunya untuk menuruti kebiasaan nenek moyang mereka harus berpikir panjang. Kerbau dan sapi atau kambing dan babi, sudah dapat diternakkan. Sedangkan satwa yang lain yang masih ditangkap dari hutan, perlu perhatian khusus dan dilakukan penangkaran untuk memenuhi kebutuhan upacara adat, agar adat dan kepercayaan dapat berjalan terus, disamping itu keberadaan satwa dapat dipertahankan keberadaannya.

Penangkaran penyu hijau telah dilakukan di Bali, yang umumnya paling banyak mengkonsumsi Penyu Hijau *(Chelonia mydas)* . PHPA, dalam hal ini KSDA mempelopori penangkaran penyu hijau, untuk memberikan contoh kepada masyarakat, bahwa penyu ini perlu dipertahankan keberadaannya. Kebutuhan akan penyu di Bali sangatlah besar, yang digunakan untuk berbagai keperluan uparaca, mulai dari acara "Ngaben" sampai pemotongan gigi. Semuanya menggunakan "penyu" sebagai binatang persyaratan agar upacara tersebut lebih bermakna.

Kesulitan telah dirasakan oleh mereka. Para nelayan harus berlayar ribuan mil dari Bali untuk mendapatkan penyu. Mereka mengumpulkan dari Sabang hingga Merauke, dan menurut catatan, setiap tahunnya penyu yang mendarat untuk keperluan masyarakat Bali, khususnya Denpasar selatan, pertahunnya mencapai 20 ribu ekor. Itu yang tercatat, belum lagi di daerah lain. Mudah-mudahan usaha penangkaran berhasil, hingga penyu hijau tidak hanya tinggal kerangkanya saja yang sering dipajang (Eds).

MENGENAL KEHIDUPAN PENYU & KURA-KURA

Penyu Belimbing (Dermochelis coriacea) mendarat untuk bertelur.

Penyu, kura-kura merupakan suatu kelompok reptilia yang homogen. Hewan ini mudah dikenal dari perisai yang membungkus tubuh yang mirip dengan kotak. Perisai bagian atas /perisai punggung disebut Karapax, terbentuk dari lapisan kulit dermal yang menyatu dengan tulang rusuk yang tumbuh melebar yang tersusun lebih kuirang 59-61 tulang. Sedangkan perisai bawah/perut disebut Plastron, juga terbentuk dari lapisan tulang. Semua tubuh terbungkus perisai, hanya kepala, tungkai, dan ekornya saja yang menonjol keluar.

Berdasarkan cara hewan-hewan ini menarik kepalanya ke dalam perisai, maka bangsa penyu dan kura-kura dipisahkan menjadi dua Sub Ordo, yaitu Cryptodira yang terdiri dari 11 Famili dan Pleurodira, yang hanya terdiri 2 famili. Cryptodira, menarik lehernya ke dalam perisai pada suatu bidang yang berbentuk huruf "S" dan umumnya, satwa ini dapat menyembunyikan seluruh kepala, dan anggota tubuhnya ke dalam perisai. Sedangkan Pleurodira tak dapat melakukannya, hanya sebagian kepala ditarik ke dalam perisai, dan selebihnya disembunyikan ke samping.

Bangsa kura-kura (Ordo Testudinata) terdiri dari Kura-kura, Penyu dan Terrapin. Dalam bahasa Inggris dikenal dengan Tortoise, Turtle dan Terrapin. Tiga istilah yang kadang-kadang diartikan berbeda. Namun demikian, mereka mempunyai ciri-ciri yang tidak jauh berbeda.

Pertumbuhan.

Bangsa kura-kura dan penyu yang ada di dunia ini, ada berbagai bentuk dan ukuran. Ukuran yang paling kecil yang telah diketemukan, hanya berukuran kurang dari 12 Cm, yang merupakan jenis dari Ordo Testudinata yang terkecil. Sedangkan yang terbesar dengan ukuran garis tengah 183 Cm dengan berat tubuh mencapai hampir 700 Kilogram.

Pertumbuhan bangsa Testudinata, sangat tergantung dari habitat, temperature, curah hujan, sinar matahari, tipe makanan dan jenis kelamin. Pertambahan karapax dan plastron, sangat lambat, dan menurut beberapa sumber dan laporan yang dikumpulkan, hanya 0,08-1,35 cm pertahun (penyu hijau). Sedangkan untuk penyu sisik yang diberi makanan potongan-potongan ikan dengan dosis kurang dari 5 % dari berat tubuh, pertumbuhan tubuhnya lebih cepat. Rata-rata pertumbuh-

Pergerakan Penyu Hijau di darat, umumnya lebih lambat dari pada Kura-kura.

an panjang karapax penyu tersebut setiap tahunnya 12 Cm, lebar karapax 9,5 Cm sedangkan berat hampir 6 kg. Untuk di alam kemungkinan lebih lambat.

Pergerakan

Satwa ini tergolong binatang yang pergerakannya sangat lamban. Alat gerak berupa dua pasang kaki. Kaki kura-kura dan penyu berbeda, karena mereka hidup pada habitat yang berlainan. Kaki penyu, yang hidup di perairan, kedua pasang kakinya mengalami perubahan, yang disesuaikan dengan tempat hidup mereka.

Kura-kura gurun pergerakannya diperkirakan antara 0,22-0,48 Km/jam. Charles Darwin, melaporkan bahwa pergerakan Kura-kura raksasa di P. Galapagos mencapai 6,4 Km per hari. Penyu laut yang pergerakannya dengan berenang mungkin yang tercepat, yaitu mencapai 30 Km/jam, hampir sebanding dengan manusia yang lari di daratan.

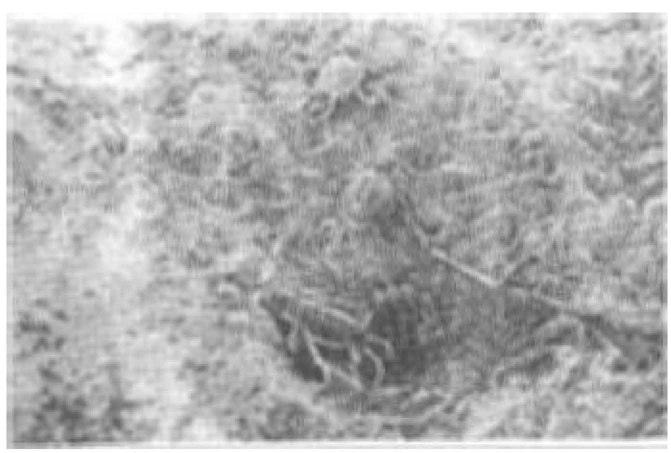
Perkembangbiakan.

Pertumbuhan bangsa kura-kura dan penyu yang begitu lambat, mempengaruhi kematangan sexual mereka. Menurut beberapa penelitian, perkembangan Ordo testudinata hingga siap melakukan perkawinan, berumur 30-50 tahun. Proses perkawinannyapun demikian sulitnya. Umumnya diawali dengan "percumbuan" jantan terhadap betina. Percumbuan hingga terjadinya perkawinan, lebih kurang berlangsung hingga 2-3 bulan, sebelum penyu/kura-kura bertelur.

Pada umumnya semua ordo Testudinata, bertelur di darat, bagi yang hidup di perairan seperti bangsa penyu. Ada yang menggali lubang pada tepian pantai, sungai, tapi adapula yang membuat lubang atau sarang pada tumpukan dedaunan yang kering. Dan bahkan ada yang bertelur pada semak belukar serta telurnya hanya ditutupi dengan dedaunan.

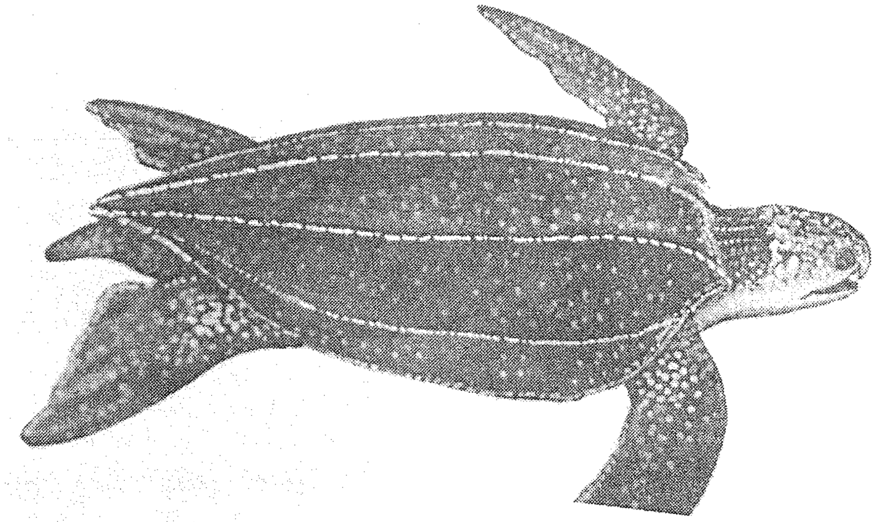
Untuk menhindari dari predator, umumnya mereka membuat lebih dari satu sarang, biasanya 2-3 sarang dalam satu musim bertelur. Jumlah telur setiap jenis berbeda. Kura-kura dan penyu yang terkecil, hanya bertelur antara 1-4 butir dalam satu musim bertelur, sedangkan bagi yang besar, dalam musim bertelur mencapai ratusan butir dalam interval 10 hari.

Masa penetasan kura-kura dan penyu berkisar antara 4-12 bulan. Serta telur-telur yang menetas, ada sebagian jenis yang langsung meninggalkan sarang, seperti penyu hijau, tapi ada beberapa jenis yang hingga 2 tahun tetap ada ditempat.



Anak-anak penyu yang baru menetas dan langsung menuju ke lautan lepas.

Makanan.



Kura-kura dan penyu, tergolong satwa yang omnivora, makan berbagai jenis makanan. Walaupun kadang-kadang memakan binatang lain, akan tetapi mereka bukanlah tipe pemburu mangsa. Makanan mereka berupa tumbuh-tumbuhan, serangga, bangkai binatang, binatang tanah seperti cacing, moluska dan larva serangga.

Umumnya jenis makanan mereka berubah, sesuai dengan pertambahan umur. Ada beberapa jenis kura-kura yang masa kecilnya lebih cenderung memakan serangga atau binatang dalam tanah. Sedangkan menginjak dewasa mereka lebih cenderung ke pemakan tumbuhan.

Perilaku Sosial

Pengertian sosial dalam kehidupan sehari-hari, oleh para pakar perilaku hewan, bahwa binatang yang bersangkutan paling tidak melakukan kontak langsung dengan individu lain di dalam hidupnya. Baik saat berpasangan, memomong anak, perkelahian dalam merebutkan daerah teritorial ataupun pasangan dsb.

Bagi Ordo Testunidata, kecil kemungkinannya mempunyai daerah kekuasaan di dalam hidupnya, seperti halnya satwa-satwa tingkat tinggi. Namun mereka mempunyai daerah jelajah di dalam mencari makanan. Boleh jadi kura-kura daratan dan semi aquatik, daerah jelajahnya tumpang tindih, yang memungkinkan berkembang menjadi hidup bersama.

Walaupun tidak seperti kehidupan satwa tingkat tinggi, penyu dan kura-kura paling tidak mempunyai kehidupan yang bersosial, misalnya saat berpasangan dengan pasangannya, melakukan migrasi secara berkelompok untuk mencari makan, ataupun saat bertelur.

Beberapa jenis penyu dan kura-kura saat musim bertelur, melakukan berbarengan dengan individu lain pada suatu daerah yang cocok bagi mereka, seperti penyu laut dari Genus Lepidochelys di Pantai Costarica. Ratusan penyu turun ke darat dan bertelur secara masal.

Anak-anak penyu di daerah tropik, umumnya yang baru menetas langsung mengembara di lautan, kadang-kadang masih terlihat hidup berkelompok, dan mereka bekerja sama saling menguntungkan. Misalnya individu yang satu melakukan pembersihan atau memakan alga yang hidup pada karapasnya. Ada laporan beberapa jenis penyu yang membersihkan atau memakan ektoparasit pada jenis satwa lain, seperti Badak.

Sekelompok Penyu Laut yang bertelur secara masal di pantai Amerika Latin.

KEHIDUPAN PENYU

Penyu dan Kura-kura yang ditangkap untuk dikonsumsi manusia

Penyu, merupakan kerabat kura-kura dan reptilia ini hanya hidup di perairan, sehingga alat pergerakannyapun disesuaikan dengan kehidupan mereka di perairan. Ada dua golongan penyu yang sesuai dengan tempat tinggal mereka, yaitu Penyu Air Tawar (Freshwater Turtle) dan Penyu Laut (Sea Turtle).

Seperti halnya Reptilia lainnya, Penyu oleh beberapa ahli, tergolong satwa yang primitif. Secara normal, satwa ini mempunyai umur yang panjang, dan merupakan salah satu hewan purbakala yang mengalami proses evolusi yang lama. Di dalam kandang, penyu dapat bertahan hidup hingga 150-an tahun atau bahkan lebih, sedangkan di alam lebih pendek. Satwa ini telah didapati sejak masa Cretaceus, yaitu sekitar 150 juta tahun yang silam. Sedangkan fosil yang diketemukan diperkirakan berumur 200 juta tahun.

Red Data

Semua bagian penyu, dapat dimanfaatkan. Daging penyu sangat lezat, telurnya dapat dimakan, karapace (kerangka) dapat dijadikan hiasan ataupun digunakan untuk berbagai kerajinan mulai dari gantungan kunci, sisir dan hiasan lampu. Oleh karena itu dalam konferensi se dunia mengenai pelestarian penyu *(World Conference of Sea Turtle Conservation)* yang diadakan di Amerika Serikat bulan Nopember 1980, semua penyu laut dinyatakan dilindungi dan dimasukan ke dalam Red Data Book, karena populasinya semakin berkurang dan terancam kepunahan.

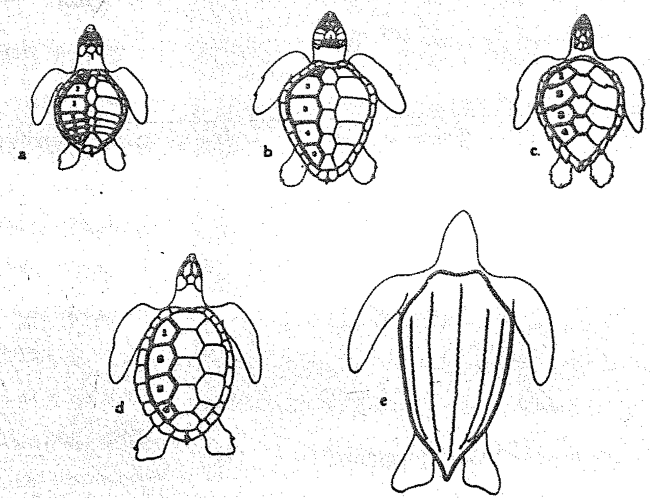
Ordo Testudinata (penyu dan kura-kura) di dunia ini ada kurang lebih 75 Genus yang terdiri dari 75 famili dan 244 jenis. Sedangkan penyu di Indonesia ada 6 jenis, yang telah diketahui diantaranya adalah Penyu Hijau *(Chelonia mydas)*, Penyu Sisik *(Eretmochelys imbricata)*, Penyu Abu-abu *(Lepidochelys olivacea)*, Penyu Belimbing *(Dermochelys coriacea)*, Penyu Tempayan/Penyu Bromo *(Caretta caretta)*, Penyu Pipih *(Navator depressa)*.

Keenam penyu tersebut, sudah dimasukkan ke dalam daftar CITES (Convetion International Trade Endangered Species) dan telah diakui sebagai satwa yang In dangered Species. Sedangkan di Indonesia baru 3 jenis yang dilindungi, antara lain Penyu Sisik, Penyu Belimbing dan Penyu Slengkrah/Bromo.

Penyu Hijau di dasar lautan.

Ciri-ciri Beberapa Jenis Penyu.

Penyu-penyu yang ditemui dibeberapa di daerah pesisir di Indonesia, telah disebutkan diatas. Mereka bersifat kosmopolitan dan dapat ditemui dimana-mana. Di samping ini beberapa contoh ciciri-ciri secara morfologis penyu yang sering ditemui di pesisir Indonesia.



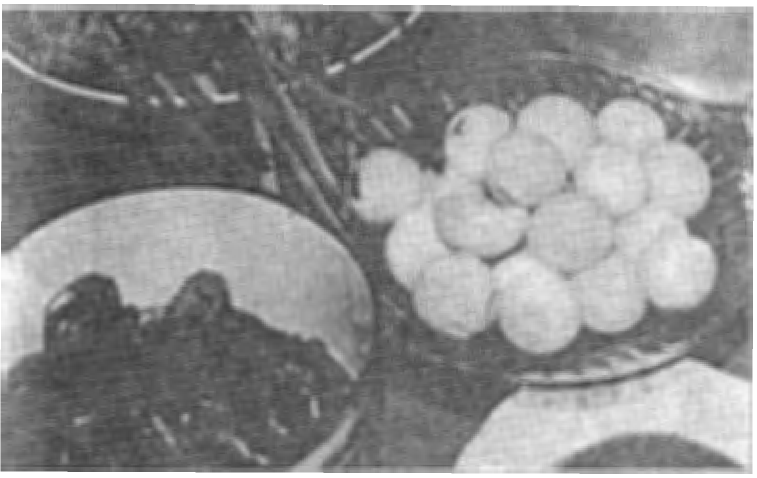
a. Penyu Abu-abu *(Lepidochelys olivacea)*, b. Penyu Tempayan *(Caretta caretta)*, c.Penyu sisik *(Eretmochelys imbricata)*, d. Penyu *Hijua (Chelonia mydas)* dan d. Penyu Belimbing *(Dermochelys coriacea)*

PENYU DAGING PALING BANYAK DIKONSUMSI

Pengambilan telur penyu untuk konsumsi

Daging penyu, menurut yang sering mengkonsumsi, merupakan daging yang lezat. Tidak hanya dagingnya yang dapat dimakan, tetapi semua bagian dapat digunakan. Mulai dari karapax untuk hiasan atau kerajinan tangan lainnya, selain daging dan telurnya dapat dimakan. Penyu daging atau lebih dikenal dengan Penyu hijau *(Chelonia mydas)* tak asing lagi bagi masyarakat nelayan dan masyarakat di Bali.

Beberapa data yang dikumpulkan, penangkapan Penyu Hijau, semakin bertambah. Akan tetapi usaha dan hasil penangkapan di alam semakin sulit ditemukan dan menyebabkan harga penyu hijau semakin melambung. Di Pelabuhan Benoa Bali pendaratan penyu hijau dan penyu sisik yang dicatat oleh Sub Balai Konservasi Sumber Daya Alam Bali (SBKSDA) oleh para pemburu penyu hingga saat ini, hasil tangkapan setiap tahunnya bervariasi dari tahun 1981 - 1991 berkisar antara 12 - 24 ribu ekor



Banyak telur penyu dijual di warung makan

pertahun. Sedangkan tahun 1992 sampai dengan tahun 1994, setiap tahunnya rata-rata 19 ribu ekor. Menurut penuturan para nelayan, mereka menangkap penyu cukup jauh dari Bali misalnya mereka harus mencari ke Kalimantan, Sumatera, Maluku, Nusa Tenggara dan bahkan sampai ke Sorong Irian Jaya. Untuk kebutuhan penyu di Indonesia, setiap tahunnya diperkirakan mencapai 100 ribu ekor, belum terhitung telur-telur penyu yang diambil dari lubang-lubang perteluran.

GAYA HIDUP PENYU HIJAU

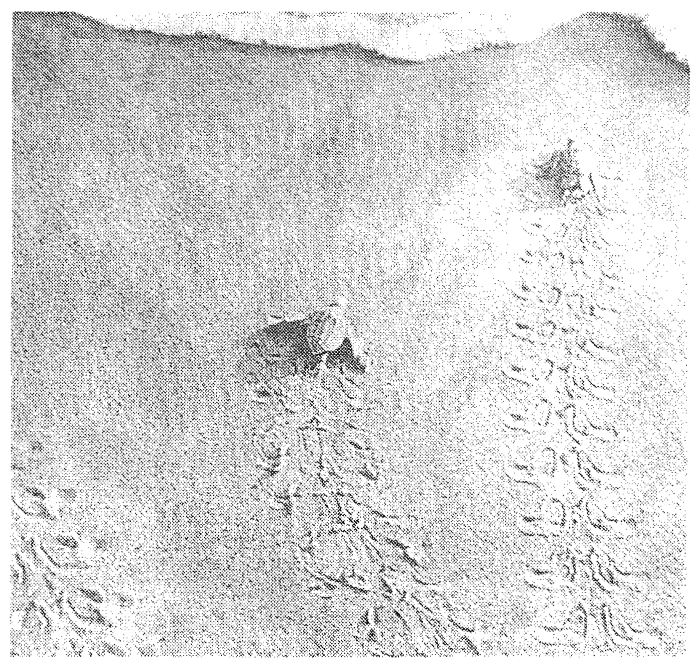
Habitat dan Makanan.

Penyu hijau seperti halnya dengan jenis-jenis penyu lainnya, memerlukan dua habitat dan lingkungan untuk kehidupannya, yaitu perairan atau laut dan daratan yang berpasir untuk bertelur. Habitat di laut penyu hijau menyukai daerah perairan berkarang, yang tak begitu dalam, tidak lebih dari 200 meter di mana dasarnya banyak ditumbuhi dengan rumput laut dan alga laut, yang merupakan makanan utamanya. Makanan penyu hijau dari saat tukik (anak penyu yang baru menetas) hingga dewasa, mengalami perubahan makanan. Saat masih berupa tukik hingga berumur 1 tahun, penyu ini bersifat Carnivora, memakan berbagai jenis binatang laut. Setelah menginjak besar, lebih dari 1 tahun, mereka lebih cenderung sebagai Herbivora, dan mencari makanan ke daerah yang relatif dangkal.

Migrasi.

Di dalam hidupnya, beberapa jenis binatang akan malakukan perjalanan yang panjang, untuk melakukan tujuan tertentu. Banyak jenis burung , serangga melakukan perjalanan ribuan mil jauhnya saat musim perkembangan biak, paceklik atau perubahan musim. Penyu hijaupun melakukan migrasi pada saat-saat tertentu secara berkelompok.

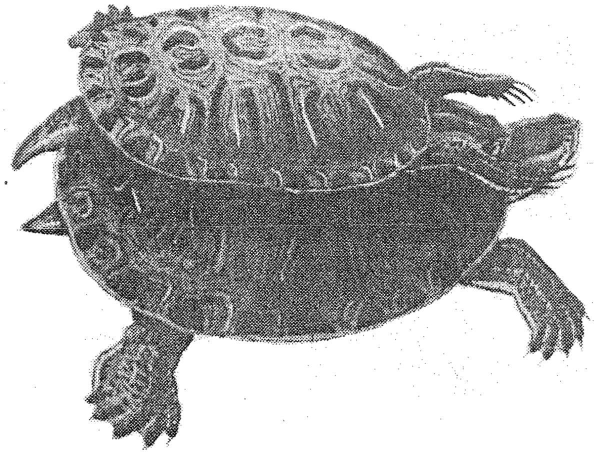
Perpindahan secara masal ini, bagi penyu hijau, dilakukan secara musiman, dan diperkirakan perjalanan yang ditempuh mencapai ribuan kilometer, sering kali harus melintasi lautan yang luas. Perpindahan ini dilakukan saat mencari makan, ataupun untuk meletakkan telurnya di pesisir yang mempunyai pantai yang putih bersih.



Penyu Belimbing yang kembali setelah bertelur

Perkembangbiakan.

Semua jenis penyu, melakukan perkawinannya di laut. Perkawinannya sungguh rumit, dan berlangsung berjam-jam. Seekor betina, yang ekornya lebih pendek daripada jantan, saat musim kawinnya dapat



melayani lebih dari satu jantan, karena penyu betina mempunyai kantong untuk menyimpan sperma. Kadang-kadang terjadi antara penyu jantan dengan jantan lain berkelahi untuk merebutkan pasangannya.

Perkawinan tersebut terjadi selama 2-3 bulan sebelum musim bertelur. Dan frekuensi bertelur saat musimnya terjadi sebanyak 4-7 kali, dan interval waktu dari peneluran antara 11-15 hari. Banyaknya telur yang dihasilkan berkisar 80 - 200 butir, umumnya waktu bertelur pada malam hari antara pk. 20.00 - 04.00 dini hari.

Pelepasan anak-anak penyu di penetasan

Penyu, bertelur tidak setiap tahun, namun hanya terjadi setiap 2-3 tahun bahkan 5-9 tahun. Di daerah Pangumbahan, Citireum daerah Jawa Barat, peneluran penyu terjadi sepanjang tahun, dan puncaknya terjada pada bulan Agustus - November. Sedangkan di Sukamade peningkatan penyu bertelur terjadi bulan Oktober - Maret, di Sumbawa puncak penyu bertelur bulan April-Juli, di Pulau Berhala bulan Noprmber-Januari.

Umumnya penyu bertelur memilih pantai yang berpasir bersih dan putih, sedikit miring, dan mereka membuat lubang, menyukai dibawah pohon pandan *(Pandanus tectorius)* serta pada suasana yang sepi, dan tidak ada sinar. Lubang ditimbun dan kembali ke laut. Selang beberapa hari, datang lagi untuk meletakkan telurnya, dan menurut beberapa peneliti, jaraknya tidak berjauhan dengan lubang pertama. Demikian terjadi beberapa kali. Masa inkubasi/penetasan antara 50-55 hari.

Tidak semua telur penyu dapat menetas. Umumnya telur-telur yang menetas bersamaan, dan keluar dari lubangpun, bila bersama-sama akan mudah dilakukan. Kebersamaan dalam penetasan ini, diduga mempunyai ikatan sosial yang cukup kuat, atau saat induk meletakkan telur bersamaan. Hanya yang cacat saja yang akan tertinggal di dalam lubang.

Tukik-tukik yang telah menetas, langsung menuju ke lautan, disinilah banyak predator yang mengancam kehidupan tukik, mulai dari satwa darat seperti babi, elang hingga predator perairan seperti ikan hiu dan sebangsanya. Bagi yang dapat berhasil bertahan hidup dan luput dari predator, tukik-tukik ini sering terlihat hidup bergerombol dalam mencari makanan. Mereka menjadi dewasa diperkirakan berumur antara 20-30 tahun, dan dapat siap untuk berbiak.

Pertumbuhan mereka sangan lambat, menurut penelitian Ni Wayan Masih (1992) di penangkaran Penyu Hijau di Serangan Bali, setiap individu sangat bervariasi antara 30-290 gram perbulan atau pertambahan perpanjangan antara 0,5 - 4,5 cm perbulan.

Saingan dan Pemangsa Penyu Hijau

Ikan duyung yang dianggap pesaing penyu mati ditangan manusia

Saingan utama penyu hijau di alam, terutama adalah satwa lautan yang bersifat herbivora, pemakan tumbuhan, seperti, ikan duyung dan jenis-jenis ikan herbivora lainnya.

Sedangkan pe mangsa utama, adalah manusia, dan banyak masyarakat Indonesia menyukainya, selain bebe rapa bagian tubuh penyu dapat dimanfaatkan. Pemangsa alam atau predator saat masih berupa telur dalam lubang diantaranya adalah babi hutan, kucing hutan, biawak, ketam, burung sampai manusia. Sedangkan saat menjadi tukik antara lain babi hutan, ular, burung elang dan ikan-ikan karnivora.

Usaha Penyelamatan.

Kekhawatiran akan musnahnya suatu satwa karena eksploitasi yang terus menerus untuk memenuhi kebutuhan manusia, maka ada beberapa usaha untuk mempertahankan keberadaannya atau menyelaraskan antara penangkapan dan penyediaan melalui penangkaran.

Usaha penangkaran dan atau membantu penyelamatan dengan membuat lokasi penetasan, telah dilakukan dibeberapa daerah yang sering dikunjungi penyu-penyu untuk bertelur. Misalnya di pantau Pangumbahan, Citireum Suaka Margasatwa Cikepuh, Sukamade yang berada dalam kawasan Taman Nasional Meru Betiri dan di Tanjung Benoa Bali yang diprakarsai oleh Sub Balai KSDA Denpasar Bali.

Usaha-usaha ini umumnya terbatas pada pengambilan telur saat penyu penyu mendarat, kemudian dipindahkan ke lokasi penetasan yang sudah disiapkan.

Usaha ini untuk menghindari dari pencurian telur oleh pemburu ataupun predator. Sehingga setiap malam petugas terus berpatroli di sepanjang pantai untuk mengecek ada tidaknya penyu yang mendarat.

Usaha usaha lain untuk penyelamatan penyu antara lain melindungi habitat pendaratan penyu, pemasangan tanda-tanda, menutup sebagian lokasi peneluran penyu untuk umum.

Setelah menetas, tukik-tukik dipelihara beberapa saat, diberi makan secukupnya, dan kemudian dilepas ke lautan lepas. Sedangkan usaha penangkaran, seperti di Denpasar Bali, anak-anak penyu tersebut diberi makanan, sedangkan yang dewasa, yang umumnya herbivora, diberi makan rumput laut. Telur-telur, masih didatangkan dari lokasi-lokasi pendaratan penyu seperti di Sukamade atau Citireum.

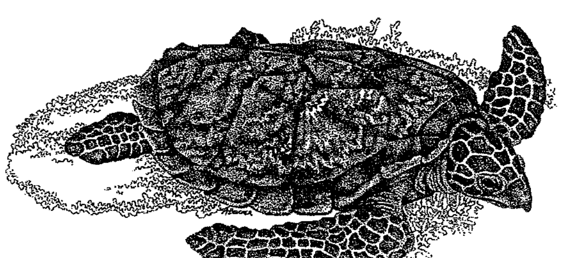
Perburuan Penyu di lautan lepas.

MARINE TURTLES OF INDONESIA

POPULATION VIABILITY AND CONSERVATION ASSESSMENT AND MANAGEMENT WORKSHOP

December 11-14, 1995
Cisarua, Indonesia

Section 8:
Appendix II
IUCN Guidelines and Policies



THE IUCN POLICY STATEMENT ON CAPTIVE BREEDING

Prepared by the
SSC Captive Breeding Specialist Group

As approved by the 22nd Meeting of the IUCN Council Gland, Switzerland

4 September 1987

SUMMARY: Habitat protection alone is not sufficient if the expressed goal of the World Conservation Strategy the maintenance of biotic diversity, is to be achieved. Establishment of self-sustaining captive populations and other supportive intervention will be needed to avoid the loss of many species, especially those at high risk in greatly reduced, highly fragmented, and disturbed habitats captive breeding programmes need to be established before specks are reduced to critically low numbers, and thereafter need to be coordinated Internationally according to sound biological principles, with a view to the maintaining or re establishment of viable populations in the wild.

PROBLEM STATEMENT

IUCN data indicate that about 3 per cent of terrestrial earth is gazetted for protection. Some of this and much of the other 97 per cent is becoming untenable for many species, and remaining populations are being greatly reduced and fragmented. From modern population biology one can predict that many species will be lost under these conditions. On average more than one mammal, bird, or reptile species has been bst in each year this century. Since extinctions of most taxa outside these groups are not recorded, the loss rate for all species is much higher.

Certain groups of species are at particularly high risk, especially forms with restricted distribution, those of large body size, those of high economic value, those at the top of food chains, and those which occur only in climax habitats. Species in these categories are likely to be lost first, but a wide range of other forms are also at risk. Conservation over the long term will require management to reduce risk, including *ex situ* populations which could support and interact demographically and genetically with wild populations.

FEASIBILITY

Over 3,000 vertebrate species are being bred in zoos and other captive animal facilities. When a serious attempt is made, most species breed in captivity, and viable populations can be maintained over the long term. A wealth of experience is available in these institutions, including husbandry, veterinary medicine, reproductive biology, behaviour, and genetics. They offer space for supporting populations of many threatened taxa, using resources not competitive with those for *in situ* conservation. Such captive stocks have in the past provided critical support for some wild populations (e.g. American bison, *Bison bison*), and have been the sole escape from extinction for others which have since been re-introduced to the wild (e.g. Arabian oryx, *Oryx leucoryx*).

RECOMMENDATION

IUCN urges that those national and international organizations and those individual institutions concerned with maintaining wild animals in captivity commit themselves to a general policy of developing demographically self-sustaining captive populations of endangered species wherever necessary.

SUGGESTED PROTOCOL

WHAT: The specific problems of the species concerned need to be considered, and appropriate aims for a captive breeding programme made explicit.

WHEN: The vulnerability of small populations has been consistently under estimated. This has erroneously shifted the timing of establishment of captive populations to the last moment, when the crisis is enormous and when extinction is probable. Therefore, timely recognition of such situations is critical, and is dependent on information on wild population status, particularly that provided by the IUCN Conservation Monitoring Centre. Management to best reduce the risk of extinction requires the establishment of supporting captive populations much earlier, preferably when the wild population is still in the thousands. Vertebrate taxa with a current census below one thousand individuals in the wild require close and swift cooperation between field conservationists and captive breeding specialists, to make their effort complementary and minimize the likelihood of the extinction of these taxa.

HOW: Captive populations need to be founded and managed according to sound scientific principles for the primary purpose of securing the survival of species through stable, self-sustaining captive populations. Stable captive populations preserve the options of reintroduction and/or supplementation of wild populations.

A framework of international cooperation and coordination between captive ~ breeding institutions holding species at risk must be based upon agreement to cooperatively manage such species for demographic security and genetic diversity. The IUCN/SSC Captive Breeding Specialist Group is an appropriate advisory body concerning captive breeding science and resources.

Captive programmes involving species at risk should be conducted primarily for the benefit of the species and without commercial transactions. Acquisition of animals for such programmes should not encourage commercial ventures or trade. Whenever possible, captive programmes should be carried out in parallel with field studies and conservation efforts aimed at the species in its natural environment.

DRAFT GUIDELINES FOR RE-INTRODUCTIONS

Introduction

These policy guidelines have been drafted by the Re-introduction Specialist Group of the IUCN's Species Survival Commission (Guidelines for determining procedures for disposal of species confiscated in trade are being developed separately by IUCN for CITES.) in response to the increasing occurrence of reintroduction projects world-wide, and consequently, to the growing need for specific policy guidelines to help ensure that the re-introductions achieve their intended conservation benefit, and do not cause adverse side-effects of greater impact. Although the IUCN developed a Position Statement on the Translocation of Living Organisms in 1987, more detailed guidelines were felt to be essential in providing more comprehensive coverage of the various factors involved in re-introduction exercises.

These guidelines are intended to act as a guide for procedures useful to re-introduction programmes and do not represent an inflexible code of conduct. Many of the points are more relevant to re-introductions using captive-bred individuals than to translocation of wild species. Others are especially relevant to globally endangered species with limited numbers of founders. Each re-introduction proposal should be rigorously reviewed on its individual merits. On the whole, it should be noted that re-introduction is a very lengthy and complex process.

This document is very general, and worded so that it covers the full range of plant and animal taxa. It will be regularly revised. Handbooks for re-introducing individual groups of animals and plants will be developed in future.

1. Definition of Terms

a. "Re-introduction ":

An attempt to establish a species (The taxonomic unit referred to throughout the document is species: it may be a lower taxonomic unit [e.g. sub-species or race] as long as it can be unambiguously defined.) in an area which was once part of its historical range, but from which it has become extinct (CITES criterion of "extinct": species not definitely located in the wild during the past 50 years of conspecifics.). ("Re-establishment" is a synonym, but implies that the re-introduction has been successful) .

b. "Translocation ":

Deliberate and mediated movement of wild individuals or populations from one part of their range to another.

c. "Reinforcement/Supplementation":

Addition of individuals to an existing population.

d. "Conservation/Benign Introductions":

An attempt to establish a species, for the purpose of conservation, outside its recorded distribution but within an appropriate habitat and eco-geographical area.

2. Aims and Objectives of the Re-Introduction

a. Aims:

A re-introduction should aim to establish a viable, free-ranging population in the wild, of a species or subspecies which was formerly globally or locally extinct (extirpated). In some circumstances, a re-introduction may have to be made into an area which is fenced or otherwise delimited, but it should be within the species' former natural habitat and range, and require minimal long-term management.

b. Objectives:

The objectives of a re-introduction will include: to enhance the long-term survival of a species; to re-establish a keystone species (in the ecological or cultural sense) in an ecosystem; to maintain natural biodiversity; to provide long-term economic benefits to the local and/or national economy; to promote conservation awareness; or a combination of these.

Re-introductions or translocation of species for short-term, sporting or commercial purposes - where there is no intention to establish a viable population - are a different issue, beyond the scope of these guidelines. These include fishing and hunting activities.

3. Multi disciplinary Approach

A re-introduction requires a multi disciplinary approach involving a team of persons drawn from a variety of backgrounds. They may include persons from: governmental natural resource management agencies; non-governmental organizations; funding bodies; universities; veterinary institutions; zoos (and private animal breeders) and/or botanic gardens, with a full range of suitable expertise. Team leaders should be responsible for coordination between the various bodies and provision should be made for publicity and public education about the project.

4. Pre-Project Activities

a. Biological:

(I) Feasibility study and background research

- An assessment should be made of the taxonomic status of individuals to be re-introduced. They must be of the same subspecies as those which were extirpated, unless adequate numbers are not available. An investigation of historical information about the loss and fate of individuals from the re-introduction area, as well as molecular genetic studies, should be undertaken in case of doubt. A study of genetic variation within and between populations of this and related taxa can also be helpful. Special care is needed when the population has long been extinct.

- Detailed studies should be made of the status and biology of wild populations (if they exist) to determine the species' critical needs; for animals, this would include descriptions of habitat preferences, intra specific variation and adaptations to local ecological conditions, social behavior, group composition, home range size, shelter and food requirements, foraging and feeding behavior, predators and diseases. For plants it would include biotic and abiotic habitat requirements, dispersal mechanisms, reproductive biology, symbiotic relationships (e.g. with mycorrhizae, pollinators), insect pests and diseases. Overall, a firm knowledge of the natural history of the species in question is crucial to the entire re-introduction scheme.

- The build-up of the released population should be modeled under various sets of conditions, in order to specify the optimal number and composition of individuals to be released per year and the numbers of years necessary to promote establishment of a viable population.

- A Population and Habitat Viability Analysis will aid in identifying significant environmental and population variables and assessing their potential interactions, which would guide long-term population management.

(ii) Previous Re-introductions

- Thorough research into previous re-introductions of the same or similar species and wide-ranging contacts with persons having relevant expertise should be conducted prior to and while developing re-introduction protocol.

(iii) Choice of release site

- Site should be within the historic range of species and for an initial reinforcement or re-introduction have very few, or no, remnant wild individuals (to prevent disease spread, social disruption and introduction of alien genes). A conservation/ benign introduction should be undertaken only as a last resort when no opportunities for re-introduction into the original site or range exist.

• The re-introduction area should have assured, long-term protection (whether formal or otherwise).

(iv) Evaluation of re-introduction site

• Availability of suitable habitat: re-introductions should only take place where the habitat and landscape requirements of the species are satisfied, and likely to be sustained for the for-seeable future. The possibility of natural habitat change since extirpation must be considered. The area should have sufficient carrying capacity to sustain growth of the re-introduced population and support a viable (self-sustaining) population in the long run.

• Identification and elimination of previous causes of decline: could include disease; over-hunting; over-collection; pollution; poisoning; competition with or predation by introduced species; habitat loss; adverse effects of earlier research or management programmes; competition with domestic livestock, which may be seasonal.

• Where the release site has undergone substantial degradation caused by human activity, a habitat restoration programme should be initiated before the reintroduction is carried out.

(v) Availability of suitable release stock

• Release stock should be ideally closely-related genetically to the original native stock.

• If captive or artificially propagated stock is to be used, it must be from a population which has been soundly managed both demographically and genetically, according to the principles of contemporary conservation biology.

• Re-introductions should not be carried out merely because captive stocks exist, nor should they be a means of disposing of surplus stock.

• Removal of individuals for re-introduction must not endanger the captive stock population or the wild source population. Stock must be guaranteed available on a regular and predictable basis, meeting specifications of the project protocol.

• Prospective release stock must be subjected to a thorough veterinary screening process before shipment from original source. Any animals found to be infected or which test positive for selected pathogens must be removed from the consignment, and the uninfected, negative remainder must be placed in strict quarantine for a suitable period before retest. If clear after retesting, the animals may be placed for shipment.

• Since infection with serious disease can be acquired during shipment, especially if this is intercontinental, great care must be taken to minimize this risk.

• Stock must meet all health regulations prescribed by the veterinary authorities of the recipient country and adequate provisions must be made for quarantine if necessary.

• Individuals should only be removed from a wild population after the effects of translocation on the donor population have been assessed, and after it is guaranteed that these effects will not be negative.

b. Socio-Economic and Legal Activities

• Re-introductions are generally long-term projects that require the commitment of long-term financial and political support.

• Socio-economic studies should be made to assess costs and benefits of the e-introduction programme to local human populations.

• A thorough assessment of attitudes of local people to the proposed project is necessary to ensure long term protection of the re-introduced population, especially if the cause of species' decline was due to human factors (e.g. over-hunting, over-collection, loss of habitat). The programme should be fully understood, accepted and supported by local communities.

• Where the security of the re-introduced population is at risk from human activities, measures should be taken to minimize these in the re-introduction area. If these measures are inadequate, the re-introduction should be abandoned or alternative release areas sought.

• The policy of the country to re-introductions and to the species concerned should be assessed. This might include checking existing national and international legislation and regulations, and provision of new measures as necessary. Re-introduction must take place with the full permission and involvement of all relevant government agencies of the recipient or host country. This is particularly important in re-introductions in border areas, or involving more than one state.

• If the species poses potential risk to life or property, these risks should be minimized and adequate provision made for compensation where necessary; where all other solutions fail, removal or destruction of the released individual should be considered.

In the case of migratory/mobile species, provisions should be made for crossing of international/state boundaries.

5. Planning. Preparation and Release Stages

• Construction of a Multi disciplinary team with access to expert technical advice for all phases of the programme. IUCN/SSC Draft Reintroduction Guidelines 6

• Approval of all relevant government agencies and land owners, and coordination with national and international conservation organizations.

• Development of transport plans for delivery of stock to the country and site of re-introduction, with special emphasis on ways to minimize stress on the individuals during transport.

• Identification of short-and long-term success indicators and prediction of programme duration, in context of agreed aims and objectives.

• Securing adequate funding for all programme phases.

• Design of pre- and post- release monitoring programme so that each re-introduction is a carefully designed experiment, with the capability to test methodology with scientifically collected data.

• Appropriate health and genetic screening of release stock. Health screening of closely related species in re-introduction area.

• If release stock is wild-caught, care must be taken to ensure that: a) the stock is free from infectious or contagious pathogens and parasites before shipment and b) the stock will not be exposed to vectors of disease agents which may be present at the release site (and absent at the source site) and to which it may have no acquired immunity.

• If vaccination prior to release, against local endemic or epidemic diseases of wild stock or domestic livestock at the release site, is deemed appropriate, this must be carried out during the "Preparation Stage" so as to allow sufficient time for the development of the required immunity.

• Appropriate veterinary or horticultural measures to ensure health of released stock throughout programme. This is to include adequate quarantine arrangements, especially where founder stock travels far or crosses international boundaries to release site.

• Determination of release strategy (acclimatization of release stock to release area; behavioral training - including hunting and feeding; group composition, number, release patterns and techniques; timing).

• Establishment of policies on interventions (see below).

• Development of conservation education for long-term support; professional training of individuals involved in long-term programme; public relations through the mass media and in local community; involvement where possible of local people in the programme.

• The welfare of animals for release is of paramount concern through all these stages.

6. Post-Release Activities

• Post release monitoring of all (or sample of) individuals. This most vital aspect may be by direct (e.g. tagging, telemetry) or indirect (e.g. spoor, informants) methods as suitable.

- Demographic, ecological and behavioral studies of released stock.
- Study of processes of long-term adaptation by individuals and the population.
- Collection and investigation of mortalities.
- Interventions (e.g. supplemental feeding; veterinary aid; horticultural aid) when necessary.
- Decisions for revision rescheduling, or discontinuation of programme where necessary.
- Habitat protection or restoration to continue where necessary.
- Continuing public relations activities, including education and mass media coverage.
- Evaluation of cost-effectiveness and success of re- introduction techniques.
- Regular publications in scientific and popular literature.

IUCN GUIDELINES FOR THE PLACEMENT OF CONFISCATED LIVE ANIMALS[1]

Statement of Principle:

When live animals are confiscated by government authorities, these authorities have a responsibility to dispose of them appropriately. Within the confines of national and international law, the ultimate on disposition of confiscated animals must achieve three goals: 1) to maximise conservation value of the specimens without in any way endangering the health, behavioral repertoire, genetic characteristics, or conservation status of wild or captive populations of the species[1]; 2) to discourage further illegal or irregular[2] trade in the species; and 3) to provide a humane solution, whether this involves maintaining the animals in captivity, returning them to the wild, or employing euthanasia to destroy them.

Statement of Need:

Increased regulation of trade in wild plants and animals and enforcement of these regulations has resulted in an increase in the number of wildlife shipments intercepted by government authorities as a result of non-compliance with these regulations. In some instances, the interception is a result of patently illegal trade; in others, it is in response to other irregularities. While in some cases the number of animals in a confiscated shipment is small, in many others the number is in the hundreds. Although in many countries confiscated animals have usually been donated to zoos and aquaria, this option is proving less viable with large numbers of animals and, increasingly, for common species. The international zoo community has recognized that placing animals of low conservation priority in limited cage space may benefit those individuals but may also detract from conservation efforts as a whole. They are, therefore, setting conservation priorities for cage space (IUDZG/CBSG 1993).

With improved interdiction of the illegal trade in animals there is an increasing demand for information to guide confiscating agencies in the disposal of specimens. This need has been reflected in the formulation of specific guidelines for several groups of organisms such as parrots (Birdlife International in prep) and primates (Harcourt in litt.). However, no general guidelines exists.

In light of these trends, there is an increasing demand - and urgent need - for information and advice to guide confiscating authorities in the disposition of live animals. Although specific guidelines have been formulated for certain groups of organisms, such as parrots (Birdlife International in prep.) and primates (Harcourt 1987), no general guidelines exist.

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[1] Although this document refers to species, in the case of species with well-defined subspecies and races, the issues addressed will apply to lower taxonomic units.

When disposing of confiscated animals, authorities must adhere to both national and international law. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) requires that confiscated individuals of species listed on the treaty's Appendices be returned to the "state of export . . . or to a rescue centre or such other place as the Management Authority deems appropriate and consistent with the purpose of the Convention." (Article VIII). However the treaty does not elaborate on this requirement, and CITES Management Authorities must act according to their own interpretation, not only with respect to repatriation but also as regards what constitutes disposition that is "appropriate and consistent" with the treaty. Although the present guidelines are intended to assist CITES Management Authorities in making this assessment, they are designed to be of general applicability to all confiscated live animals.

The lack of specific guidelines has resulted in confiscated animals being disposed of in a variety of ways. In some cases, release of confiscated animals into existing wild populations has been made after careful evaluation and with due regard for existing guidelines (IUCN 1987, IUCN 1995). In other cases, such releases have not been well planned and have been inconsistent with general conservation objectives and humane considerations, such as releasing animals in inappropriate habitat, dooming these individuals to starvation or certain death from other causes against which the animals are not equipped or adapted. Such releases may also have strong negative conservation value by threatening existing wild populations as a result of: 1) diseases and parasites acquired by the released animals while in captivity spreading into existing wild populations; 2) individuals released into existing populations, ro in areas near to existing populations, not being of the same race or sub-species as those in the wild population, resulting in mixing of distinct genetic lineages; 3) animals held in captivity, particularly juveniles and immatures, acquiring an inappropriate behavioral repertoire from individuals of other species, and/or either losing certain behaviors, or not developing the full behavioral repertoire, necessary for survival in the wild. Also, it is possible that release of these animals could result in inter-specific hybridisation.

Disposition of confiscated animals is not a simple process. Only on rare occasions will the optimum course to take be clear-cut or result in an action of conservation value. Options for the disposition of confiscated animals have thus far been influenced by the public's perception that returning animals to the wild is the optimal solution in terms of both animals welfare and conservation. A growing body of scientific study of re-introduction of captive animals suggests that such actions may be among the least appropriate options for many reasons. This recognition requires that the options available to confiscating authorities for disposition be carefully reviewed.

Management Options:

In deciding on the disposition of confiscated animals, priority must be given to the well-being and conservation of existing wild populations of the species involved, with all efforts made to ensure the humane treatment of the confiscated individuals. Options for disposition fall into three

principal categories: 1) maintenance of the individual(s) in captivity; 2) returning the individual(s) in question to the wild; and 3) euthanasia.
Within a conservation perspective, by far the most important consideration in reviewing the options for disposition is the conservation status of the species concerned. Where the confiscated animals represent an endangered or threatened species, particular effort should be directed towards evaluating whether and how these animals might contribute to a conservation programme for the species. The decision as to which option to employ in the disposition of confiscated animals will depend on various legal, social, economic and biological factors. The "Decision Tree"[1] provided in the present guidelines is intended to facilitate consideration of these options. The tree has been written so that it may be used for both threatened and common species. However, it recognizes that the conservation status of the species will be the primary consideration affecting the options available for placement, particularly as the expense and difficulty of returning animals to the wild (see below) will often only be justified for threatened species. International networks of experts, such as the IUCN-Species Survival Commission Specialist Groups, should be able to assist confiscating authorities, and CITES Scientific and Management Authorities, in their deliberations as to the appropriate disposition of confiscated specimens.

Sending animals back automatically to the country from which they were shipped, the country in which they originated (if different), or another country m which the species exists, does not solve any problems. Repatriation to avoid addressing the question of disposition of confiscated animals is irresponsible as the authorities in these countries will face the same issues concerning placement as the authorities in the original confiscating country.

OPTION 1-- **CAPTIVITY**

Confiscated animals are already in captivity; there are numerous options for maintaining them in captivity. Depending on the circumstances, animals can be donated, loaned, or sold. Placement may be in zoos or other facilities, or with private individuals. Finally, placement may be either in the country of origin, the country of export (if different), the country of confiscation. or in a country with adequate and/or specialised facilities for the species in question. If animals are maintained in captivity, in preference to either being returned to the wild or euthanized, they must be afforded humane conditions and ensured proper care for their natural lives.

Zoos and aquaria are the captive facilities most commonly considered for disposition of animals, but a variety of captive situations exist where the primary aim of the institution or individuals involved is not the propagation and resale of wildlife. These include:

> **Rescue centres**, established specifically to treat injured or confiscated animals, are sponsored by a number of humane organisations in many countries.
>
> **Life-time care facilities** devoted to the care of confiscated animals have been built in a few countries.

Specialist societies or clubs devoted to the study and care of single taxa or species(e.g., reptiles, amphibians, birds) have, in some instances, provided an avenue for the disposition of confiscated animals without involving sale through intermediaries. Placement may be made directly to these organisations or to individuals who are members.

Humane Societies may be willing to ensure placement of confiscated specimens with private individuals who can provide humane life-time care.

Research laboratories (either commercial or non-commercial, e.g. universities) maintain collections of exotic animals for many kinds of research (e.g. behavioural, ecological, physiological, psychological, medical). Attitudes towards vivisection, or even towards the non-invasive use of animals in research laboratories as captive study populations, vary widely from country to country. Whether transfer of confiscated animals to research institutions is appropriate will therefore engender some debate. However, it should be noted that transfer to facilities involved in research conducted under humane conditions may offer an alternative -- and one which may eventually contribute information relevant to the species' conservation. In many cases, the lack of known provenance and the risk that the animal in question has been exposed to unknown pathogens will make transfer to a research institution an option that will be rarely exercised or desired.

CAPTIVITY - Sale, Loan or Donation

Animals can be placed with an institution or individual in a number of ways. It is critical, however. that two issues be separated: the ownership of the animals and/or their progeny, and the payment of a fee by the institution/individual receiving the animals. Paying the confiscating authority, or the country of origin, does not necessarily give the person or institution making the payment any rights (these may rest with the confiscating authority). Similarly, ownership of an animal can be transferred without payment. Confiscating authorities and individuals or organizations participating in the placement of confiscated specimens must clarify ownership. both of the specimens being transferred and their progeny. Laws dictating right of ownership of wildlife differ between nations, in some countries ownership remains with the government, in others the owner of the land inhabited by the wildlife has automatic rights over the animals.

When drawing up the terms of transfer many items must be considered, including:

-- ownership of both the animals involved and their offspring (dictated by national law) must be specified as one of the terms and conditions of the transfer (it may be necessary to insist there is no breeding for particular species, e.g. primates). Either the country of origin or the country of confiscation may wish to retain ownership of the animals and/or their progeny. Unless specific legal provisions apply, it is impossible to assure the welfare of the animals following a sale which includes a transfer of ownership.

-- sale or payment of a fee to obtain certain rights (e.g. ownership of offspring) can provide a means of placement that helps offset the costs of confiscation.

--sale and transfer of ownership should only be considered in certain circumstances, such as where the animals in question are not threatened and not subject to a legal proscription on trade (e.g., CITES Appendix I) and there is no risk of stimulating further illegal or irregular trade.

--sale to commercial captive breeders may contribute to reducing the demand for wild-caught individuals.

--sale may risk creating a public perception of the confiscating State perpetuating or benefitting from illegal or irregular trade.

--if ownership is transferred to an organization to achieve a welfare or conservation goal, the confiscating authority should stipulate what will happen to the specimens should the organization wish to sell/transfer the specimens to another organization or individual.

--confiscating authorities should be prepared to make public the conditions under which confiscated animals have been transferred and, where applicable, the basis for any payments involved.

CAPTIVITY-- **Benefits**

The benefits of placing confiscated animals in a facility that will provide life-time care under humane conditions include;

a) educational value;
b) potential for captive breeding for eventual re-introduction;
c) possibility for the confiscating authority to recoup from sale costs of confiscation;
d) potential for captive bred individuals to replace wild-caught animals as a source for trade.

CAPTIVITY- **Concerns**

The concerns raised by placing animals in captivity include:

A) **Disease.** Confiscated animals may serve as vectors for disease. The potential consequences of the introduction of alien disease to a captive facility are more serious than those of introducing disease to wild populations (see discussion page 9); captive conditions might encourage disease spread to not only conspecifics. As many diseases can not be screened for, even the strictest quarantine and most extensive screening for disease can not ensure that an animal is disease free. Where quarantine cannot adequately ensure that an individual is disease free, isolation for an indefinite period, or euthanasia, must be carried out.

B) **Escape.** Captive animals maintained outside their range can escape from captivity and become pests. Accidental introduction of exotic species can cause tremendous damage and in certain cases, such as the escape of mink from fur farms in the United

Kingdom, the introduction of exotics can result from importation of animals for captive rearing.

C) **Cost of Placement**. While any payment will place a value on an animal, there is little evidence that trade would be encouraged if the institution receiving a donation of confiscated animals were to reimburse the confiscating authority for costs of care and transportation. However, payments should be explicitly for reimbursement of costs of confiscation and care, and, where possible, the facility receiving the animals should bear all such costs directly.

D) **Potential to Encourage Undesired Trade**. Some (e.g., Harcourt 1987) have maintained that any transfer - whether commercial or non-commercial - of confiscated animals risks promoting a market for these species aud creating a perception of the confiscating state being involved in illegal or irregular trade.

Birdlife International (in prep.) suggests that in certain circumstances sale of confiscated animals does not necessarily promote undesired trade. They offer the following requirements that must be met for permissible sale by the confiscating authority: I) the species to be sold is already available for sale legally in the confiscating country in commercial quantities; and 2) wildlife traders under indictment for; or convicted of, crimes related to import of wildlife are prevented from purchasing the animals in question. However, experience in selling confiscated animals in the USA suggests that it is virtually impossible to ensure that commercial dealers suspected or implicated in illegal or irregular trade are excluded, directly or indirectly, in purchasing confiscated animals.

In certain circumstances sale or loan to commercial captive breeders may have a clearer potential for the conservation of the species, or welfare of the individuals, than non-commercial disposition or euthanasia. However, such breeding programmes must be carefully assessed as it may be difficult to determine the effects of these programmes on wild populations.

OPTION 2-- RETURN TO THE WILD

These guidelines suggest that return to the wild would be a desirable option in only a very small number of instances and under very specific circumstances. The rationale behind many of the decision options iii this section are discussed in greater detail in the IUCN Re-introduction Guidelines (IUCN/SSC RSG 1995) which, it is important to note, make a clear distinction between the different options for returning animals to the wild. These are elaborated below.

I) **Re-introduction**: an attempt to establish a population in an area that was once part of the range of the species but from which it has become extirpated.
Some of the best known re-introductions have been of species that had become extinct in the wild. Examples include: Pere David's deer (*Elaphurus davidanus*) and the Arabian

oryx (*Oryx leucoryx.*). Other re-introduction programmes have involved species that exist in some parts of their historical range but have been eliminated from other areas; the aim of these programmes is to re-establish a population in all area, or region, from which the species has disappeared. An example of this type of r~introduction is the recent re-introduction of the swift fox (*Vulpes velox*) in Canada.

2) **Reinforcement of an Existing Population**: the addition of individuals to all existing population of the same taxon.

Reinforcement can be a powerful conservation tool when natural populations are diminished by a process which, at least in theory, can be reversed. An example of a successful reinforcement project is the golden lion tamarin *(Leontopithecus rosalia)* project in Brazil. Habitat loss, coupled with capture of live animals for pets, resulted in a rapid decline of the golden lion tamarin. when reserves were expanded, and capture for the pet trade curbed, captive-bred golden lion tamarins were then used to supplement depleted wild populations.

Reinforcement has been most commonly pursued when individual animals injured by human activity have been provided with veterinary care and released. Such activities are common in many western countries, and specific programmes exist for species as diverse as hedgehogs and birds of prey. However common an activity, reinforcement carries with it the very grave risk that individuals held in captivity, even temporarily, are potential vectors for the introduction of disease into wild populations.

Because of inherent disease risks and potential behavioural abnormalities, reinforcement should only be employed in instances where there is a direct and measurable conservation benefit (demographically and/or genetically, and/or to enhance conservation in the public's eye), for example when reinforcement will significantly add to the viability of the wild population into which an individual is being placed.

3) **Conservation Introductions:** (also referred to as Beneficial or Benign Introductions - IUCN 1995): an attempt to establish a species, for the purpose of conservation, outside its recorded distribution but within a suitable habitat in which a population can be established without predicted detriment to native species.

Extensive use of conservation introductions has been made in New Zealand, where endangered birds have been transferred to off-shore islands that were adjacent to, but not part of the animals' original range. Conservation introductions can also be a component of a larger programme of re-introduction, an example being the breeding of red wolves on islands outside their natural range and subsequent transfer to mainland range areas (Smith 1990).

RETURN To THE WILD - CONCERNS

Before return to the wild of confiscated animals is considered, several issues of concern must be considered in general terms; welfare, conservation value, cost, and disease.

a) **Welfare**. While some consider return to the wild to be humane, ill-conceived projects may return animals to the wild which then die from starvation or suffer an inability to adapt to an unfamiliar or inappropriate environment. This is not humane. Humane considerations require that each effort to return confiscated animals to the wild be thoroughly researched and carefully planned. Such returns also require long-term commitment in terms of monitoring the fate of released individuals. Some (e.g., International Academy of Animal Welfare Sciences 1992) have advocated that the survival prospects for released animals must at least approximate those of wild animals of the same sex and age class in order for return to the wild to be seriously considered. While such demographic data on wild populations are, unfortunately, rarely available, the spirit of this suggestion should be respected -- there must be humane treatment of confiscated animals when attempting to return them to the wild.

b) **Conservation Value And Cost**. In cases where returning confiscated animals to the wild appears to be the most humane option, such action can only be undertaken if it does not threaten existing populations of conspecifics or populations of other interacting species, or the ecological integrity of the area in which they live. The conservation of the species as a whole, and of other animals already living free, must take precedent over the welfare of individual animals that are already in captivity.

Before animals are used in programmes in which existing populations are reinforced, or new populations are established, it must be determined that returning these individuals to the wild will make a significant contribution to the conservation of the species, or populations of other interacting species. Based solely on demographic considerations, large populations are less likely to go extinct, and therefore reinforcing existing very small wild populations may reduce the probability of extinction. In very small populations a lack of males or females may result in reduced population growth or population decline and, therefore, reinforcing a very small population lacking animals of a particular sex may also improve prospects for survival of that population. However, genetic and behavioural considerations, as well as the possibility of disease introduction, also play a fundamental role in determining the long term survival of a population.

The cost of returning animals to the wild in an appropriate manner can be prohibitive for all but the most endangered species (Stanley Price 1989; Seal et al. 1989). The species for which the conservation benefits clearly outweigh these costs represent a tiny proportion of the species which might, potentially, be confiscated In the majority of cases, the costs of appropriate, responsible (re)introduction will preclude return to the wild. Poorly planned or executed (re)introduction programmes are no better than dumping animals in the wild and should be vigorously opposed on both conservation and humane grounds.

c) **Founders And Numbers Required**. Most re-introductions require large numbers of founders, usually released in smaller groups over a period of time. Hence, small groups of confiscated animals may be inappropriate for re-introduction programmes, and even larger groups will require careful management if they are to have any conservation value for re-introduction programmes. In reality, confiscated specimens will most often only be of potential value for reinforcing an existing population, despite the many potential problems this will entail.

c) **Source of Individuals**. If the precise provenance of the animals is not known (they may be from several different provenances), or if there is any question of the source of animals, supplementation may lead to inadvertent pollution of distinct genetic races or sub~species. If particular local races or sub-species show specific adaptation to their local environments mixing in individuals from other races or sub-species may be damaging to the local population. Introducing an individual or individuals into the wrong habitat type may also doom that individual to death.

a) **Disease**. Animals held in captivity and/or transported, even for a very short time, may be exposed to a variety of pathogens. Release of these animals to the wild may result in introduction of disease to con-specifics or unrelated species with potentially catastrophic effects. Even if there is a very small risk that confiscated animals have been infected by exotic pathogens, the potential effects of introduced diseases on wild populations are so great that this will often prevent returning confiscated animals to the wild (Woodford and Rossiter 1993, papers in *J Zoo and Wildlife Medicine* 24(3), 1993).

Release of any animal into the wild which has been held in captivity is risky. Animals held in captivity are more likely to acquire diseases and parasites. While some of these diseases can be tested for, tests do not exist for many animal diseases. Furthermore, animals held in captivity are frequently exposed to diseases not usually encountered in their natural habitat. Veterinarians and quarantine officers, taking that the species in question is only susceptible to certain diseases, may not test for the diseases picked up in captivity. It should be assumed that all diseases are potentially contagious.

Given that any release incurs some risk, the following "precautionary principle" must be adopted: *if there is no conservation value in releasing confiscated specimens, the possibility of accidentally introducing a disease, or behavioural and genetic aberrations into the environment which are not already present, however unlikely, may rule out returning confiscated specimens to the wild as a placement option.*

RETURN To THE WILD: BENEFITS

There are several benefits of returning animals to the wild, either through re-introduction for the establishment of a new population or reinforcement of an existing population.

a) **Threatened Populations**: In situations where the existing population is severely threatened, such an action might improve the long-term conservation potential of the species as a whole, or of a local population of the species (e.g., golden lion tamarins).

b) **Public Statement**: Returning animals to the wild makes a strong political/educational statement concerning the fate of animals (e.g., orangutans (*Pongo pygmaeus*) and chimpanzees *(Pan troglodytes*) - Aveling & Mitchell 1982, but see Rijksen & Rijksen-Graatsma 1979) and may serve to promote local conservation values. However, as part of any education or public awareness programmes, the costs and difficulties associated with the return to the wild must be emphasized.

OPTION 3- EUTHANASIA

Euthanasia: the <u>killing</u> of animals carried out according to humane guidelines -- is unlikely to be a popular option amongst confiscating authorities for disposition of confiscated animals. However, it cannot be over-stressed that euthanasia may frequently be the most feasible option available for economic, conservation and humane reasons. hi many cases, authorities confiscating live animals will encounter the following situations:

a) Return to the wild in some manner is either unnecessary (e.g., in the case of a very common species), impossible, or prohibitively expensive as a result of the need to conform to biological (IUCN/SSC RSG ~995) and animal welfare guidelines (International Academy of We1fare Sciences 1992).

b) Placement in a captive facility is impossible, or there are serious concerns that sale will be problematic or controversial.

c) During transport, or while held in captivity, the animals have contracted a chronic disease that is incurable and, therefore, are a risk to any captive or wild population. hi such situations, there may be no practical alternative to euthanasia.

EUTHANASIA -ADVANTAGES:

a) From the point of view of conservation of the species involved, and of protection of existing captive and wild populations of animals, euthanasia carries far fewer risks (e.g. loss of any unique behavioural/genetic/ecological variations within an individual representing variation within the species) when compared to returning animals to the wild.

b) Euthanasia will also act to discourage the activities that gave rise to confiscation, be it smuggling or other patently illegal trade, incomplete or irregular paperwork, poor packing, or other problems, as the animals in question are removed entirely from trade.

c) Euthanasia may be in the best interest of the welfare of the confiscated animals. Release to the wild will carry enormous risks for existing wild populations and may pose severe challenges to the survival prospects of the individual animals, who may, as a result, die of starvation, disease or predation.

d) Cost: euthanasia is cheap compared to other options. There is potential for diverting resources which might have been used for re-introduction or lifetime care to conservation of the species in the wild.

When animals are euthanized, or when they die a natural death while in captivity, the dead specimen should be placed in the collection of a natural history museum, or another reference collection in a university or research institute. Such reference collections are of great importance to studies of biodiversity. if such placement is impossible, carcasses should be incinerated to avoid illegal trade in animal parts or derivatives.

EUTHANASIA- RISKS

a) There is a risk of losing unique behavioural, genetic and ecological material within an individual or group of individuals that represents variation within a species.

DECISION TREE ANALYSIS

For decision trees dealing with "Return to the Wild" and "Captive Options" the confiscating party must first ask the question:

Question 1: Will "Return to the Wild" make a significant contribution to the conservation of the species?

The most important consideration in deciding on placement of confiscated specimens is the conservation of the species in question. Conservation interests are best served by ensuring the survival of as many individuals as possible. The release of confiscated animals therefore must improve the prospects for survival of the existing wild population. Returning an individual to the wild that has benn held in captivity will always involve some level of risk to existing populations of the same or other species in the ecosystem to which the animal is returned because there can never be absolute certainty that a confiscated animal is disease- and parasite-free. In most instances, the benefits of return to the wild will be outweighed by the costs and risks of such an action. If returning animals to the wild is not of conservation value, captive options pose fewer risks and may offer more humane alternatives.

Q1 Answer: No: Investigate "Captive Options"
Yes: Investigate "Return to the Wild Options"

DECISION TREE ANALYSIS: CAPTIVITY

The decision to maintain confiscated animals in captivity involves a simpler set of considerations than that involving attempts to return confiscated animals to the wild.

Question 2: Have animals been subjected to a comprehensive veterinary screening and quarantine?

Animals that may be transferred to captive facilities must have a clean bill of health because of the risk of introducing disease to captive populations.

Theses animals must be placed in quarantine to determine if they are disease-free before being transferred to a captive-breeding facility.

Q2 Answer: Yes: Proceed to Question 3.
No: Quarantine and screen and move to Question 3.

Question 3: Have animals been found to be disease-free by comprehensive veterinary screening and quarantine or can they be treated for any infection discovered?

If; during quarantine animals are found to harbour diseases that cannot reasonably be cured, they must be euthanized to prevent infection of other animals. If the animals are suspected to have come into contact with diseases for which screening is impossible, extended quarantine, donation to a research facility, or euthanasia must be considered.

Q3 Answer: Yes: Proceed to Question 4
No: If chronic and incurable infection, first offer animals to research institutions. impossible to place in such institutions, euthanize.

Question 4: Are there grounds for concern that sale will stimulate further illegal or irregular trade?

Commercial sale of Appendix I species is not permitted under the Convention as it is undesirable to stimulate trade in these species. Species not listed in any CITES appendix, but which are nonetheless seriously threatened with extinction, should be afforded the same caution.

Sale of confiscated animals, where legally permitted, is a difficult option to consider. while the benefits of sale -- income and quick disposition -- are clear, there are many problems that may arise as a result of further commercial transactions of the specimens involved. Equally, it should be noted that there may be circumstances where such problems arise as a result of a non-commercial transaction or that, conversely, sale to commercial captive breeders may contribute to production of young offsetting the capture from the wild.

More often than not, sale of threatened species should not take place. Such sales or trade in threatened species may be legally proscribed in some countries, or by CITES. There may be rare cases where a commercial captive breeding operation may purchase or receive individuals for breeding, which may reduce pressure on wild populations subject to trade. In all circumstances, the confiscating authority should be satisfied that:

1) those involved in the illegal or irregular transaction that gave rise to confiscation cannot obtain the animals;
2) the sale does not compromise the objective of confiscation; and, finally,
3) the sale will not increase illegal, irregular or otherwise undesired trade in the species.

Previous experience with sale in some countries (e.g., the USA) has indicated that selling confiscated animals is beset by both logistic and political problems and that, in addition to being controversial, it may also be counter-productive to conservation objectives.

Q4 Answer: Yes: Proceed to Question 5a.
No: Proceed to Question 5b.

Question 5a: Is space available in a non-commercial captive facility (e.g., life-time care facility, zoo, rescue centre, specialist society, their members or private individuals)?

Question 5b: Is space available in a non-commercial captive facility (e.g., life-time care facility, zoo, rescue centre, specialist society, their members or private individuals) or is there a commercial facility breeding this species, and is the facility interested in the animals?

Transfer of animals to non-commercial captive-breeding facilities, if sale may stimulate further illegal or irregular trade, or commercial captive breeding facilities, an option only if sale will not stimulate further illegal or irregular trade, should generally provide a safe and acceptable means of disposition of confiscated animals. when a choice must be made between several such institutions, the paramount consideration should be which facility can:

1) offer the opportunity for the animals to participate in a captive breeding programme;
2) provide the most consistent care; and
3) ensure the welfare of the animals.

The terms and conditions of the transfer should be agreed between the confiscating authority and the recipient institution. Terms and conditions for such agreements should include:

I) a clear commitment to ensure life-time care or, in the event that this becomes impossible, transfer to another facility that can ensure life-time care, or euthanasia;
2) clear specification of ownership of the specimens concerned (as determined by national law) and, where breeding may occur, the offspring. Depending on the circumstances, ownership may be vested with the confiscating authority, the country of origin or export, or with the recipient facility.
3) clear specification of conditions under which the animal(s) or their progeny may be sold.

In the majority of instances, there will be no facilities or zoo or aquarium space available in the country in which animals are confiscated. Where this is the case other captive options should be investigated. This could include transfer to a captive facility outside the country of confiscation particularly in the country of origin, or, if transfer will not stimulate further illegal trade, placement in a commercial captive breeding facility. However, these breeding programmes must be carefully assessed and approached with caution. It may be difficult to monitor these programmes and such programmes may unintentionally, or intentionally, stimulate trade in wild animals. The conservation potential of this transfer, or breeding loan, must be carefully weighed against even the smallest risk of stimulating trade which would further endanger the wild population of the species.

In many countries, there are active specialist societies or clubs of individuals with considerable expertise in the husbandry and breeding of individual Species or groups of Species. Such societies can assist in finding homes for confiscated animals without involving sale through intermediaries. In this case, individuals receiving confiscated animals must have demonstrated expertise in the husbandry of the species concerned and must be provided with adequate information and advice by the club or society concerned. Transfer to specialist societies or individual members must be made according to terms and conditions agreed with the confiscating authority. Such agreements may be the same or similar to those executed with Lifetime Care facilities or zoos. Placement with these societies or members is an option if sale of the confiscated animals may or may not stimulate trade.

Q5 Answer: Yes: Execute agreement and Sell
No: Proceed to Question 6.

Question 6: Are institutions interested in animals for research under humane conditions?

Many research laboratories maintain collections of exotic animals for research conducted under humane conditions. If these animals are kept in conditions that ensure their welfare, transfer to such institutions may provide an acceptable alterative to other options, such as sale or euthanasia. As in the preceding instances, such transfer should be subject to terms and conditions agreed with the confiscating authority; in addition to those already suggested, it may be advisable to include terms that stipulate the types of research the confiscating authority considers permissible. If no placement is possible, the animals should be euthanized.

Q6 Answer: Yes: Execute Agreement and Transfer.
No: Euthanize.

DECISION TREE ANALYSIS -- RETURN TO THE WILD

Question 2: Have animals been subjected to a comprehensive veterinary screening and quarantine?

Because of the risk of introducing disease to wild populations, animals that may be released must have a clean bill of health. These animals must be placed in quarantine to determine if they are disease free before being considered for released.

Q2 Answer: Yes: Proceed to Question 3.
No: Quarantine and screen and move to Question 3

Question 3: Have animals been found to be disease free by comprehensive veterinary screening and quarantine or can they be treated for any infection discovered?

1. If during quarantine, the animals are found to harbour diseases that cannot reasonably be cured, unless any institutions are interested in the animals for research under humane conditions, they must be euthanized to prevent infection of other animals. If the animals are suspected to have come into contact with diseases for which screening is impossible, extended quarantine, donation to a research facility, or euthanasia must be considered.

Q3 Answer: Yes: Proceed to Question 4
No: if chronic and incurable infection, first offer animals to research institutions. if impossible to place in such institutions, euthanize.

Question 4: Can country of origin and site of capture be confirmed?

The geographical location from which confiscated individuals have been removed from the wild must be determined if these individuals are to be re-introduced or used to supplement existing populations. In most cases, animals should only be returned to the population from which they were taken, or from populations which are known to have natural exchange of individuals with this population.

If provenance of the animals is not known, release for reinforcement may lead to inadvertent hybridisation of distinct genetic races or sub-species. Related species of animals that may live in sympatry in the wild and never hybridise have been known to hybridise when held in captivity or shipped in multi-Species groups. This type of generalisation of species recognition under abnormal conditions can result in behavioural problems compromising the success of any future release and can also pose a threat to wild populations by artificially destroying reproductive isolation that is behaviourally mediated.

Q4 Answer: Yes: Proceed to Question 5.
No: Pursue 'Captive Options'.

Question 5: Do the animals exhibit behavioural abnormalities which might make them unsuitable for return to the wild?

Behavioural abnormalities as a result of captivity can result in animals which are not suitable for release into the wild. A wide variety of behavioural traits and specific behavioural skills are necessary for survival, in the short-term for the individual, and in the long-term for the population. Skills for hunting, avoiding predators, food selectivity etc. are necessary to ensure survival.

Q5 Answer: Yes: Pursue 'Captive Options'.
No; Proceed to Question 6.

Question 6:Can individuals be returned expeditiously to origin (specific location), and will benefits to conservation of the species outweigh any risks of such action?

Repatriation of the individual and reinforcement of the population will only be options under certain conditions and following the IUCN/RSG 1995 guidelines:

1) Appropriate habitat for such an operation still exists in the specific location that the individual was removed from; and
2) sufficient funds are available, or can be made available.

Q6 Answer: Yes: Repatriate and reinforce at origin (specific location) following IUCN guidelines.
No: Proceed to Question 7.

Question 7: For the species in question, does a generally recognized programme exist whose aim is conservation of the species and eventual return to the wild of confiscated individuals and or their progeny? Contact IUCN/SSC, IUDZG, Studbook Keeper, or Breeding Programme Coordinator.

In the case of Species for which active captive breeding and or re-introduction programmes exist, and for which further breeding stock/founders are required, confiscated animals should be transferred to such programmes after consultation with the appropriate scientific authorities. If the Species in question is part of a captive breeding programme, but the taxon (sub-species or race) is not part of this programme (e.g. Maguire & Lacy 1990), other methods of disposition must be considered. Particular attention should be paid to genetic screening to avoid jeopardizing captive breeding programmes through inadvertent hybridisation.

Q7 Answer: Yes: Executer agreement and transfer to existing programme.
No: Proceed to Question 8.

Question 8: Is there a need and is it feasible to establish a new reintroduction programme following IUCN Guidelines?

In cases where individuals cannot be transferred to existing reintroduction programmes, return to the wild, following appropriate guidelines, will only be possible under the following circumstances: 1) appropriate habitat exists for such an operation; 2) sufficient funds are available, or can be made available, to support a programme over the many years that (re)introduction will require; and 3) either sufficient numbers of animals are available so that re-introduction efforts are potentially viable, or only reinforcement of existing populations is considered. In the majority of cases, at least one, if not all, of these requirements will fail to be met. In this instance, either conservation introductions outside the historical range of the Species or other options for disposition of the animals must be considered.

It should be emphasized that if a particular species or taxon is confiscated with some frequency, consideration should be made as to whether to establish a re-introduction, reinforcement, or introduction programme. Animals should not be held by the confiscating authority indefinitely while such programmes are planned, but should be transferred to a holding facility after consultation with the organization which is establishing the new programme.

Q8 Answer: Yes: Execute agreement and transfer to holding facility or new programme.
No: Pursue 'Captive Options'.

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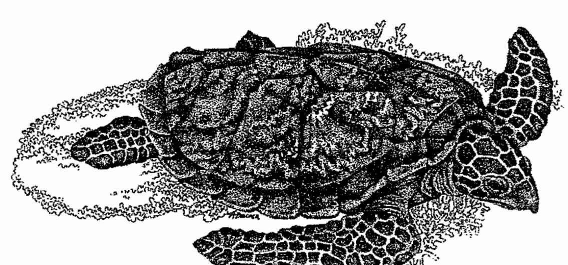
MARINE TURTLES OF INDONESIA

POPULATION VIABILITY AND CONSERVATION ASSESSMENT AND MANAGEMENT WORKSHOP

December 11-14, 1995
Cisarua, Indonesia

Section 9:
VORTEX Technical Reference



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VORTEX: A Computer Simulation Model for Population Viability Analysis

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Abstract

Population Viability Analysis (PVA) is the estimation of extinction probabilities by analyses that incorporate identifiable threats to population survival into models of the extinction process. Extrinsic forces, such as habitat loss, over-harvesting, and competition or predation by introduced species, often lead to population decline. Although the traditional methods of wildlife ecology can reveal such deterministic trends, random fluctuations that increase as populations become smaller can lead to extinction even of populations that have, on average, positive population growth when below carrying capacity. Computer simulation modelling provides a tool for exploring the viability of populations subjected to many complex, interacting deterministic and random processes. One such simulation model, VORTEX, has been used extensively by the Captive Breeding Specialist Group (Species Survival Commission, IUCN), by wildlife agencies, and by university classes. The algorithms, structure, assumptions and applications of VORTEX are described in this paper.

VORTEX models population processes as discrete, sequential events, with probabilistic outcomes. VORTEX simulates birth and death processes and the transmission of genes through the generations by generating random numbers to determine whether each animal lives or dies, to determine the number of progeny produced by each female each year, and to determine which of the two alleles at a genetic locus are transmitted from each parent to each offspring. Fecundity is assumed to be independent of age after an animal reaches reproductive age. Mortality rates are specified for each pre-reproductive age–sex class and for reproductive-age animals. Inbreeding depression is modelled as a decrease in viability in inbred animals.

The user has the option of modelling density dependence in reproductive rates. As a simple model of density dependence in survival, a carrying capacity is imposed by a probabilistic truncation of each age class if the population size exceeds the specified carrying capacity. VORTEX can model linear trends in the carrying capacity. VORTEX models environmental variation by sampling birth rates, death rates, and the carrying capacity from binomial or normal distributions. Catastrophes are modelled as sporadic random events that reduce survival and reproduction for one year. VORTEX also allows the user to supplement or harvest the population, and multiple subpopulations can be tracked, with user-specified migration among the units.

VORTEX outputs summary statistics on population growth rates, the probability of population extinction, the time to extinction, and the mean size and genetic variation in extant populations.

VORTEX necessarily makes many assumptions. The model it incorporates is most applicable to species with low fecundity and long lifespans, such as mammals, birds and reptiles. It integrates the interacting effects of many of the deterministic and stochastic processes that have an impact on the viability of small populations, providing opportunity for more complete analysis than is possible by other techniques. PVA by simulation modelling is an important tool for identifying populations at risk of extinction, determining the urgency of action, and evaluating options for management.

Introduction

Many wildlife populations that were once widespread, numerous, and occupying contiguous habitat, have been reduced to one or more small, isolated populations. The causes of the original decline are often obvious, deterministic forces, such as over-harvesting,

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habitat destruction, and competition or predation from invasive introduced species. Even if the original causes of decline are removed, a small isolated population is vulnerable to additional forces, intrinsic to the dynamics of small populations, which may drive the population to extinction (Shaffer 1981; Soulé 1987; Clark and Seebeck 1990). Of particular impact on small populations are stochastic processes. With the exception of aging, virtually all events in the life of an organism are stochastic. Mating, reproduction, gene transmission between generations, migration, disease and predation can be described by probability distributions, with individual occurrences being sampled from these distributions. Small samples display high variance around the mean, so the fates of small wildlife populations are often determined more by random chance than by the mean birth and death rates that reflect adaptations to their environment.

Although many processes affecting small populations are intrinsically indeterminate, the average long-term fate of a population and the variance around the expectation can be studied with computer simulation models. The use of simulation modelling, often in conjunction with other techniques, to explore the dynamics of small populations has been termed Population Viability Analysis (PVA). PVA has been increasingly used to help guide management of threatened species. The Resource Assessment Commission of Australia (1991) recently recommended that 'estimates of the size of viable populations and the risks of extinction under multiple-use forestry practices be an essential part of conservation planning'. Lindenmayer *et al.* (1993) describe the use of computer modelling for PVA, and discuss the strengths and weaknesses of the approach as a tool for wildlife management.

In this paper, I present the PVA program VORTEX and describe its structure, assumptions and capabilities. VORTEX is perhaps the most widely used PVA simulation program, and there are numerous examples of its application in Australia, the United States of America and elsewhere.

The Dynamics of Small Populations

The stochastic processes that have an impact on populations have been usefully categorised into demographic stochasticity, environmental variation, catastrophic events and genetic drift (Shaffer 1981). Demographic stochasticity is the random fluctuation in the observed birth rate, death rate and sex ratio of a population even if the probabilities of birth and death remain constant. On the assumption that births and deaths and sex determination are stochastic sampling processes, the annual variations in numbers that are born, die, and are of each sex can be specified from statistical theory and would follow binomial distributions. Such demographic stochasticity will be important to population viability only in populations that are smaller than a few tens of animals (Goodman 1987), in which cases the annual frequencies of birth and death events and the sex ratios can deviate far from the means. The distribution of annual adult survival rates observed in the remnant population of whooping cranes (*Grus americana*) (Mirande *et al.* 1993) is shown in Fig. 1. The innermost curve approximates the binomial distribution that describes the demographic stochasticity expected when the probability of survival is 92·7% (mean of 45 non-outlier years).

Environmental variation is the fluctuation in the probabilities of birth and death that results from fluctuations in the environment. Weather, the prevalence of enzootic disease, the abundances of prey and predators, and the availability of nest sites or other required microhabitats can all vary, randomly or cyclically, over time. The second narrowest curve on Fig. 1 shows a normal distribution that statistically fits the observed frequency histogram of crane survival in non-outlier years. The difference between this curve and the narrower distribution describing demographic variation must be accounted for by environmental variation in the probability of adult survival.

Catastrophic variation is the extreme of environmental variation, but for both methodological and conceptual reasons rare catastrophic events are analysed separately from the more typical annual or seasonal fluctuations. Catastrophes such as epidemic disease,

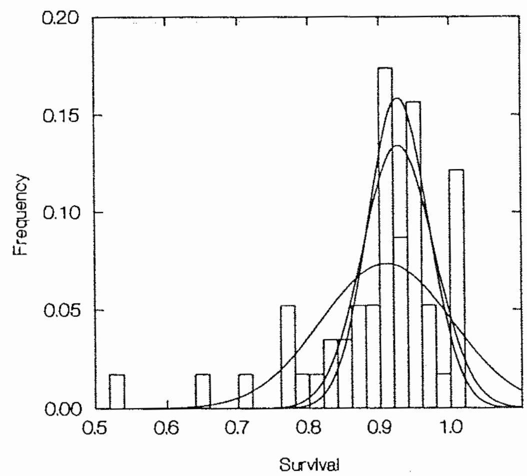

Fig. 1. Frequency histogram of the proportion of whooping cranes surviving each year, 1938–90. The broadest curve is the normal distribution that most closely fits the overall histogram. Statistically, this curve fits the data poorly. The second highest and second broadest curve is the normal distribution that most closely fits the histogram, excluding the five leftmost bars (7 outlier 'catastrophe' years). The narrowest and tallest curve is the normal approximation to the binomial distribution expected from demographic stochasticity. The difference between the tallest and second tallest curves is the variation in annual survival due to environmental variation.

hurricanes, large-scale fires, and floods are outliers in the distribution of environmental variation (e.g. five leftmost bars on Fig. 1). As a result, they have quantitatively and sometimes qualitatively different impacts on wildlife populations. (A forest fire is not just a very hot day.) Such events often precipitate the final decline to extinction (Simberloff 1986, 1988). For example, one of two populations of whooping crane was decimated by a hurricane in 1940 and soon after went extinct (Doughty 1989). The only remaining population of the black-footed ferret (*Mustela nigripes*) was being eliminated by an outbreak of distemper when the last 18 ferrets were captured (Clark 1989).

Genetic drift is the cumulative and non-adaptive fluctuation in allele frequencies resulting from the random sampling of genes in each generation. This can impede the recovery or accelerate the decline of wildlife populations for several reasons (Lacy 1993). Inbreeding, not strictly a component of genetic drift but correlated with it in small populations, has been documented to cause loss of fitness in a wide variety of species, including virtually all sexually reproducing animals in which the effects of inbreeding have been carefully studied (Wright 1977; Falconer 1981; O'Brien and Evermann 1988; Ralls *et al.* 1988; Lacy *et al.* 1993). Even if the immediate loss of fitness of inbred individuals is not large, the loss of genetic variation that results from genetic drift may reduce the ability of a population to adapt to future changes in the environment (Fisher 1958; Robertson 1960; Selander 1983).

Thus, the effects of genetic drift and consequent loss of genetic variation in individuals and populations have a negative impact on demographic rates and increase susceptibility to environmental perturbations and catastrophes. Reduced population growth and greater fluctuations in numbers in turn accelerate genetic drift (Crow and Kimura 1970). These synergistic destabilising effects of stochastic process on small populations of wildlife have been described as an 'extinction vortex' (Gilpin and Soulé 1986). The size below which a population is likely to be drawn into an extinction vortex can be considered a 'minimum viable population' (MVP) (Seal and Lacy 1989), although Shaffer (1981) first defined a MVP more stringently as a population that has a 99% probability of persistence for 1000 years. The estimation of MVPs or, more generally, the investigation of the probability of extinction constitutes PVA (Gilpin and Soulé 1986; Gilpin 1989; Shaffer 1990).

Methods for Analysing Population Viability

An understanding of the multiple, interacting forces that contribute to extinction vortices is a prerequisite for the study of extinction–recolonisation dynamics in natural populations inhabiting patchy environments (Gilpin 1987), the management of small populations (Clark and Seebeck 1990), and the conservation of threatened wildlife (Shaffer 1981, 1990; Soulé 1987; Mace and Lande 1991). Because demographic and genetic processes in small populations are inherently unpredictable, the expected fates of wildlife populations can be described in terms of probability distributions of population size, time to extinction, and genetic variation. These distributions can be obtained in any of three ways: from analytical models, from empirical observation of the fates of populations of varying size, or from simulation models.

As the processes determining the dynamics of populations are multiple and complex, there are few analytical formulae for describing the probability distributions (e.g. Goodman 1987; Lande 1988; Burgmann and Gerard 1990). These models have incorporated only few of the threatening processes. No analytical model exists, for example, to describe the combined effect of demographic stochasticity and loss of genetic variation on the probability of population persistence.

A few studies of wildlife populations have provided empirical data on the relationship between population size and probability of extinction (e.g. Belovsky 1987; Berger 1990; Thomas 1990), but presently only order-of-magnitude estimates can be provided for MVPs of vertebrates (Shaffer 1987). Threatened species are, by their rarity, unavailable and inappropriate for the experimental manipulation of population sizes and long-term monitoring of undisturbed fates that would be necessary for precise empirical measurement of MVPs. Retrospective analyses will be possible in some cases, but the function relating extinction probability to population size will differ among species, localities and times (Lindenmayer *et al.* 1993).

Modelling the Dynamics of Small Populations

Because of the lack of adequate empirical data or theoretical and analytical models to allow prediction of the dynamics of populations of threatened species, various biologists have turned to Monte Carlo computer simulation techniques for PVA. By randomly sampling from defined probability distributions, computer programs can simulate the multiple, interacting events that occur during the lives of organisms and that cumulatively determine the fates of populations. The focus is on detailed and explicit modelling of the forces impinging on a given population, place, and time of interest, rather than on delineation of rules (which may not exist) that apply generally to most wildlife populations. Computer programs available to PVA include SPGPC (Grier 1980*a*, 1980*b*), GAPPS (Harris *et al.* 1986), RAMAS (Ferson and Akçakaya 1989; Akçakaya and Ferson 1990; Ferson 1990), FORPOP (Possingham *et al.* 1991), ALEX (Possingham *et al.* 1992), and SIMPOP (Lacy *et al.* 1989; Lacy and Clark 1990) and its descendant VORTEX.

SIMPOP was developed in 1989 by converting the algorithms of the program SPGPC (written by James W. Grier of North Dakota State University) from BASIC to the C programming language. SIMPOP was used first in a PVA workshop organised by the Species Survival Commission's Captive Breeding Specialist Group (IUCN), the United States Fish and Wildlife Service, and the Puerto Rico Department of Natural Resources to assist in planning and assessing recovery efforts for the Puerto Rican crested toad (*Peltophryne lemur*). SIMPOP was subsequently used in PVA modelling of other species threatened with extinction, undergoing modification with each application to allow incorporation of additional threatening processes. The simulation program was renamed VORTEX (in reference to the extinction vortex) when the capability of modelling genetic processes was implemented in 1989. In 1990, a version allowing modelling of multiple populations was briefly named VORTICES. The only version still supported, with all capabilities of each previous version, is VORTEX Version 5.1.

VORTEX has been used in PVA to help guide conservation and management of many species, including the Puerto Rican parrot (*Amazona vittata*) (Lacy *et al.* 1989), the Javan rhinoceros (*Rhinoceros sondaicus*) (Seal and Foose 1989), the Florida panther (*Felis concolor coryi*) (Seal and Lacy 1989), the eastern barred bandicoot (*Perameles gunnii*) (Lacy and Clark 1990; Maguire *et al.* 1990), the lion tamarins (*Leontopithecus rosalia* ssp.) (Seal *et al.* 1990), the brush-tailed rock-wallaby (*Petrogale penicillata penicillata*) (Hill 1991), the mountain pygmy-possum (*Burramys parvus*), Leadbeater's possum (*Gymnobelideus leadbeateri*), the long-footed potoroo (*Potorous longipes*), the orange-bellied parrot (*Neophema chrysogaster*) and the helmeted honeyeater (*Lichenostomus melanops cassidix*) (Clark *et al.* 1991), the whooping crane (*Grus americana*) (Mirande *et al.* 1993), the Tana River crested mangabey (*Cercocebus galeritus galeritus*) and the Tana River red colobus (*Colobus badius rufomitratus*) (Seal *et al.* 1991), and the black rhinoceros (*Diceros bicornis*) (Foose *et al.* 1992). In some of these PVAs, modelling with VORTEX has made clear the insufficiency of past management plans to secure the future of the species, and alternative strategies were proposed, assessed and implemented. For example, the multiple threats to the Florida panther in its existing habitat were recognised as probably insurmountable, and a captive breeding effort has been initiated for the purpose of securing the gene pool and providing animals for release in areas of former habitat. PVA modelling with VORTEX has often identified a single threat to which a species is particularly vulnerable. The small but growing population of Puerto Rican parrots was assessed to be secure, except for the risk of population decimation by hurricane. Recommendations were made to make available secure shelter for captive parrots and to move some of the birds to a site distant from the wild flock, in order to minimise the damage that could occur in a catastrophic storm. These recommended actions were only partly implemented when, in late 1989, a hurricane killed many of the wild parrots. The remaining population of about 350 Tana River red colobus were determined by PVA to be so fragmented that demographic and genetic processes within the 10 subpopulations destabilised population dynamics. Creation of habitat corridors may be necessary to prevent extinction of the taxon. In some cases, PVA modelling has been reassuring to managers: analysis of black rhinos in Kenya indicated that many of the populations within sanctuaries were recovering steadily. Some could soon be used to provide animals for re-establishment or supplementation of populations previously eliminated by poaching. For some species, available data were insufficient to allow definitive PVA with VORTEX. In such cases, the attempt at PVA modelling has made apparent the need for more data on population trends and processes, thereby helping to justify and guide research efforts.

Description of VORTEX

Overview

The VORTEX computer simulation model is a Monte Carlo simulation of the effects of deterministic forces, as well as demographic, environmental and genetic stochastic events, on wildlife populations. VORTEX models population dynamics as discrete, sequential events that occur according to probabilities that are random variables, following user-specified distributions. The input parameters used by VORTEX are summarised in the first part of the sample output given in the Appendix.

VORTEX simulates a population by stepping through a series of events that describe an annual cycle of a typical sexually reproducing, diploid organism: mate selection, reproduction, mortality, increment of age by one year, migration among populations, removals, supplementation, and then truncation (if necessary) to the carrying capacity. The program was designed to model long-lived species with low fecundity, such as mammals, birds and reptiles. Although it could and has been used in modelling highly fecund vertebrates and invertebrates, it is awkward to use in such cases as it requires complete specification of the percentage of females producing each possible clutch size. Moreover, computer memory limitations often hamper such analyses. Although VORTEX iterates life events on an annual cycle, a user could model 'years' that are other than 12 months' duration. The simulation of the population is itself iterated to reveal the distribution of fates that the population might experience.

Demographic Stochasticity

VORTEX models demographic stochasticity by determining the occurrence of probabilistic events such as reproduction, litter size, sex determination and death with a pseudo-random number generator. The probabilities of mortality and reproduction are sex-specific and pre-determined for each age class up to the age of breeding. It is assumed that reproduction and survival probabilities remain constant from the age of first breeding until a specified upper limit to age is reached. Sex ratio at birth is modelled with a user-specified constant probability of an offspring being male. For each life event, if the random value sampled from the uniform 0–1 distribution falls below the probability for that year, the event is deemed to have occurred, thereby simulating a binomial process.

The source code used to generate random numbers uniformly distributed between 0 and 1 was obtained from Maier (1991), according to the algorithm of Kirkpatrick and Stoll (1981). Random deviates from binomial distributions, with mean p and standard deviation s, are obtained by first determining the integral number of binomial trials, N, that would produce the value of s closest to the specified value, according to

$$N = p(1-p)/s^2 .$$

N binomial trials are then simulated by sampling from the uniform 0–1 distribution to obtain the desired result, the frequency or proportion of successes. If the value of N determined for a desired binomial distribution is larger than 25, a normal approximation is used in place of the binomial distribution. This normal approximation must be truncated at 0 and at 1 to allow use in defining probabilities, although, with such large values of N, s is small relative to p and the truncation would be invoked only rarely. To avoid introducing bias with this truncation, the normal approximation to the binomial (when used) is truncated symmetrically around the mean. The algorithm for generating random numbers from a unit normal distribution follows Latour (1986).

VORTEX can model monogamous or polygamous mating systems. In a monogamous system, a relative scarcity of breeding males may limit reproduction by females. In polygamous or monogamous models, the user can specify the proportion of the adult males in the breeding pool. Males are randomly reassigned to the breeding pool each year of the simulation, and all males in the breeding pool have an equal chance of siring offspring.

The 'carrying capacity', or the upper limit for population size within a habitat, must be specified by the user. VORTEX imposes the carrying capacity via a probabilistic truncation whenever the population exceeds the carrying capacity. Each animal in the population has an equal probability of being removed by this truncation.

Environmental Variation

VORTEX can model annual fluctuations in birth and death rates and in carrying capacity as might result from environmental variation. To model environmental variation, each demographic parameter is assigned a distribution with a mean and standard deviation that is specified by the user. Annual fluctuations in probabilities of reproduction and mortality are modelled as binomial distributions. Environmental variation in carrying capacity is modelled as a normal distribution. The variance across years in the frequencies of births and deaths resulting from the simulation model (and in real populations) will have two components: the demographic variation resulting from a binomial sampling around the mean for each year, and additional fluctuations due to environmental variation and catastrophes (see Fig. 1 and section on The Dynamics of Small Populations, above).

Data on annual variations in birth and death rates are important in determining the probability of extinction, as they influence population stability (Goodman 1987). Unfortunately, such field information is rarely available (but see Fig. 1). Sensitivity testing, the examination of a range of values when the precise value of a parameter is unknown, can help to identify whether the unknown parameter is important in the dynamics of a population.

Catastrophes

Catastrophes are modelled in VORTEX as random events that occur with specified probabilities. Any number of types of catastrophes can be modelled. A catastrophe will occur if a randomly generated number between zero and one is less than the probability of occurrence. Following a catastrophic event, the chances of survival and successful breeding for that simulated year are multiplied by severity factors. For example, forest fires might occur once in 50 years, on average, killing 25% of animals, and reducing breeding by survivors by 50% for the year. Such a catastrophe would be modelled as a random event with 0·02 probability of occurrence each year, and severity factors of 0·75 for survival and 0·50 for reproduction.

Genetic Processes

Genetic drift is modelled in VORTEX by simulation of the transmission of alleles at a hypothetical locus. At the beginning of the simulation, each animal is assigned two unique alleles. Each offspring is randomly assigned one of the alleles from each parent. Inbreeding depression is modelled as a loss of viability during the first year of inbred animals. The impacts of inbreeding are determined by using one of two models available within VORTEX: a Recessive Lethals model or a Heterosis model.

In the Recessive Lethals model, each founder starts with one unique recessive lethal allele and a unique, dominant non-lethal allele. This model approximates the effect of inbreeding if each individual in the starting population had one recessive lethal allele in its genome. The fact that the simulation program assumes that all the lethal alleles are at the same locus has a very minor impact on the probability that an individual will die because of homozygosity for one of the lethal alleles. In the model, homozygosity for different lethal alleles are mutually exclusive events, whereas in a multilocus model an individual could be homozygous for several lethal alleles simultaneously. By virtue of the death of individuals that are homozygous for lethal alleles, such alleles would be removed slowly by natural selection during the generations of a simulation. This reduces the genetic variation present in the population relative to the case with no inbreeding depression, but also diminishes the subsequent probability that inbred individuals will be homozygous for a lethal allele. This model gives an optimistic reflection of the impacts of inbreeding on many species, as the median number of lethal equivalents per diploid genome observed for mammalian populations is about three (Ralls *et al.* 1988).

The expression of fully recessive deleterious alleles in inbred organisms is not the only genetic mechanism that has been proposed as a cause of inbreeding depression. Some or most of the effects of inbreeding may be a consequence of superior fitness of heterozygotes (heterozygote advantage or 'heterosis'). In the Heterosis model, all homozygotes have reduced fitness compared with heterozygotes. Juvenile survival is modelled according to the logarithmic model developed by Morton *et al.* (1956):

$$\ln S = A - BF$$

in which S is survival, F is the inbreeding coefficient, A is the logarithm of survival in the absence of inbreeding, and B is a measure of the rate at which survival decreases with inbreeding. B is termed the number of 'lethal equivalents' per haploid genome. The number of lethal equivalents per diploid genome, $2B$, estimates the number of lethal alleles per individual in the population if all deleterious effects of inbreeding were due to recessive lethal alleles. A population in which inbreeding depression is one lethal equivalent per diploid genome may have one recessive lethal allele per individual (as in the Recessive Lethals model, above), it may have two recessive alleles per individual, each of which confer a 50% decrease in survival, or it may have some other combination of recessive deleterious alleles that equate in effect with one lethal allele per individual. Unlike the situation with fully recessive deleterious alleles, natural selection does not remove deleterious alleles at heterotic loci because all alleles are deleterious when homozygous and beneficial when present in heterozygous combination with other alleles. Thus, under the Heterosis model, the impact of inbreeding on survival does not diminish during repeated generations of inbreeding.

Unfortunately, for relatively few species are data available to allow estimation of the effects of inbreeding, and the magnitude of these effects varies considerably among species (Falconer 1981; Ralls *et al.* 1988; Lacy *et al.* 1993). Moreover, whether a Recessive Lethals model or a Heterosis model better describes the underlying mechanism of inbreeding depression and therefore the response to repeated generations of inbreeding is not well-known (Brewer *et al.* 1990), and could be determined empirically only from breeding studies that span many generations. Even without detailed pedigree data from which to estimate the number of lethal equivalents in a population and the underlying nature of the genetic load (recessive alleles or heterosis), applications of PVA must make assumptions about the effects of inbreeding on the population being studied. In some cases, it might be considered appropriate to assume that an inadequately studied species would respond to inbreeding in accord with the median (3·14 lethal equivalents per diploid) reported in the survey by Ralls *et al.* (1988). In other cases, there might be reason to make more optimistic assumptions (perhaps the lower quartile, 0·90 lethal equivalents), or more pessimistic assumptions (perhaps the upper quartile, 5·62 lethal equivalents).

Deterministic Processes

VORTEX can incorporate several deterministic processes. Reproduction can be specified to be density-dependent. The function relating the proportion of adult females breeding each year to the total population size is modelled as a fourth-order polynomial, which can provide a close fit to most plausible density-dependence curves. Thus, either positive population responses to low-density or negative responses (e.g. Allee effects), or more complex relationships, can be modelled.

Populations can be supplemented or harvested for any number of years in each simulation. Harvest may be culling or removal of animals for translocation to another (unmodelled) population. The numbers of additions and removals are specified according to the age and sex of animals. Trends in the carrying capacity can also be modelled in VORTEX, specified as an annual percentage change. These changes are modelled as linear, rather than geometric, increases or decreases.

Migration among Populations

VORTEX can model up to 20 populations, with possibly distinct population parameters. Each pairwise migration rate is specified as the probability of an individual moving from one population to another. This probability is independent of the age and sex. Because of between-population migration and managed supplementation, populations can be recolonised. VORTEX tracks the dynamics of local extinctions and recolonisations through the simulation.

Output

VORTEX outputs (1) probability of extinction at specified intervals (e.g., every 10 years during a 100-year simulation), (2) median time to extinction if the population went extinct in at least 50% of the simulations, (3) mean time to extinction of those simulated populations that became extinct, and (4) mean size of, and genetic variation within, extant populations (see Appendix and Lindenmayer *et al.* 1993).

Standard deviations across simulations and standard errors of the mean are reported for population size and the measures of genetic variation. Under the assumption that extinction of independently replicated populations is a binomial process, the standard error of the probability of extinction (SE) is reported by VORTEX as

$$SE(p) = \sqrt{[p \times (1-p)/n]}\ ,$$

in which the frequency of extinction was p over n simulated populations. Demographic and genetic statistics are calculated and reported for each subpopulation and for the metapopulation.

Availability of the VORTEX Simulation Program

VORTEX Version 5.1 is written in the C programming language and compiled with the Lattice 80286C Development System (Lattice Inc.) for use on microcomputers using the MS-DOS (Microsoft Corp.) operating system. Copies of the compiled program and a manual for its use are available for nominal distribution costs from the Captive Breeding Specialist Group (Species Survival Commission, IUCN), 12101 Johnny Cake Ridge Road, Apple Valley, Minnesota 55124, U.S.A. The program has been tested by many workers, but cannot be guaranteed to be error-free. Each user retains responsibility for ensuring that the program does what is intended for each analysis.

Sequence of Program Flow

(1) The seed for the random number generator is initialised with the number of seconds elapsed since the beginning of the 20th century.

(2) The user is prompted for input and output devices, population parameters, duration of simulation, and number of interations.

(3) The maximum allowable population size (necessary for preventing memory overflow) is calculated as

$$N_{max} = (K + 3s) \times (1 + L)$$

in which K is the maximum carrying capacity (carrying capacity can be specified to change linearly for a number of years in a simulation, so the maximum carrying capacity can be greater than the initial carrying capacity), s is the annual environmental variation in the carrying capacity expressed as a standard deviation, and L is the specified maximum litter size. It is theoretically possible, but very unlikely, that a simulated population will exceed the calculated N_{max}. If this occurs then the program will give an error message and abort.

(4) Memory is allocated for data arrays. If insufficient memory is available for data arrays then N_{max} is adjusted downward to the size that can be accommodated within the available memory and a warning message is given. In this case it is possible that the analysis may have to be terminated because the simulated population exceeds N_{max}. Because N_{max} is often several-fold greater than the likely maximum population size in a simulation, a warning it has been adjusted downward because of limiting memory often will not hamper the analyses. Except for limitations imposed by the size of the computer memory (VORTEX can use extended memory, if available), the only limit to the size of the analysis is that no more than 20 populations exchanging migrants can be simulated.

(5) The expected mean growth rate of the population is calculated from mean birth and death rates that have been entered. Algorithms follow cohort life-table analyses (Ricklefs 1979). Generation time and the expected stable age distribution are also estimated. Life-table estimations assume no limitation by carrying capacity, no limitation of mates, and no loss of fitness due to inbreeding depression, and the estimated intrinsic growth rate assumes that the population is at the stable age distribution. The effects of catastrophes are incorporated into the life-table analysis by using birth and death rates that are weighted averages of the values in years with and without catastrophes, weighted by the probability of a catastrophe occurring or not occurring.

(6) Iterative simulation of the population proceeds via steps 7–26 below. For exploratory modelling, 100 iterations are usually sufficient to reveal gross trends among sets of simulations with different input parameters. For more precise examination of population behaviour under various scenarios, 1000 or more simulations should be used to minimise standard errors around mean results.

(7) The starting population is assigned an age and sex structure. The user can specify the exact age–sex structure of the starting population, or can specify an initial population size and request that the population be distributed according to the stable age distribution calculated from the life table. Individuals in the starting population are assumed to be unrelated. Thus, inbreeding can occur only in second and later generations.

(8) Two unique alleles at a hypothetical genetic locus are assigned to each individual in the starting population and to each individual supplemented to the population during the simulation. VORTEX therefore uses an infinite alleles model of genetic variation. The subsequent fate of genetic variation is tracked by reporting the number of extant alleles each year, the expected heterozygosity or gene diversity, and the observed heterozygosity. The expected heterozygosity, derived from the Hardy–Weinberg equilibrium, is given by

$$H_e = 1 - \Sigma(p_i^2),$$

in which p_i is the frequency of allele i in the population. The observed heterozygosity is simply the proportion of the individuals in the simulated population that are heterozygous. Because of the starting assumption of two unique alleles per founder, the initial population has an observed heterozygosity of 1·0 at the hypothetical locus and only inbred animals can become homozygous. Proportional loss of heterozygosity by means of random genetic drift is independent of the initial heterozygosity and allele frequencies of a population (assuming that the initial value was not zero) (Crow and Kimura 1970), so the expected heterozygosity remaining in a simulated population is a useful metric of genetic decay for comparison across scenarios and populations. The mean observed heterozygosity reported by VORTEX is the mean inbreeding coefficient of the population.

(9) The user specifies one of three options for modelling the effect of inbreeding: (a) no effect of inbreeding on fitness, that is, all alleles are selectively neutral, (b) each founder individual has one unique lethal and one unique non-lethal allele (Recessive Lethals option), or (c) first-year survival of each individual is exponentially related to its inbreeding coefficient (Heterosis option). The first case is clearly an optimistic one, as almost all diploid

populations studied intensively have shown deleterious effects of inbreeding on a variety of fitness components (Wright 1977; Falconer 1981). Each of the two models of inbreeding depression may also be optimistic, in that inbreeding is assumed to have an impact only on first-year survival. The Heterosis option allows, however, for the user to specify the severity of inbreeding depression on juvenile survival.

(10) Years are iterated via steps 11–25 below.

(11) The probabilities of females producing each possible litter size are adjusted to account for density dependence of reproduction (if any).

(12) Birth rate, survival rates and carrying capacity for the year are adjusted to model environmental variation. Environmental variation is assumed to follow binomial distributions for birth and death rates and a normal distribution for carrying capacity, with mean rates and standard deviations specified by the user. At the outset of each year a random number is drawn from the specified binomial distribution to determine the percentage of females producing litters. The distribution of litter sizes among those females that do breed is maintained constant. Another random number is drawn from a specified binomial distribution to model the environmental variation in mortality rates. If environmental variations in reproduction and mortality are chosen to be correlated, the random number used to specify mortality rates for the year is chosen to be the same percentile of its binomial distribution as was the number used to specify reproductive rate. Otherwise, a new random number is drawn to specify the deviation of age- and sex-specific mortality rates for their means. Environmental variation across years in mortality rates is always forced to be correlated among age and sex classes.

The carrying capacity (K) of the year is determined by first increasing or decreasing the carrying capacity at year 1 by an amount specified by the user to account for linear changes over time. Environmental variation in K is then imposed by drawing a random number from a normal distribution with the specified values for mean and standard deviation.

(13) Birth rates and survival rates for the year are adjusted to model any catastrophes determined to have occurred in that year.

(14) Breeding males are selected for the year. A male of breeding age is placed into the pool of potential breeders for that year if a random number drawn for that male is less than the proportion of breeding-age males specified to be breeding.

(15) For each female of breeding age, a mate is drawn at random from the pool of breeding males for that year. The size of the litter produced by that pair is determined by comparing the probabilities of each potential litter size (including litter size of 0, no breeding) to a randomly drawn number. The offspring are produced and assigned a sex by comparison of a random number to the specified sex ratio at birth. Offspring are assigned, at random, one allele at the hypothetical genetic locus from each parent.

(16) If the Heterosis option is chosen for modelling inbreeding depression, the genetic kinship of each new offspring to each other living animal in the population is determined. The kinship between a new animal, A, and another existing animal, B is

$$f_{AB} = 0 \cdot 5 \times (f_{MB} + f_{PB})$$

in which f_{ij} is the kinship between animals i and j, M is the mother of A, and P is the father of A. The inbreeding coefficient of each animal is equal to the kinship between its parents, $F = f_{MP}$, and the kinship of an animal to itself is $f_{AA} = 0 \cdot 5 \times (1 + F)$. [See Ballou (1983) for a detailed description of this method for calculating inbreeding coefficients.]

(17) The survival of each animal is determined by comparing a random number to the survival probability for that animal. In the absence of inbreeding depression, the survival probability is given by the age and sex-specific survival rate for that year. If the Heterosis model of inbreeding depression is used and an individual is inbred, the survival probability is multiplied by e^{-bF} in which b is the number of lethal equivalents per haploid genome.

If the Recessive Lethals model is used, all offspring that are homozygous for a lethal allele are killed.

(18) The age of each animal is incremented by 1, and any animal exceeding the maximum age is killed.

(19) If more than one population is being modelled, migration among populations occurs stochastically with specified probabilities.

(20) If population harvest is to occur that year, the number of harvested individuals of each age and sex class are chosen at random from those available and removed. If the number to be removed do not exist for an age–sex class, VORTEX continues but reports that harvest was incomplete.

(21) Dead animals are removed from the computer memory to make space for future generations.

(22) If population supplementation is to occur in a particular year, new individuals of the specified age class are created. Each immigrant is assigned two unique alleles, one of which will be a recessive lethal in the Recessive Lethals model of inbreeding depression. Each immigrant is assumed to be genetically unrelated to all other individuals in the population.

(23) The population growth rate is calculated as the ratio of the population size in the current year to the previous year.

(24) If the population size (N) exceeds the carrying capacity (K) for that year, additional mortality is imposed across all age and sex classes. The probability of each animal dying during this carrying capacity truncation is set to $(N-K)/N$, so that the expected population size after the additional mortality is K.

(25) Summary statistics on population size and genetic variation are tallied and reported. A simulated population is determined to be extinct if one of the sexes has no representatives.

(26) Final population size and genetic variation are determined for the simulation.

(27) Summary statistics on population size, genetic variation, probability of extinction, and mean population growth rate, are calculated across iterations and printed out.

Assumptions Underpinning VORTEX

It is impossible to simulate the complete range of complex processes that can have an impact on wild populations. As a result there are necessarily a range of mathematical and biological assumptions that underpin any PVA program. Some of the more important assumptions in VORTEX include the following.

(1) Survival probabilities are density independent when population size is less than carrying capacity. Additional mortality imposed when the population exceeds K affects all age and sex classes equally.

(2) The relationship between changes in population size and genetic variability are examined for only one locus. Thus, potentially complex interactions between genes located on the same chromosome (linkage disequilibrium) are ignored. Such interactions are typically associated with genetic drift in very small populations, but it is unknown if, or how, they would affect population viability.

(3) All animals of reproductive age have an equal probability of breeding. This ignores the likelihood that some animals within a population may have a greater probability of breeding successfully, and breeding more often, than other individuals. If breeding is not at random among those in the breeding pool, then decay of genetic variation and inbreeding will occur more rapidly than in the model.

(4) The life-history attributes of a population (birth, death, migration, harvesting, supplementation) are modelled as a sequence of discrete and therefore seasonal events. However, such events are often continuous through time and the model ignores the possibility that they may be aseasonal or only partly seasonal.

(5) The genetic effects of inbreeding on a population are determined in VORTEX by using one of two possible models: the Recessive Lethals model and the Heterosis model. Both models have attributes likely to be typical of some populations, but these may vary within and between species (Brewer *et al.* 1990). Given this, it is probable that the impacts of inbreeding will fall between the effects of these two models. Inbreeding is assumed to depress only one component of fitness: first-year survival. Effects on reproduction could be incorporated into this component, but longer-term impacts such as increased disease susceptibility or decreased ability to adapt to environmental change are not modelled.

(6) The probabilities of reproduction and mortality are constant from the age of first breeding until an animal reaches the maximum longevity. This assumes that animals continue to breed until they die.

(7) A simulated catastrophe will have an effect on a population only in the year that the event occurs.

(8) Migration rates among populations are independent of age and sex.

(9) Complex, interspecies interactions are not modelled, except in that such community dynamics might contribute to random environmental variation in demographic parameters. For example, cyclical fluctuations caused by predator–prey interactions cannot be modelled by VORTEX.

Discussion

Uses and Abuses of Simulation Modelling for PVA

Computer simulation modelling is a tool that can allow crude estimation of the probability of population extinction, and the mean population size and amount of genetic diversity, from data on diverse interacting processes. These processes are too complex to be integrated intuitively and no analytic solutions presently, or are likely to soon, exist. PVA modelling focuses on the specifics of a population, considering the particular habitat, threats, trends, and time frame of interest, and can only be as good as the data and the assumptions input to the model (Lindenmayer *et al.* 1993). Some aspects of population dynamics are not modelled by VORTEX nor by any other program now available. In particular, models of single-species dynamics, such as VORTEX, are inappropriate for use on species whose fates are strongly determined by interactions with other species that are in turn undergoing complex (and perhaps synergistic) population dynamics. Moreover, VORTEX does not model many conceivable and perhaps important interactions among variables. For example, loss of habitat might cause secondary changes in reproduction, mortality, and migration rates, but ongoing trends in these parameters cannot be simulated with VORTEX. It is important to stress that PVA does not predict in general what will happen to a population; PVA forecasts the likely effects only of those factors incorporated into the model.

Yet, the use of even simplified computer models for PVA can provide more accurate predictions about population dynamics than the even more crude techniques available previously, such as calculation of expected population growth rates from life tables. For the purpose of estimating extinction probabilities, methods that assess only deterministic factors are almost certain to be inappropriate, because populations near extinction will commonly be so small that random processes dominate deterministic ones. The suggestion by Mace and Lande (1991) that population viability be assessed by the application of simple rules (e.g., a taxon be considered Endangered if the total effective population size is below 50 or the total census size below 250) should be followed only if knowledge is insufficient to allow more accurate quantitative analysis. Moreover, such preliminary judgments, while often important in stimulating appropriate corrective measures, should signal, not obviate, the need for more extensive investigation and analysis of population processes, trends and threats.

Several good population simulation models are available for PVA. They differ in capabilities, assumptions and ease of application. The ease of application is related to the number of simplifying assumptions and inversely related to the flexibility and power of the model. It is unlikely that a single or even a few simulation models will be appropriate for all PVAs. The VORTEX program has some capabilities not found in many other population simulation programs, but is not as flexible as are some others (e.g., GAPPS; Harris *et al.* 1986). VORTEX is user-friendly and can be used by those with relatively little understanding of population biology and extinction processes, which is both an advantage and a disadvantage.

Testing Simulation Models

Because many population processes are stochastic, a PVA can never specify what will happen to a population. Rather, PVA can provide estimates of probability distributions describing possible fates of a population. The fate of a given population may happen to fall at the extreme tail of such a distribution even if the processes and probabilities are assessed precisely. Therefore, it will often be impossible to test empirically the accuracy of PVA results by monitoring of one or a few threatened populations of interest. Presumably, if a population followed a course that was well outside of the range of possibilities predicted by a model, that model could be rejected as inadequate. Often, however, the range of plausible fates generated by PVA is quite broad.

Simulation programs can be checked for internal consistency. For example, in the absence of inbreeding depression and other confounding effects, does the simulation model predict an average long-term growth rate similar to that determined from a life-table calculation? Beyond this, some confidence in the accuracy of a simulation model can be obtained by comparing observed fluctuations in population numbers to those generated by the model, thereby comparing a data set consisting of tens to hundreds of data points to the results of the model. For example, from 1938 to 1991, the wild population of whooping cranes had grown at a mean exponential rate, r, of 0·040, with annual fluctuations in the growth rate, SD (r), of 0·141 (Mirande *et al.* 1993). Life-table analysis predicted an r of 0·052. Simulations using VORTEX predicted an r of 0·046 into the future, with a SD (r) of 0·081. The lower growth rate projected by the stochastic model reflects the effects of inbreeding and perhaps imbalanced sex ratios among breeders in the simulation, factors that are not considered in deterministic life-table calculations. Moreover, life-table analyses use mean birth and death rates to calculate a single estimate of the population growth rate. When birth and death rates are fluctuating, it is more appropriate to average the population growth rates calculated separately from birth and death rates for each year. This mean growth rate would be lower than the growth rate estimated from mean life-table values.

When the simulation model was started with the 18 cranes present in 1938, it projected a population size in 1991 ($N \pm \mathrm{SD} = 151 \pm 123$) almost exactly the same as that observed ($N = 146$). The large variation in population size across simulations, however, indicates that very different fates (including extinction) were almost equally likely. The model slightly underestimated the annual fluctuations in population growth [model SD (r)$=$0·112 *v.* actual SD (r)$=$0·141]. This may reflect a lack of full incorporation of all aspects of stochasticity into the model, or it may simply reflect the sampling error inherent in stochastic phenomena. Because the data input to the model necessarily derive from analysis of past trends, such retrospective analysis should be viewed as a check of consistency, not as proof that the model correctly describes current population dynamics. Providing another confirmation of consistency, both deterministic calculations and the simulation model project an over-wintering population of whooping cranes consisting of 12% juveniles (less than 1 year of age), while the observed frequency of juveniles at the wintering grounds in Texas has averaged 13%.

Convincing evidence of the accuracy, precision and usefulness of PVA simulation models would require comparison of model predictions to the distribution of fates of many replicate populations. Such a test probably cannot be conducted on any endangered species, but could and should be examined in experimental non-endangered populations. Once simulation models are determined to be sufficiently descriptive of population processes, they can guide management of threatened and endangered species (see above and Lindenmayer *et al.* 1993). The use of PVA modelling as a tool in an adaptive management framework (Clark *et al.* 1990) can lead to increasingly effective species recovery efforts as better data and better models allow more thorough analyses.

Directions for Future Development of PVA Models

The PVA simulation programs presently available model life histories as a series of discrete (seasonal) events, yet many species breed and die throughout much of the year. Continuous-time models would be more realistic and could be developed by simulating the time between life-history events as a random variable. Whether continuous-time models would significantly improve the precision of population viability estimates is unknown. Even more realistic models might treat some life-history events (e.g., gestation, lactation) as stages of specified duration, rather than as instantaneous events.

Most PVA simulation programs were designed to model long-lived, low fecundity (K-selected) species such as mammals, birds and reptiles. Relatively little work has been devoted to developing models for short-lived, high-fecundity (r-selected) species such as many amphibians and insects. Yet, the viability of populations of r-selected species may be highly affected by stochastic phenomena, and r-selected species may have much greater minimum viable populations than do most K-selected species. Assuring viability of K-selected species in a community may also afford adequate protection for r-selected species, however, because of the often greater habitat-area requirements of large vertebrates. Populations of r-selected species are probably less affected by intrinsic demographic stochasticity because large numbers of progeny will minimise random fluctuations, but they are more affected by environmental variations across space and time. PVA models designed for r-selected species would probably model fecundity as a continuous distribution, rather than as a completely specified discrete distribution of litter or clutch sizes; they might be based on life-history stages rather than time-increment ages; and they would require more detailed and accurate description of environmental fluctuations than might be required for modelling K-selected species.

The range of PVA computer simulation models becoming available is important because the different assumptions of the models provide capabilities for modelling diverse life histories. Because PVA models always simplify the life history of a species, and because the assumptions of no model are likely to match exactly our best understanding of the dynamics of a population of interest, it will often be valuable to conduct PVA modelling with several simulation programs and to compare the results. Moreover, no computer program can be guaranteed to be free of errors. There is a need for researchers to compare results from different PVA models when applied to the same analysis, to determine how the different assumptions affect conclusions and to cross-validate algorithms and computer code.

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James W. Grier made available his simulation program, SPGPC, which provided many of the algorithms on which the first version of VORTEX (SIMPOP) was based. I thank Ulysses S. Seal, Thomas J. Foose, Jon Ballou, Nathan R. Flesness, Tim W. Clark, Gary Backhouse, David Lindenmayer, Simon Bennett, and many of the staff of the Department of Conservation and Environment, Victoria, Australia, for many helpful comments on VORTEX and PVA. Tim W. Clark, David Lindenmayer and two anonymous reviewers provided valuable critiques of drafts of this paper.

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Appendix. Sample Output from VORTEX

Explanatory comments are added in italics

VORTEX – simulation of genetic and demographic stochasticity

TEST *Simulation label and output file name*

Fri Dec 20 09:21:18 1991

2 population(s) simulated for 100 years, 100 runs

VORTEX first lists the input parameters used in the simulation:

HETEROSIS model of inbreeding depression

with 3·14 lethal equivalents per diploid genome

Migration matrix:

	1	2
1	0·9900	0·0100
2	0·0100	0·9900

i.e. 1% probability of migration from Population 1 to 2, and from Population 2 to 1

First age of reproduction for females: 2 for males: 2

Age of senescence (death): 10

Sex ratio at birth (proportion males): 0·5000

Population 1:

Polygynous mating; 50·00 per cent of adult males in the breeding pool.

Reproduction is assumed to be density independent.

50·00 (EV = 12·50 SD) per cent of adult females produce litters of size 0

25·00 per cent of adult females produce litters of size 1

25·00 per cent of adult females produce litters of size 2

EV is environmental variation

50·00 (EV = 20·41 SD) per cent mortality of females between ages 0 and 1

10·00 (EV = 3·00 SD) per cent mortality of females between ages 1 and 2

10·00 (EV = 3·00 SD) per cent annual mortality of adult females (2<=age<=10)

50·00 (EV = 20·41 SD) per cent mortality of males between ages 0 and 1

10·00 (EV = 3·00 SD) per cent mortality of males between ages 1 and 2

10·00 (EV = 3·00 SD) per cent annual mortality of adult males (2<=age<=10)

EVs have been adjusted to closest values possible for binomial distribution.

EV in reproduction and mortality will be correlated.

Frequency of type 1 catastrophes: 1·000 per cent
with 0·500 multiplicative effect on reproduction
and 0·750 multiplicative effect on survival

Frequency of type 2 catastrophes: 1·000 per cent
with 0·500 multiplicative effect on reproduction
and 0·750 multiplicative effect on survival

Initial size of Population 1: (set to reflect stable age distribution)

Age	1	2	3	4	5	6	7	8	9	10	Total	
	1	0	1	1	0	1	0	0	1	0	5	Males
	1	0	1	1	0	1	0	0	1	0	5	Females

Carrying capacity = 50 (EV = 0·00 SD)
with a 10·000 per cent decrease for 5 years.

Animals harvested from population 1, year 1 to year 10 at 2 year intervals:
1 females 1 years old
1 female adults (2<=age<=10)
1 males 1 years old
1 male adults (2<=age<=10)

Animals added to population 1, year 10 through year 50 at 4 year intervals:
1 females 1 years old
1 females 2 years old
1 males 1 years old
1 males 2 years old

Input values are summarised above, results follow.

VORTEX now reports life-table calculations of expected population growth rate.

Deterministic population growth rate (based on females, with assumptions of no limitation of mates and no inbreeding depression):

r = −0·001 lambda = 0·999 RO = 0·997

Generation time for: females = 5·28 males = 5·28

Note that the deterministic life-table calculations project approximately zero population growth for this population.

Stable age distribution:

Age class	females	males
0	0·119	0·119
1	0·059	0·059
2	0·053	0·053
3	0·048	0·048
4	0·043	0·043
5	0·038	0·038
6	0·034	0·034
7	0·031	0·031
8	0·028	0·028
9	0·025	0·025
10	0·022	0·022

Ratio of adult (>=2) males to adult (>=2) females: 1·000

Population 2:

Input parameters for Population 2 were identical to those for Population 1.
Output would repeat this information from above.

Simulation results follow.

Population1

Year 10

N[Extinct] = 0, P[E] = 0·000
N[Surviving] = 100, P[S] = 1·000
Population size = 4·36 (0·10 SE, 1·01 SD)
Expected heterozygosity = 0·880 (0·001 SE, 0·012 SD)
Observed heterozygosity = 1·000 (0·000 SE, 0·000 SD)
Number of extant alleles = 8·57 (0·15 SE, 1·50 SD)

Population summaries given, as requested by user, at 10-year intervals.

Year 100

N[Extinct] = 86, P[E] = 0·860
N[Surviving] = 14, P[S] = 0·140
Population size = 8·14 (1·27 SE, 4·74 SD)
Expected heterozygosity = 0·577 (0·035 SE, 0·130 SD)
Observed heterozygosity = 0·753 (0·071 SE, 0·266 SD)
Number of extant alleles = 3·14 (0·35 SE, 1·29 SD)

In 100 simulations of 100 years of Population1:
86 went extinct and 14 survived.
This gives a probability of extinction of 0·8600 (0·0347 SE),
or a probability of success of 0·1400 (0·0347 SE).
99 simulations went extinct at least once.
Median time to first extinction was 5 years.
Of those going extinct,
mean time to first extinction was 7·84 years (1·36 SE, 13·52 SD).
123 recolonisations occurred.
Mean time to recolonisation was 4·22 years (0·23 SE, 2·55 SD).
110 re-extinctions occurred.
Mean time to re-extinction was 54·05 years (2·81 SE, 29·52 SD).

Mean final population for successful cases was 8·14 (1·27 SE, 4·74 SD)

Age 1	Adults	Total	
0·14	3·86	4·00	Males
0·36	3·79	4·14	Females

During years of harvest and/or supplementation
mean growth rate (r) was 0·0889 (0·0121 SE, 0·4352 SD)
Without harvest/supplementation, prior to carrying capacity truncation,
mean growth rate (r) was −0·0267 (0·0026 SE, 0·2130 SD)

Population growth in the simulation (r = −0·0267) was depressed relative to the projected growth rate calculated from the life table (r = −0·001) because of inbreeding depression and occasional lack of available mates.

Note: 497 of 1000 harvests of males and 530 of 1000 harvests of females could not be completed because of insufficient animals.

Final expected heterozygosity was 0·5768 (0·0349 SE, 0·1305 SD)
Final observed heterozygosity was 0·7529 (0·0712 SE, 0·2664 SD)
Final number of alleles was 3·14 (0·35 SE, 1·29 SD)

Population2

Similar results for Population 2, omitted from this Appendix, would follow.

******** Metapopulation Summary ********

Year 10

N[Extinct] = 0, P[E] = 0·000
N[Surviving] = 100, P[S] = 1·000
Population size = 8·65 (0·16 SE, 1·59 SD)
Expected heterozygosity = 0·939 (0·000 SE, 0·004 SD)
Observed heterozygosity = 1·000 (0·000 SE, 0·000 SD)
Number of extant alleles = 16·92 (0·20 SE, 1·96 SD)

Metapopulation summaries are given at 10-year intervals.

Year 100

N[Extinct] = 79, P[E] = 0·790
N[Surviving] = 21, P[S] = 0·210
Population size = 10·38 (1·37 SE, 6·28 SD)
Expected heterozygosity = 0·600 (0·025 SE, 0·115 SD)
Observed heterozygosity = 0·701 (0·050 SE, 0·229 SD)
Number of extant alleles = 3·57 (0·30 SE, 1·36 SD)

In 100 simulations of 100 years of Metapopulation:
79 went extinct and 21 survived.
This gives a probability of extinction of 0·7900 (0·0407 SE),
or a probability of success of 0·2100 (0·0407 SE).
97 simulations went extinct at least once.
Median time to first extinction was 7 years.
Of those going extinct,
mean time to first extinction was 11·40 years (2·05 SE, 20·23 SD).
91 recolonisations occurred.
Mean time to recolonisation was 3·75 years (0·15 SE, 1·45 SD).
73 re-extinctions occurred.
Mean time to re-extinction was 76·15 years (1·06 SE, 9·05 SD).

Mean final population for successful cases was 10·38 (1·37 SE, 6·28 SD)

Age 1	Adults	Total	
0·48	4·71	5·19	Males
0·48	4·71	5·19	Females

During years of harvest and/or supplementation
mean growth rate (r) was 0·0545 (0·0128 SE, 0·4711 SD)
Without harvest/supplementation, prior to carrying capacity truncation,
mean growth rate (r) was −0·0314 (0·0021 SE, 0·1743 SD)

Final expected heterozygosity was 0·5997 (0·0251 SE, 0·1151 SD)
Final observed heterozygosity was 0·7009 (0·0499 SE, 0·2288 SD)
Final number of alleles was 3·57 (0·30 SE, 1·36 SD)

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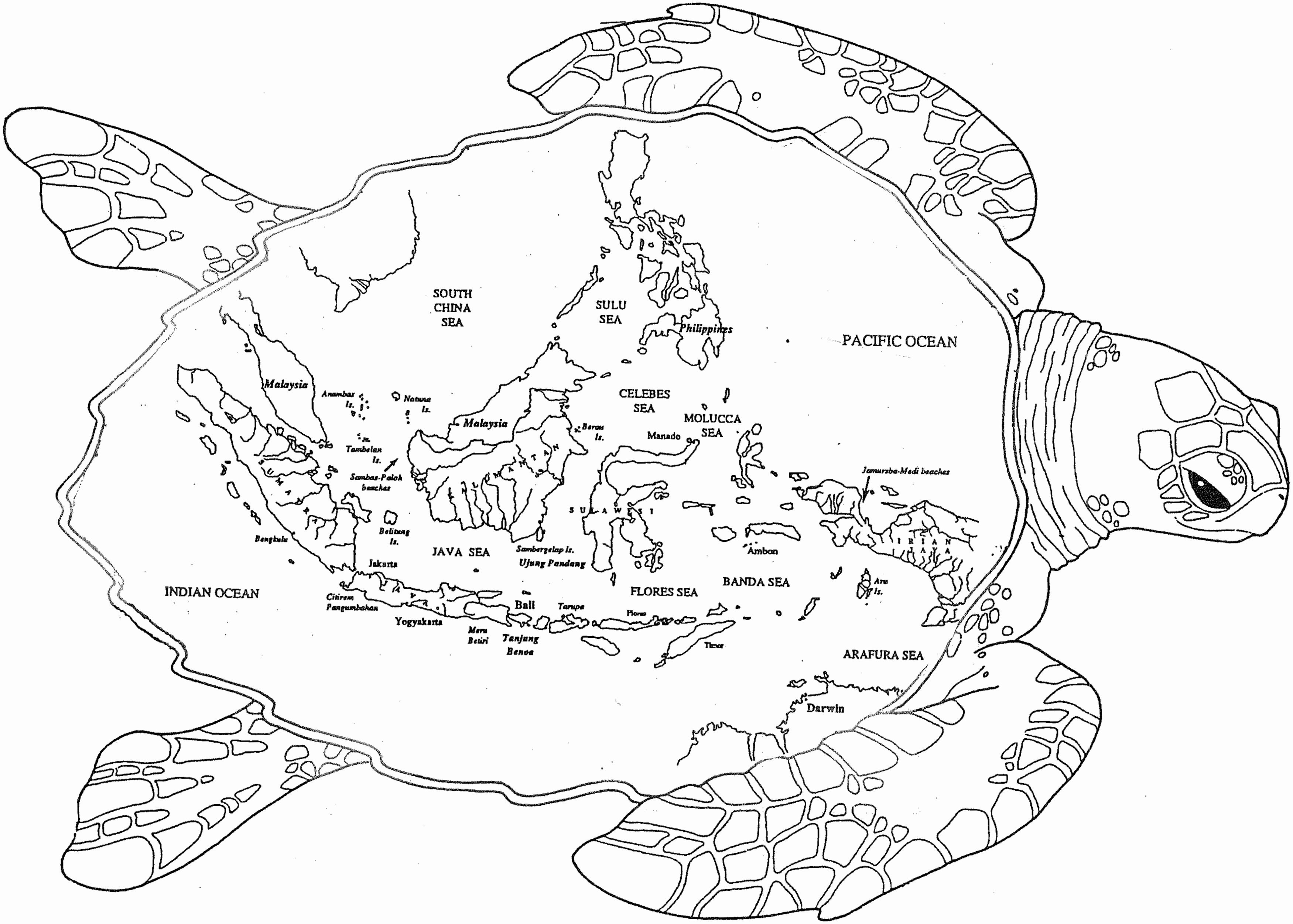

SOUTH CHINA SEA
SULU SEA
Philippines
PACIFIC OCEAN
Malaysia
Anambas Is.
Natuna Is.
Malaysia
Berau Is.
CELEBES SEA
MOLUCCA SEA
Manado
Tambelan Is.
Sambas-Paloh beaches
SUMATRA
KALIMANTAN
SULAWESI
Jamursba-Medi beaches
IRIAN JAYA
Belitung Is.
Bengkulu
JAVA SEA
Sambergelap Is.
Ujung Pandang
Ambon
Jakarta
INDIAN OCEAN
FLORES SEA
BANDA SEA
Aru Is.
Citirem Pangumbahan
JAVA
Bali
Tarupa
Flores
Yogyakarta
Meru Betiri
Tanjung Benoa
Timor
ARAFURA SEA
Darwin