

# Post-Nesting Migration and Mitochondrial DNA Structures of Olive Ridley Turtles (*Lepidochelys olivacea*) Nested on Beaches of the Bird's Head of Papua and the Lesser Sunda Regions, Indonesia

Windia Adnyana<sup>1</sup>, Made Jayaratha<sup>2</sup>, Hidayatun Ni'sa Purwanasari<sup>3</sup>, I Nengah Wandia<sup>4</sup>, Kiki Dethmers<sup>5</sup>, Colin J Limpus<sup>6</sup>

<sup>1,4</sup>The Faculty of Veterinary Medicine, Udayana University, Bali-Indonesia

<sup>2,3</sup>Previously studied at the Coastal and Marine Master Program at Udayana University, Bali-Indonesia, Previously worked at North Australia Marine Research Alliance - Darwin, Australia

<sup>5</sup>, University of Queensland, Australia<sup>6</sup>

DOI: 10.29322/IJSRP.10.07.2020.p10390

<http://dx.doi.org/10.29322/IJSRP.10.07.2020.p10390>

**Abstract-** The olive ridley turtle (*Lepidochelys olivacea*) is widely distributed throughout Indonesia but is the least studied species of marine turtles in the south-east Asian region. This is the first detailed study of the population structure and migration of olive ridleys in Indonesia, which contributes significantly to the regional understanding of the species. We followed the movement of 9 post-nesting female olive ridleys using satellite telemetry from two geographically separated areas; the Papua Bird's Head Peninsula and the Western Lesser Sunda region. Results showed that each population used different migration pathways and feeding grounds. While all Papuan olives migrated southeastward towards relatively similar foraging ground in the waters of Arafura Seas, the Lesser Sunda turtles moved to different directions. As a consequence for their migration pathways, the two populations would face different threats. During inter-nesting periods, both populations used the entire water column in the vicinity of their nesting beaches, suggested that protection of the nesting beach only would not be adequate to secure these turtles. Expansion to the nearby water is needed to give a better protection. In view of the distance to the nearest shores, the Lesser Sunda olives used a much smaller marine area for their inter-nesting movement, which could be practically and easily managed by only the local district governments. On the other hand, a large inter-nesting area used by Papuan olives suggested the need to undertake a collaborative and coordinative effort between the district, provincial and national government to improve their survival. Apart from their different movement areas which brought them to different threats/consequences, the Papuan and Lesser Sunda olives populations, which are separated by more than 1000 kilometers and interrupted by many seas, are known to be genetically distinct, representing separate management units; each represents the logical focus for recovery actions. Accordingly, management to restore this population will require local effort to increase survivorship and reduce mortality at the nesting beach and its respective migratory pathways and feeding areas.

**Index Terms-** Indonesia, Bird's Head Papua, Lesser Sunda, Post-nesting migration, mtDNA structure, olive ridley.

## I. INTRODUCTION

Olive ridley (*Lepidochelys olivacea*) turtles are globally distributed throughout the tropical regions of the Atlantic, Pacific, and Indian Oceans. This species is considered the most abundant sea turtle species (Reichert 1993) and the only species to exhibit synchronous mass nesting in regions of East Pacific and the Northern Indian Ocean, known as arribadas (Pritchard et al. 1997; Shanker et al. 2004a). However, most other nesting areas have supported only small or moderate-sized nesting aggregations (up to several thousand nesting females annually) (Hendrickson and Albert, 1961; Maxwell, 2011) The East Indian and West Pacific (EIWP) region supports multiple olive ridley nesting populations but very few have been investigated for population function and trends such as the Australian populations (Limpus et al. 1997). The majority are yet to be described. The olive ridleys in the Indonesian archipelago are of particular interest because the country's chain of islands spans between two major oceanic systems and as such is the region where turtles from both basins are expected to meet. Multiple nesting populations are scattered throughout the country but little is known about their population status and dispersal range.

As with other marine turtle species, global genetic studies of olive ridleys indicate limited female-mediated interbreeding between the major breeding aggregations resulting in strong population structure (Bowen et al. 1998; Shanker et al. 2004b). Separate genetic stocks have been identified across its distribution range in the Indian and Pacific oceans including the eastern India coast, Sri Lanka, Andaman and Nicobar Islands (India), Peninsular Malaysia, and Northern Territory and western Cape York Peninsula (Australia) (Bowen et al. 1998; Shanker et al. 2004b; Jensen et al. 2013; FitzSimmons and Limpus, 2014), but regional genetic structuring is relatively weak. Important sampling gaps remain in the east and northeast Indian Ocean, the South China Sea, Arafura Sea and Timor Sea.

The north-eastern Indian Ocean populations, with a combined estimated 1000 clutches laid annually, lie between the large mass-nesting populations on the eastern Indian coast and Mexico and Costa Rica in the East Pacific, with hundreds of thousands of females nesting annually in each location (Marquez 1990). No mass-nesting is known to occur in the EIWP region. There has been only sporadic nesting in the western Pacific, although a small nesting population in the Solomon Islands have recently discovered (Limpus, pers comm). The once large olive ridley nesting populations of Myanmar, Peninsula Malaysia and Thailand have been decimated due to past egg harvests (Limpus, 1993, 1997). In the extreme, the unique genetic stock that bred in eastern Peninsula Malaysia is now presumed extinct. Occasional nesting is reported in Malaysian Sarawak, some parts of the Phillipines (Turtle Conservation Society Malaysia). and in Papua New Guinea. Within Indonesia, sporadic nesting occurs at multiple sites in Sumatra, Java and Sunda Islands, West Papua and East Timor. In Australia, a few thousand olive ridley turtles nest annually, restricted to several areas across the north of the country and western Northern Territory genetic stock appears to be the largest breeding population remaining in the EIWP.

Large scale egg harvests and other anthropogenic threats such as by-catch in fisheries (Frazier et al. 2007) and exploitation (Campbell 2007), (Cornelius et al. 2007) have caused western Pacific populations to decline by as much as 90% relative to the 1970s (Fonseca et al. 2009). The olive ridley populations of the EIWP are subject to similar threats as well entanglement in marine debris and derelict fishing gear (Jensen et al. 2013), entangling turtles from Australian and Indonesian stocks in the Arafura Sea. The West Papuan sites have long been a model of ecosystem-based management for various NGOs (WWF, TNC, CI) and the site in East Java is an Indonesian Government focus area for olive ridley conservation in the region.

Here, we assess two major olive ridley nesting sites within the Indonesian archipelago; the Bird's Head Peninsula of West

Papua (West Pacific Ocean) and the in Lesser Sunda Region (East Indian Ocean) with year-round nesting and estimated density of 400 - 500 nests per year at each site (Adnyana and Hitipeuw, 2008). Using satellite tracking data and genetic analysis we describe the migratory range and of population differentiation these two geographically disjoint populations. This study provides scientific baseline to assess potential impacts of natural and anthropogenic threats to the EIWP olive ridley population and to better understand the dynamics of olive ridley populations within this region in general.

## II. METHODS

### Satellite telemetry

Five olive ridleys from the Bird's Head Peninsula (Jamursba Medi and Kaironi beaches) and four from the Lesser Sunda (Alas Purwo and Southern Bali beaches) were outfitted with satellite-linked transmitters during the 2008 and 2009 nesting seasons (Table 1). Three different models of transmitters: a Telonic A-2010 (Telonics Inc. USA), Kiwisat 101 and Fastloc (Sirtrack Co, Ltd., New Zealand) were attached following the procedure described by Balazs et al. (Balazs, et al. 1996) and programmed to transmit geographic location to the Argos system on a duty cycle of 12 hrs on and 12 hrs off. The data were processed using Satellite Tracking Analysis Tool STAT (Coyne and Godley 2005) and the maps generated by Maptool were published on www.seaturtle.org. Minimum distances traveled by tracked turtles were estimated based on great circle distances between subsequent positions along track. The Argos system classifies each position into 1 of 6 location classes (LC's) as an estimate of accuracy, where LC 3 is  $\pm 150$  m, LC 2 is  $\pm 350$  m, LC 1 is  $\pm 1000$  m, and LC 0 is  $>1000$  m. LC 0 and A and B, which have an unknown accuracy, were not included in our calculations for speeds and distances.

**Table 1: Geographic locations (regions), flipper (inconnel) tag, and morphometrics of the post-nesting olive ridley turtles tagged with platform transmitter terminal (PTT) in the Birdhead Peninsula of Papua and the Lesser Sunda turtle rookeries during the 2008-2009 nesting seasons. CCL = the Curved Carapace Length; CCW = the Curved Carapace Width.**

Region	Geographic Location		Flipper Tag ID	Turtle Name	CCL (cm)	Body Weight (kg)	Release Date	Tracked (days)	PTT Model
	Latitude	Longitude							
Bird's Head Papua	0,3595	132,5180	270928	Laura	65	34,5	03/05/2008	389	ST20A2010
	0,3595	132,5180	270914	Eva	67	34	05/05/2008	198	ST20A2010
	0,3661	132,5169	222400	Mama Robeca	67	37	27/04/2009	368	KS101
	-0,7410	133,5620	222406	Tetha	67	33	20/05/2009	214	Fastloc
	-0,7410	133,5620	222402	Kiki	68	32	20/05/2009	242	KS101
Lesser Sunda	8,6219	114,3142	ID3739	Dwi	68	34	28/11/2008	261	KS101
	8,6217	114,3141	ID3779	Ari	68	35	29/06/2009	304	Fastloc
	8,6217	114,3141	ID3780	Koming	68	32	30/06/2009	180	KS101
	8,7446	115,2475	ID4303	Lucy	69	31	03/05/2009	14	KS101

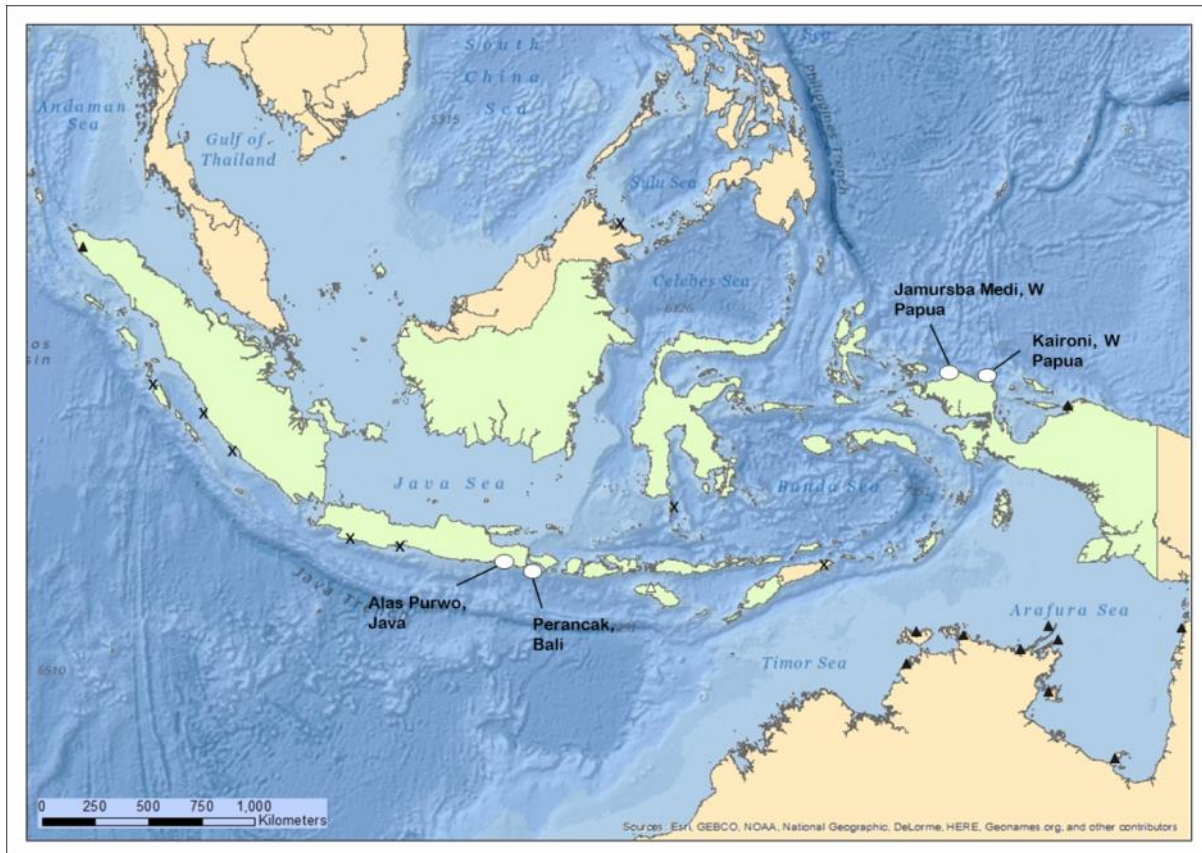
### Sample collection

Overall, we collected 92 skin tissue samples from olive ridley turtles during the 2008-2009 nesting season from the Lesser Sunda (Alas Purwo of East Java and southern part of Bali), and the Bird's Head of Papua (Jamursba Medi and Kaironi beaches) (Fig

1). Flipper (inconnel) tags (National Band Tag®, USA) were applied to each sampled turtle to ensure that each turtle was only sampled once. Samples were also collected from hatchlings at a local turtle hatchery in Bali. In this case, clutches were sampled within 2 weeks time to avoid re-sampling nesting turtles, and only

one hatchling per nest was used in the analysis. Skin samples were collected either from the distal portion of the flippers or the

shoulder/neck area of adults and from dead hatchlings and stored in a NaCl saturated solution of 20% DMSO.



**Fig 1:** Sampling sites. The white circles indicate the sites in this study. Genetic samples for Jamursba Medi and Kaironi were pooled. Triangles are sites studied by Jensen et al. (2013), and crosses indicate other known nesting areas.

#### Determination of mtDNA haplotypes

Genomic DNA was isolated from 0.1 g of skin tissue using Qiamp™ DNA Mini Kit from Qiagen®, and stored at -20°C for subsequent polymerase chain reaction (PCR). Successful DNA isolation was confirmed by running 2 µL of genomic DNA on a 1% Agarose gel and visualized with Ethidium Bromide. The samples were amplified by polymerase chain reaction (PCR) using the primers LTEi9 (GGGAATAATCAAAAGAGAAGG-3') and H950 (GTCTCGGATTTAGGGGTTT-3') primers (Abreu-Grobois, et al. 2006), designed to target a 780 bp segment of the mitochondrial DNA control region. We ran 25 µL PCR reactions containing 13 µL H<sub>2</sub>O, 1.5 µL PCR buffer (applied biosystem), 2.5 µL MgCl<sub>2</sub> (25 Mm), 2 µL dNTP (1 Mm), 1 µL of each primer (10 Mm), 1.5 µL ampli Taq gold polymerase (applied biosystem) and 2.5 µL of DNA template. The PCRs were run on a 40 thermocycler with an initial denaturing step of 5 min at 94°C, followed by 40 cycles of 94° C for 45 sec, 55° C for 45 sec, 72° C for 45 sec, and a final extension step at 72° C for 4 min. PCR products were run on a 1% agarose gel for 30 minutes at 50 Volt to confirm amplification and subsequently sent to Macrogen Inc. (Korea) for forward and reverse sequencing.

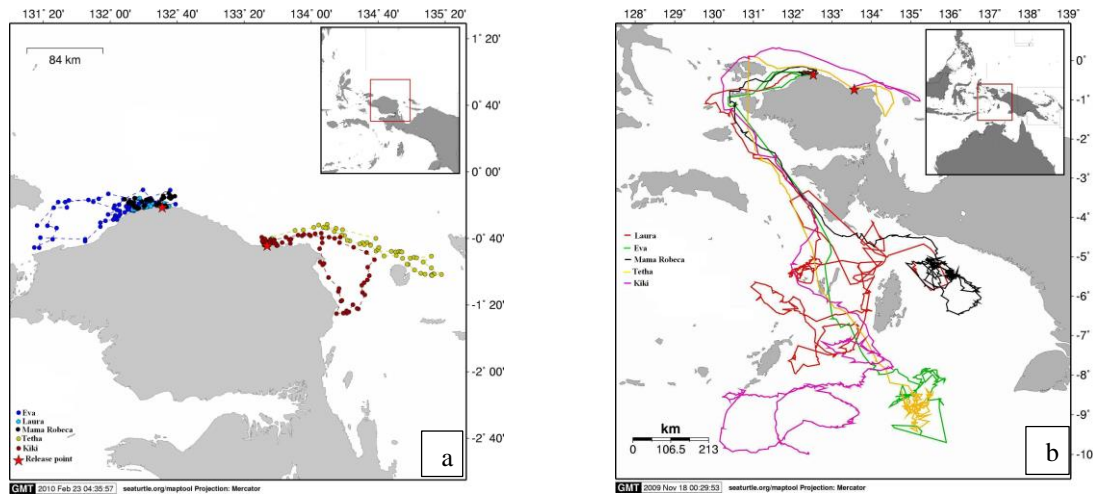
Sequences were checked and aligned using Clustal W ((Thompson, et al. 1994)) as implemented in Geneious (version 8.0.4) and blasted against *Lepidochelys olivacea* sequences published in Genbank. New sequences were checked against the sequence reference list maintained by NOAA's Southwest Fisheries Science Centre in California and naming was done in concordance with the consolidated nomenclature for olive ridley turtles. Population genetic parameters were estimated in DNAsp 4.10 (Rozas, et al. 2003) and Arlequin version 3.5.1.3 (Excoffier and Lischer 2011). Estimates of nucleotide ( $\pi$ ) and haplotype (h) diversity, pairwise F<sub>ST</sub> tests (10,000 replicates; Slatkin 1991), exact tests of population differentiation (100,000 replicates; Raymond & Rousset 1995) and AMOVA (10,000 replicates; Excoffier et al. 1992) were used to quantify genetic diversity. In the AMOVA, both sequence-based ( $\Phi$ ST) and conventional F<sub>ST</sub> distance measures were used to calculate within and among population diversity.

### III. RESULTS

#### Satellite telemetry

Transmissions from the Papuan ridleys lasted between 198 and 389 days (**Table 1**). All turtles stayed within the inter-nesting area for up to 29 days after attachment of the PTT tags (**Fig 2a**). Subsequent nesting events did occur but not necessarily at the same beach. For example, turtle Kiki nested and was tagged at Kaironi beach (20 May 2009) and subsequently nested (29 May 2009) on Numfoor Island, 160 km eastwards, and turtle Eva was tagged after nesting at Jamursba Medi beach (5 May 2008) and subsequently nested (15 May 2008) on small sandy island 40 km further to the West. The three turtles released from Jamursba Medi, remained within an area of up to 160 km to the west of their

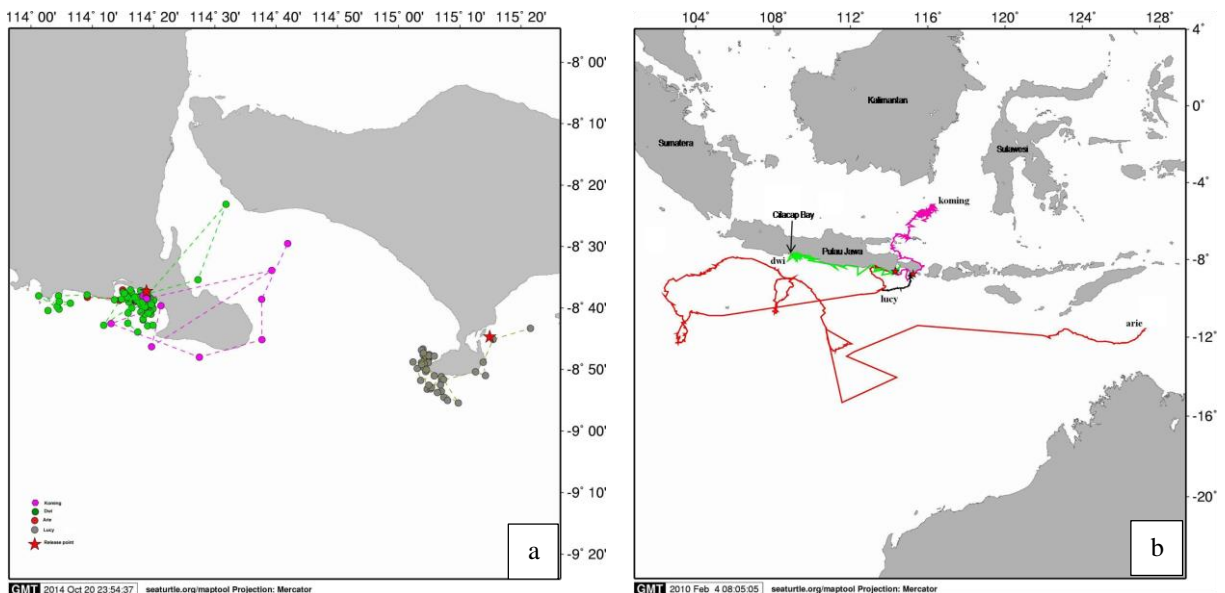
release point, while the two turtles released from Kaironi beach occupied an area of up to 210 km to the east of their release point. None of the tagged turtles used the 120 km coastal area between Jamursba Medi beach and Kaironi Beach. We recorded a total swimming distance of 2925 - 5930 km for the Papuan turtles to foraging areas at approximately 600 – 1060 km distance from the nesting beaches (**Fig 2b**). The migration routes were relatively similar; all turtles swam south-eastwards towards the Arafura Seas and needed between 34 – 64 days with an average swimming speed of 1.12 km / hr to reach their final destination.



**Fig 2: Inter-nesting areas (a) and post-nesting migration routes (b) of olive ridleys nesting in the Bird's Head of Papua. Left red star is Jamursba Medi nesting beach, and right red star is Kaironi nesting beach.**

The Lesser Sunda turtles were tracked for 180 – 304 days except for one individual (Lucy), for which the signal was lost after 15 days (**Table 1**). Immediately after nesting, the turtles returned to sea and remained within an area of up to 160 km from the southern-eastern coast of Java and Bali, with a maximum distance of 6 km off shore (**Fig 3a**). The water depths in this inter-nesting area varied between -0.5 to -80 m. As with the Papuan olive ridleys, the turtles that nested on Alas Purwo beach were observed to deposit subsequent clutches of eggs on different beaches. For example, turtle Arie which nested and was tagged in

Alas Purwo on June 29 (2009), used a beach at 115 km distance to the west for re-nesting (on July 8, 2009), and turtle Dwi re-nested (July 10, 2009) on Perancak (Bali) at 90 km to the east of Alas Purwo. Upon completion of their nesting period, the turtles moved into three different directions; one turtle (Dwi) moving westward in the Indian Ocean, hugging the southern coast of Java, another (Koming) heading north into the Java Sea, and one (Arie) initially migrating in a south-westerly direction but eventually turning 180 degrees to move eastward towards the Arafura Sea (**Fig 3b**).



**Fig 3: Inter-nesting areas (a) and post-nesting migration routes (b) of olive ridleys nesting in the Lesser Sunda region. Left red star is Alas Purwo nesting beach, and right red star is Southern Bali nesting beach.**

**Genetic diversity**

Screening of polymorphism within the 782 bp mtDNA control region fragment among 44 turtles from the 2 regions revealed 14 distinct haplotypes (Table 2). Of 15 polymorphic sites, 11 were transitions, one site contained both a transition and a transversion and two sites were characterised by inserts. A single cytosine insertion distinguished the Lo-16 haplotype and a thymine insertion was unique to the Lo-26 haplotype. Overall haplotype diversity was 0.87 but varied widely among the 3 populations ( $h = 0.32 - 0.85$ ) (Table 2). Nucleotide diversity was substantially lower among the SE Java turtles than among those nesting on the Bird’s Head peninsula ( $\pi = 0.0004$  and  $0.0048$  respectively; Table 2). No haplotypes were shared between the two regions and, with the exception of two haplotypes (Lo-01 and Lo-04), none were previously identified among other Olive ridley nesting populations within the wider East Indian West Pacific region (Jensen et al. 2013).

Of the 14 haplotypes we identified, 57% occurred uniquely in the Pacific Ocean, and 43% occurred uniquely in the Indian Ocean. Analyses of molecular variance among the populations indicated strong genetic structure ( $P < 0.001$ ; Table 3). Overall, the proportion of variation distributed among the 3 populations (Bird’s Head Papua, Alas Purwo of East Java, and Bali) was slightly higher (38%) when molecular differences among

haplotypes were included than when treating haplotypes as equidistant (30%), indicating some underlying separation of evolutionary lineages. Genetic variation within the stocks was higher than among the stocks only 10.3% of genetic variation was partitioned among regions if considering only haplotype frequencies, versus 61.4% if also considering haplotype divergence. However, this pattern was not consistent within regions. The incorporation of haplotype divergence into the AMOVA made no difference for the Indian Ocean comparisons, and it decreased the proportion of variance distributed among SE Asian MUs. Regardless of the approach, greater genetic variation within versus among MUs was indicated for the Indian Ocean and SE Asia and the opposite was indicated for the Pacific Ocean. The Barrier analysis identified a major genetic discontinuity separating all Pacific Ocean rookeries from those to the west. This phylogeographic break is also evident in AMOVA analyses; partitioning Pacific Ocean MUs from the other 11 MUs explains the greatest amount of genetic variation (68.4%) whereas only 1.54% of sequence variation was partitioned between Indian and SE Asian MUs. Exact tests for divergence of haplotype frequencies among the three rookeries (Bird’s Head Papua, Alas Purwo of East Java, and Bali) revealed that all three pairwise comparisons were significant ( $P < 0.05$ , Table 4), indicating that the three populations are genetically different.

**Table 2 Frequencies of olive ridley (*Lepidochelys olivacea*) mtDNA haplotypes among Indonesian rookeries. Haplotype nomenclature follows the naming as maintained by the National Marine Fisheries Service, NOAA.**

Region	Rookery	n	h	$\pi$	LO-01	LO-04	LO-07	LO-14	LO-16	LO-17	LO-19	LO-22	LO-23	LO-24	LO-25	LO-26	LO-75	LO-76
Lesser Sunda	Alas Purwo (East Java)	12	0.318 ( $\pm 0.164$ )	0.0004 ( $\pm 0.0005$ )	1						10						1	
	Perancak (West Bali)	12	0.727 ( $\pm 0.133$ )	0.0016 ( $\pm 0.0012$ )	1	1					3				6			1
West Papua	Jamursba Medi (Bird’s Head)	20	0.853 ( $\pm 0.060$ )	0.0048 ( $\pm 0.0028$ )			2	7	1	3		1	2	2		2		
	Overall	44	0.871 ( $\pm 0.033$ )	0.0037 ( $\pm 0.0022$ )														
	Genbank ID				JN391445	JN391448	JN391451	JN391458	JN391460	JN391461	JN391463	KC207828	KC207829					KM357630

**Table 3 Partitioning of molecular variance based on haplotype divergence ( $\Phi_{ST}$ ) and frequencies ( $F_{ST}$ ). TrN refers to distance method used (Tamura and Nei, 1993)**

	df	$\Phi_{ST}$ (TrN)	$F_{ST}$
Among populations	2	37.7	30.48
Within populations	41	62.3	69.52

**Table 4: P-values of pairwise comparisons among nesting populations based on exact tests of population differentiation derived from haplotype frequencies.**

	Alas Purwo	Perancak	Jamursba Medi
Alas Purwo	*		
Perancak	0.00098 ± 0.0010	*	
Jamursba Medi	0.00000 ± 0.0000	0.00000 ± 0.0000	*

**Discussion**

Many olive ridley rookeries in Indonesia have undergone serious declines over the last few decades (Adnyana and Hitipeuw, 2008). Therefore, understanding the geographical scale of movement is a paramount issue for their conservation management. This is the first report of olive ridley migration study from the Birdhead of Papua and the Lesser Sunda region. These geographically distant rookeries, which are separated by more than 1000 kilometers and interrupted by many seas, such as the Java Sea, Sulawesi, and Maluku Sea, as expected, hosted olive ridley populations which are genetically distinct, representing two separate management units. These two *L. olivacea* genetic stocks that are endemic to Indonesia are genetically distinct to the other seven identified genetic stocks within the Indian Ocean and Australasian region (Fig 4). There still remain numerous potential *L. olivacea* genetic stocks to be resolved. Papuan and Lesser Sunda olive populations have also different management areas which are indicated by their post-nesting migration movements and each population represents the logical focus for recovery actions. If one of these populations is depleted, restoration via natural colonization is unlikely except over the very long-term (100 or 1000's generations) (Dethmers *et al*, 2006). Accordingly, management to restore this population will require local effort to increase survivorship and reduce mortality at the nesting beaches and the respective migratory pathways and feeding areas.

During inter-nesting periods, both Papuan and Lesser Sunda olive ridley turtles used the entire water column in the vicinity of their nesting beaches. This finding suggests that protection of the nesting beach only, as it is today, is inadequate to secure these turtles. Expansion of habitat protection to include the inter-nesting habitat of the adjacent waters is needed to give better protection to the nesting populations. Indonesian law stipulated that marine areas within 12 miles from the beach line are under the jurisdiction of provincial governments. Marine area beyond 12 miles from the beach line is belongs to the national Government jurisdiction. Considering a huge inter-nesting area used by both populations, a collaborative effort should be in place between the district, provincial and national government to improve the survival of the olive ridley turtle. This study has identified that *L. olivacea* within Indonesia does not appear to have a high fidelity to individual nesting beaches. This warrants further investigation.

As expected, after completing their nesting season, turtles from these two genetically different populations moved to separate broad foraging areas. While all Papuan olive ridleys travelled south-eastward to the Arafura Sea, the East Java olive ridleys migrated to the Indian Ocean and the Java Sea. As a consequence, both populations might face different threats during their post-nesting migratory movements. The Arafura Sea has long been known as one of the important fishing areas for demersal fisheries, especially for shrimp in Indonesia. The coastal waters situated between the Province of Maluku and Papua are known to be relatively far from local community areas supports only industrial scale fisheries to operate. Based on the President Decree number 85/1982, shrimp trawl fishing areas are permitted to operate between the 130° E to the North until the 10 m isobath, including the waters around Kei Islands, Tanimbar, Aru and West Papua. Annually, 250 - 526 trawl fishing vessels were recorded to operate in this area (Purbayanto *et al*, 2004), targeting the panaeids and tiger shrimps. Although the use of Turtle Excluder Device (TED) is compulsory for any trawls fishing in this area, but most, if not all of the crews use the device while fishing as it is considered reducing their prawn capture (Wiadnyana, 2005). As the selectivity of the shrimp trawl is low, capturing different non-target fish species and other animals such as sea turtles. Prasetyo (2006) reported that 116 sea turtles of various species were incidentally captured during the fishing activity of 55 prawn vessels during 2006. They were composed of 112 green sea turtles, 2 olive ridleys, and 2 unidentified species but presumably the loggerheads. Another report specified that in 2005 and 2006, a total of 133 and 26 sea turtles, respectively, were incidentally caught by trawlers fishing in this area (Zaenudin *et al*, 2007). While in 2005 the species of the captured turtles was not defined, in 2006 they consisted of 14 olive ridley, 8 green, and 4 loggerhead turtles.

Apart from being threatened by trawl fisheries, the Papuan olive ridleys were also threatened by the activity of the longline fishery vessels operated in West Papua (Pacific) water (Zaenudin *et al*, 2007). Data collected between May and December 2006 by on-board observers who following the trip of 2 vessels from Bitung (North Sulawesi) revealed that 68 sea turtles were "fished" during their first day of hauling time. Proportionally, they were mainly olive ridleys (51) followed by the green (6), hawksbills (5),

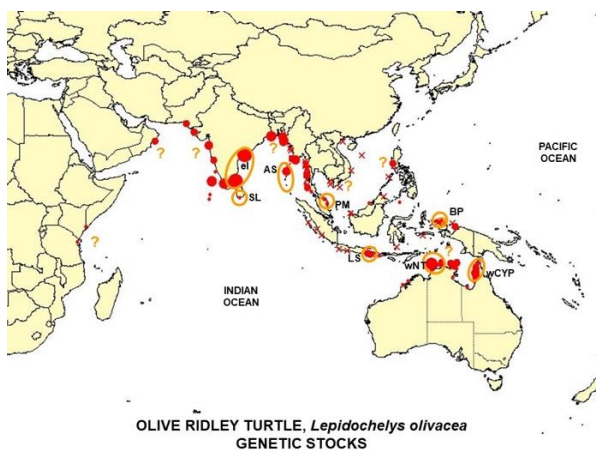
loggerheads (3), and the leatherback turtles (3). Considering the olive ridley's carnivore nature, perhaps, domination of this species incidentally captured by tuna longline fleets operated in this region relate to the use of milkfish, squid and scads as their baits. This finding emphasized the need for promoting fishing gear modification in tuna longline industry, e.g. by using C-hook instead of J-hook as the C-hook is known to reduce the bycatch of sea turtle, notably the olive ridley turtle in Indonesian water (Zaenudin *et al.*, 2007). Additionally, considering their post-nesting migration routes, the Papuan olives are most likely also susceptible to direct take done by traditional hunters of Kei Islanders and Dobo-based turtle hunters (operate in Aru Islands) targeting their plastron for Chinese market. In Kei Islands, there are a group of villages in which their people inherently having a specific communal right called *Nufit*. The *Nufit* is the right to capture the *Tabob* (sea turtles) for subsistence needs. The target species is usually the leatherback turtle (Suarez and Starbird, 1995), but other species, including olive ridley will not be spared (Manuputty and Ingratubun, 2012).

The telemetry results showed that the Lesser Sunda olive ridley turtles used both coastal and open ocean regions within Indian Ocean water. During their coastal movement, the turtle might be captured incidentally by artisanal fishers. A report published by Profauna (2005) revealed sea turtles and their products were massively traded in at least 6 locations; 2 in Central Java (Cilacap Bay and Samas Jogjakarta), 1 in East Java (Puger Banyuwangi), and 3 in West Java (Pangandaran, Pelabuhan Ratu, and Pangumbahan). One of the tracked turtle (named Dwi) was

observed end up in Cilacap Bay, the turtle trade center in Central Java which is located a few hundred kilometers at the western side of the nesting beach. Nowadays, although it is prohibited by law, products of olive ridley turtles (formalin-fixed whole body) can be easily observed traded illegally in this bay. Nevertheless, a genetic work needs to be done to ensure the connection of the traded olive ridley and the Lesser Sunda nesting population.

The olive ridley populations of the EIWP are subject to wide spread entanglement in marine debris and derelict fishing gear (Jensen *et al.* 2013), entangling turtles from Australian and Indonesian stocks in the Arafura Sea. Olive ridley turtles are the most frequently encountered turtle species beach washed and entangled in lost and discarded nets along the western coast of Cape York Peninsula in the Gulf of Carpentaria (Fig 5).

Additionally, similar to the Papuan olive ridleys, the migration pathways of Lesser Sunda olive ridleys also overlapped with the operation of the longline tuna fishery in the Indian Ocean. The interaction between turtles and this fishery was reported, and included only olive ridleys. Observers following the trips of longline vessels in 2006 recorded the incidental catch of 12 olive ridleys by Bali-based tuna fleets and 5 by the vessels based in Pelabuhan Ratu of West Java (Zaenudin *et al.*, 2007). That there was no other turtle species but olive ridleys incidentally captured by this particular fishery in these waters, indicates that these waters are important foraging habitat for the carnivorous olive ridley turtle. These findings indicate the necessity of promoting fishing gear modification to reduce bycatch in the tuna longline industry.



**Fig 4 (Left): Nesting distribution and identified genetic stocks of olive ridley turtles, *Lepidochelys olivacea*, within the Indian Ocean and Western Pacific region. (Modified from FitzSimmons and Limpus, 2014). Solid dots denote quantified nesting populations; crosses denote unquantified nesting populations for the species. Breeding localities for identified genetic stocks are encircled with orange lines. Fig5 (right): Community Ranger monitoring beach-washed large immature olive ridley turtles, *Lepidochelys olivacea*, entangled in ghost net on western Cape York Peninsula, north Queensland, Australia.**

#### REFERENCES

- [1] Abreu-Grobois FA, J Horrocks, A Formia, P Dutton, R Leroux, X Velez-Ziazo, L Soares, A Meylan (2006). New mtDNA D-loop primers which work for a variety of marine turtle species may increase the resolution of mixed stock analysis. In: Frick M, A Panagopoulous, AF Rees & K Williams (Eds). Proceedings of the 26th Annual Symposium on Sea Turtle Biology and Conservation. International Sea Turtle Society, Athens, Greece. Available from [http://www.iucn-mtsg.org/genetics/meth/primers/abreu\\_grobois\\_etal\\_new\\_dloop\\_primers.pdf](http://www.iucn-mtsg.org/genetics/meth/primers/abreu_grobois_etal_new_dloop_primers.pdf).
- [2] Adnyana W and C Hitipeuw (2008). Sea turtles in Indonesia: nesting abundance, migration pathways, major threats and management issues. Paper presented in the workshop on By-catch reduction techniques in sea turtles: where have we been and where do we go next? Lesson from Indonesia, Malaysia, and Philippines. Denpasar, Bali – Indonesia, 18 -19 August 2008.

- [3] Balazs GH, Miya RK, Beavers SC (1996) Procedures to attach a satellite transmitter to the carapace of an adult green turtle, *Chelonia mydas*. In: Keinath JA, Barnard DE, Musick JA, Bell BA (eds) Proceedings of the 15th annual symposium on sea turtle biology and conservation. NOAA Tech Mem NMFS-SEFSC-443, p 21–26
- [4] Bowen, B.W., Clark, A.M., Abreu-Grobois, F.A., Chaves, A., Reichart, H.A. & Ferl, R.J. (1998). Global phylogeography of the ridley sea turtles (*Lepidochelys* spp.) as inferred from mitochondrial DNA sequences. *Genetica*, 101, 179-189.
- [5] Campbell, L.M. (2007). Understanding human use of Olive Ridelys: implications for conservation. In: *Biology and conservation of ridley sea turtles* (ed. Plotkin, PT). John Hopkins University Press Baltimore, MD, pp. 23-43.
- [6] Cornelius, S.E., Arauz, R., Fretey, J., Godfrey, M., Marquez-Millan, R. & Shanker, K. (2007). Effect of land-based harvest of *Lepidochelys*. In: *Biology and conservation of Ridley sea turtles* (ed. Plotkin, PT). John Hopkins University Press Baltimore, MD.
- [7] Coyne MS and Godley BJ (2005). Satellite Tracking and Analysis Tool (STAT): An integrated system for archiving, analyzing and mapping animal tracking data. *Mar Ecol Prog Ser* 301: 1–7
- [8] Dethmers K, D Broderick, C Moritz, NN FitzSimmons, CJ Limpus, S Lavery, S Whiting, M Guinea, RIT Prince, R Kennett (2006). The genetic structure of Australasian green turtles (*Chelonia mydas*): exploring the geographical scale of genetic exchange. *Molecular Ecology*, 15:3931-3946.
- [9] Excoffier L, G Laval, and S Schneider (2006). Arlequin ver 3.01 An Integrated Software Package for Population Genetics Data Analysis. Computational and Molecular Population Genetics Lab (CMPG), Institute of Zoology, University of Berne, Baltzerstrasse 63012 Bern, Switzerland
- [10] FitzSimmons, N. N. and Limpus, C. J. (2014). Marine Turtle Genetic Stocks of the Indo-Pacific: identifying boundaries and knowledge gaps. *Indian Ocean Marine Turtle Newsletter* 20, 2-18.
- [11] Fonseca, L.G., Murillo, G.A., Guadamúz, L., Spínola, R.M. & Valverde, R.A. (2009). Downward but Stable Trend in the Abundance of Arribada Olive Ridley Sea Turtles (*Lepidochelys olivacea*) at Nancite Beach, Costa Rica (1971–2007). *Chelonian Conservation and Biology*, 8, 19-27.
- [12] Frazier, J., Arauz, R., Chevalier, J., Formia, A., Fretey, J., Godfrey, M. et al. (2007). Human-turtle interactions at sea. In: *Biology and conservation of ridley turtles* (ed. Plotkin, PT). John Hopkins University Press Baltimore, MD, pp. 253-295.
- [13] Hendrickson, J. R. and Albert, E. R. (1961). Nesting populations of sea turtles on the east coast of Malaya. *Bulletin Raffles Museum Singapore* 26, 190-6.
- [14] Jensen, M.P., Limpus, C.J., Whiting, S.D., Guinea, M., Prince, R.I.T., Dethmers, K.E.M. et al. (2013). Defining olive ridley turtle *Lepidochelys olivacea* management units in Australia and assessing the potential impact of mortality in ghost nets. *Endangered Species Research*, 21, 241-253.
- [15] Kumar S, K Tamura, and M Nei (2004). MEGA 3: Integrated Software for Molecular Evolutionary Genetics Analysis and Sequence Alignment. *Briefings in Bioinformatics* 5:150-163.
- [16] Limpus, C. (1993). Recommendations for conservation of marine turtles in Peninsula Malaysia. Unpublished report to Department of Fisheries, Ministry of Agriculture, Malaysia 1-60.
- [17] Limpus, CJ (1997). Marine Turtle populations of the Southeast Asia and the western Pacific region: distribution and status. (Eds Noor YR, Lubis IR, Ounsted R, Troeng S, and Abdullah A. In Proceedings of the Workshop on Marine Turtle Research and Management in Indonesia, Bogor, Wetlands International, PHPA, Environment Australia, p 37-73.
- [18] Manuputty J dan MA Ingratubun (2012). Upaya Penyelamatan Penyus Belimbing (*Dermochelys coriacea*) di Perairan Kei Maluku Tenggara, Melalui Pengembangan Kawasan Konservasi Laut. Paper presented in the Mini-Symposium: Menakar Keberhasilan Program Konservasi Penyus Laut di Indonesia. Mataram 21 October 2012. 9 p.
- [19] Marquez, R.M. (1990). Sea turtles of the world: An annotated and illustrated catalogue of sea turtle species known to date. FAO Rome, pp. iv-81.
- [20] Maxwell, F. D. (2011). Report on the Turtle-banks of the Irrawaddy Division. XXX. Reports on Inland and Sea Fisheries in the Thongwa, Myaungmya, and Bassien Districts and the Turtle-banks of the Irrawaddy Division. Pp. 1-30.
- [21] Pritchard, P.C.H., Lutz, P.L. & Musick, J.A. (1997). Evolution, phylogeny, and current status. (eds. Lutz, PL & Musick, JA). CRC Press. Inc. Boca Raton, Florida, pp. 1-28.
- [22] Profauna (2005). Final Report on the Sea Turtle Trade on the South Coast of Java. Downloaded in 18 December 2012 from <http://www.profauna.net/sites/default/files/downloads/publication-2005-sea-turtle-trade-in-java.pdf>
- [23] Purbayanto A, SH Wisudo, RI Wahju, J Santoso, B Pramono, A Marpaung (2004). Upaya Mengurangi dan Memanfaatkan Hasil Tangkapan Samping (Bycatch) Di Laut Arafura. Paper presented in Konferensi Nasional IV Sumberdaya Pesisir dan Laut. Balikpapan, Kalimantan Timur. 14 – 16 September 2004. 16 p.
- [24] Raymond M and Rousset F (1995). Genepop (Version 1.2): Population Genetics Software for Exact Tests and Ecumenicism. *Journal of Heredity*, Vol 86, (3): 248–249.
- [25] Reichart, H.A. (1993). Synopsis of biological data on the olive ridley sea turtle *Lepidochelys olivacea* (Eschscholtz, 1829) in the western Atlantic. In: Technical Memorandum National Marine Fisheries Service Southeast Fisheries Science Center. National Oceanic and Atmospheric Administration, pp. 1-78.
- [26] Rozas, J., JC Sánchez-DelBarrio, X Messeguer, and R Rozas (2003). DnaSP, DNA polymorphism analyses by the coalescent and other methods. *Bioinformatics* 19: 2496-2497
- [27] Shanker, K., Pandav, B. & Choudhury, B.C. (2004a). An assessment of the olive ridley turtle (*Lepidochelys olivacea*) nesting population in Orissa, India. *Biological Conservation*, 115: 149-160.
- [28] Shanker, K., Ramadevi, J., Choudhury, B.C., Singh, L. & Aggarwal, R.K. (2004b). Phylogeography of olive ridley turtles (*Lepidochelys olivacea*) on the east coast of India: implications for conservation theory. *Molecular Ecology*, 13:1899-1909.
- [29] Slatkin M. (1991). Inbreeding coefficients and coalescence times. *Genet Res*, 58: 167–175.
- [30] Suarez M. and C Starbird (1995). A Traditional Fishery of Leatherback Turtles in Maluku, Indonesia. *Marine Turtle Newsletter* 68:15-18
- [31] Thompson JD, TJ Gibson, F Plewniak, F Jeanmougin, DG Higgins (1997). The clustal\_x Windows interface: flexible strategies for multiple sequence alignment aided by quality analysis tools. *Nucleic Acids Research*, 25, 4876–4882.
- [32] Wiadnyana NN (2005). Assessment of Sea Turtles Mortality Caused By Fishing Practices in Indonesia. A report to WWF Indonesia. 7 p.
- [33] Zainudin IM, LP Soede, C Hitipeuw, W Adnyana (2007). Interaction of Sea Turtles with Indonesian Fisheries – Preliminary Findings. *Indian Ocean Turtle Newsletter* No. 6: 1-10.

#### ACKNOWLEDGEMENT

This work was part of a larger study entitled Tracking and Genetic Analysis of Marine Turtles in Indonesia; a collaborative effort between WWF Indonesia and Udayana University to define turtle-based MPA networks in Indonesia. We are grateful to (late) Ms Creusa Hitipeuw, Dr Lida Pet Soede and Ms Lene Topp for supporting this work.

#### AUTHORS

**First Author** – Windia Adnyana, The Faculty of Veterinary Medicine, Udayana University, Bali–Indonesia

**Second Author** – Made Jayaratha, Previously studied at the Coastal and Marine Master Program at Udayana University

**Third Author** – Hidayatun Ni'sa Purwanasari, Previously studied at the Coastal and Marine Master Program at Udayana University

**Fourth Author** – I Nengah Wandia, The Faculty of Veterinary Medicine, Udayana University, Bali–Indonesia

**Fifth Author** – Kiki Dethmers, Bali–Indonesia, Previously worked at North Australia Marine Research Alliance - Darwin, Australia



**Sixth Author** – Colin J Limpus, University of Queensland,  
Australia

**Correspondence Author** – windiaadnyana@unud.ac.id