A remarkable new swallowtail butterfly from Fiji (Lepidoptera, Papilionidae)

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Abstract: *Papilio* ***natewa*** **n. sp.**, is described from the Natewa Peninsula, Vanua Levu Island, Fiji. Given its unique characters, the systematic position of this new species within *Papilio* Linnaeus, 1758, *sensu lato* is cautiously evaluated. The presence of such a distinctive taxon in Fiji; its apparent distribution (restricted to the Natewa Peninsula), and how it previously avoided detection there are examined and discussed. It is postulated that the answers lie in a combination of the geological history of the Peninsula and the butterfly's unusual forest habitat and habits.

Eine bemerkenswerte neue Schwalbenschwanzart von Fidschi (Lepidoptera, Papilionidae)

Zusammenfassung: Die neue Schwalbenschwanzart *Papilio* ***natewa*** **n. sp.** wird von der Netewa-Halbinsel der Insel Vanua Levu im Fidschi-Archipel im Pazifik beschrieben. Wegen der ungewöhnlichen Merkmale wird die Plazierung der neuen Art in der Gattung *Papilio* Linnaeus, 1758, *sensu lato* vorsichtig und bedingt vorgeschlagen. Das Vorkommen einer so bemerkenswerten Art auf Fidschi, die vermutlich auf die Natewa-Halbinsel beschränkte Verbreitung dort und warum die Art bisher der Entdeckung entging, werden untersucht und diskutiert. Vermutlich liegt die Erklärung dafür in der Kombination der geologischen Geschichte ebendieser Halbinsel und dem Primärwaldlebensraum und Verhalten der Art.

Introduction

> *"The discovery of this species* [Aetheoptera reginae (= Ornithoptera victoriae reginae)] *in the Fiji islands is a remarkable fact, as it is difficult to understand why such a prominent and beautiful species should so long have remained undetected, or unnoticed, even by ordinary persons, especially as the chief Islands, at any rate, have been partially examined by several great Naturalists, and should be fairly well known to Europeans by this time ... however, as these insects fly high and are perhaps very local, chiefly confined to the dense forests where it is difficult to penetrate, a long time might elapse before it would be seen even by accident ..."*
>
> R. H. F. Rippon (ca. 1836–1917), naturalist and zoological illustrator, *in:* Rippon (1898–1910, p. 52)

Copies of the magnificent hand-painted monograph self-published by Rippon, from which the above passage is cited, are now very rare. It was not true of course: *Ornithoptera victoriae* is restricted to the Solomons Archipelago, with subspecies *reginae* occurring on Malaita Island (Tennent 2002). Specimens of *O. v. reginae* Salvin, 1888, in the collection of Walter, Lord Rothschild at Tring Museum in Hertfordshire, were wrongly labelled. There is a curious parallel though – the holotype of nominotypical *Ornithoptera victoriae* was labelled "Solomon Islands, Aneityum [Vanuatu] or Fiji", a circumstance brought about by the fact that when the few butterflies collected by naturalist John MacGillivray on board H.M.S. *Herald* in December 1854 arrived back in the UK at the end of the voyage, the collector himself remained in Australia and no-one knew where on the voyage the butterfly had been collected. It is now known to have been taken on Guadalcanal, Solomon Islands (Tennent 1997).

Both species referred to above belong to the Papilionidae, the swallowtail family, butterflies that are, due to their large size, colourful appearance and attractiveness to collectors, perhaps the least likely to remain undetected. The remarkable reality is that more than a century following publication of Rippon's *Icones*, and more than a century and a half since the *Herald* voyage, a previously unknown swallowtail butterfly is reported here from the Natewa Peninsula on the island of Vanua Levu, Fiji.

Butterflies are very popular, and their taxonomy and ecology are well known in comparison with many other invertebrates. In particular, the phylogenetics of Papilionidae have received much attention but research has largely focused on the higher taxonomic levels of family, subfamily, and tribe (e.g., Munroe 1961, Hancock 1983, Igarashi 1984) where there is a significant divergence of opinion amongst specialists. Interpretation of relationships remain mildly contentious, but division of the Papilionidae into three subfamilies: Baroniinae, Parnassiinae and Papilioninae (Simonsen et al. 2010) is widely accepted.

Within the tribe Papilionini (genus *Papilio sensu lato*), divisions at generic level are ambiguous and no firm consensus regarding their systematics has yet been reached. Munroe (1961) divided *Papilio* into five sections but because of perceived similarity of adult characters did not recognise any at subgeneric level, while Hancock (1983) recognised six genera based on phylogenetic inference. Igarashi (1984) recognised seven genera based on the morphology of early stages, whilst Miller (1987), in a cladistic assessment of the Papilionini, assigned all but two species to the genus *Papilio* and considered that subdivisions of *Papilio,* including those of Hancock (1983), were unjustified. Häuser et al. (2005) recognized two genera (*Chilasa* and *Papilio*), and then subdivided *Papilio* into nine subgenera (Smith & Vane-Wright 2008). Thus, systematics of the genus *Papilio*, as presently understood, remain contradictory.

Zakharov et al. (2004) inferred phylogenetic relationships for 51 species of *Papilio sensu lato* based on molecular sequence data, but suggested that few, if any, subdivisions could be delineated convincingly using morpho-

logical characters. It would be easy to add to the potential for confusion by raising a new genus, or subgenus, for the species described in this paper, which by any standards is extremely unusual and distinctive. But we prefer to err on the side of caution until further molecular investigations clear the mist. For the purposes of this paper we follow the treatment of Zakharov et al. (2004), in which *Papilio sensu lato* is treated as a single entity.

Papilio natewa n. sp.

(Figs. 1–3.)

Holotype: ♂, Fiji, Vanua Levu Island, Natewa Peninsula, forest above Natewa Village, ± 250 m, 1. viii. 2018, at *Stachytarpheta* flowers, leg. John Tennent, in coll. Fiji National Insect Collection (FNIC), Institute of Applied Science, University of the South Pacific, Suva.

Paratypes (in total 2 ♂♂): 1 ♂, data as holotype (FNIC); 1 ♂, Fiji, Vanua Levu Island, Natewa Peninsula, forest above Natewa Village, 253 m, 15. vii. 2018, feeding at *Stachytarpheta* flowers at forest edge, Visheshni Chandra (Herbarium, Institute of Applied Sciences, USP, Suva).

Etymology. The species name *natewa* derives from the type locality and the only known distribution. It also acknowledges the interest local people have in designating and supporting conservation issues on their land.

Diagnosis

♂ (Fig. 2): Forewing length 41 mm, antenna 20 mm (holotype). Head clothed with hairs, black above, with pale yellow parallel bands running from antenna and eyes to neck, pale yellow beneath, frons black; antenna black. Thorax black above, pale yellow beneath, black in leg recesses; legs with femur brown-black above and cream beneath, tarsi brown. Abdomen black above, cream-yellow laterally and beneath, with two longitudinal black bars laterally and ventro-laterally, claspers dark brown-black dorsally, cream laterally and ventrally.

Forewing elongated, costa slightly bowed, termen weakly concave, inner margin strongly bowed in median area.

Upperside brown-black, a prominent median cream band (approximately 6 mm wide at inner margin) approximately parallel to termen, extending and tapering from inner margin to vein 10 in apical area, band separated and displaced by veins into irregular spots towards termen in spaces 7 and 8, two small irregularly shaped postmedian cream spots in spaces 7 and 8, close to junction of vein 7 with both 8 and 9; cell discocellulars bordered narrowly with cream, a small cream spot in cell between junction of veins 10 and 11 with cell; cilia black.

Underside brown-black, a narrow (approx. 1.5 mm wide) postmedian cream band (near parallel with termen) extending from tornus at vein 1b to vein 8, a median cream band (placed similarly to that on upperside but slightly more extensive) connected weakly to the postmedian band along veins 7 and 8 with cream scales, postmedian and cell cream spots/markings as on upperside but slightly more extensive and extending into space 10, that near end of cell extended into a cream bar (1.5 mm wide) perpendicular to the cell cubitus and reaching it at the intersection of the cubitus with vein 4, space 11 along costa pale yellow; cell and base dusted with cream-yellow scales, those in former forming a series of four bars parallel to cubitus; cilia cream, black at apex.

Hindwing elongated, costa bowed, termen heavily serrated (concave between veins) and produced into long, tapered tail (approximately 22 mm long and 2.5 mm wide) at vein 4, inner margin slightly concave.

Upperside brown-black, a broad cream median band (approximately 7 mm wide) extending from costa to inner margin, a subterminal/postmedian cream band tapering towards costa (where it consists of cuspate spots in spaces 5–7), widening towards inner margin where it converges with the median band, leaving a vestigial patch of black ground colour in space 2; termen broadly cream between veins and continuously cream from vein 5 to tornus; tail at vein 4 cream, heavily blackened along vein, particularly in centre of tail; a prominent subtornal blue spot (approx. 4 mm diameter) in space 1b, bordered heavily and connected to the inner margin with black, a large patch of bright orange at tornus in space 1b adjacent to subtornal spot; cilia cream, except where black at ends of veins 5–8.

Underside predominantly cream, black upperside markings visible on underside as darkened scales; termen with a row of crescent-shaped black spots; blackened centre line of tail less intense; a row of postmedian unevenly shaped black spots, vestigial in spaces 3–5, otherwise prominent, each with roughly hemispherical patch of bright lustrous sky blue in basal portion of spot, that nearest to inner margin connected with patch of black along inner margin; a broad, bright orange tornal area in space 1b, less intense in space 2, adjacent to postmedian spots; another smaller orange area bordering the outer edge of the postmedian spot in space 7; a subbasal black bar (3 mm wide) roughly parallel with termen; a narrow (2 mm wide) black bar, perpendicular to inner margin and crossing humeral vein at base in space 8; cilia cream.

♂ **genitalia** (Fig. 3). Vinculum and tegumen oval-shaped dorsally, nearly straight laterally; uncus long and tapered, curved downwards and flattened towards apex; valva slightly rounded, with finely toothed harpe and pronounced curved ventrolateral spike; phallus thick laterally; vesica flanged.

♀. It will be noted that the type series, from which *P. natewa* is described here, consists of three ♂♂. It is acknowledged that other specimens, including ♀♀, have been collected but that none are available to the authors at the time of this description. However, it is also noted that ♀♀ appear very similar in appearance to ♂♂ (*cf.* Fig. 1).

Distribution. Fiji: Vanua Levu Island, Natewa Peninsula.

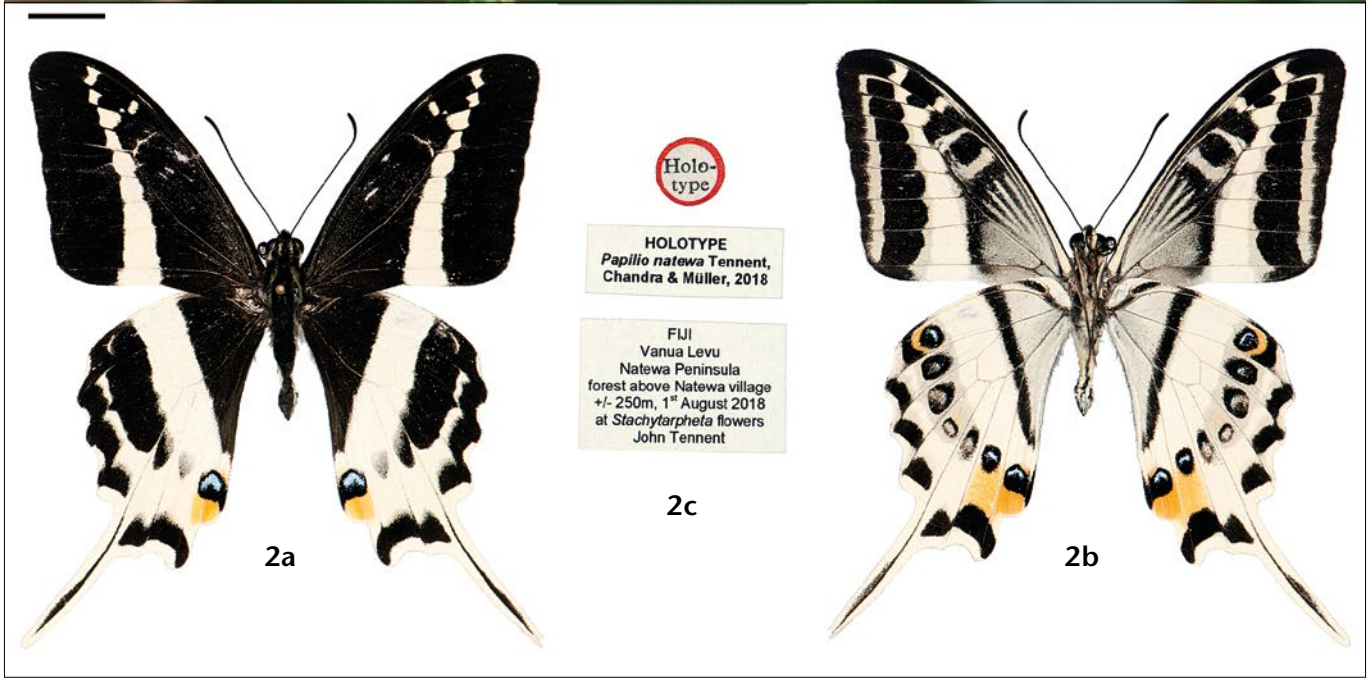

Fig. 1: *Papilio natewa*, female, the original photograph taken in June 2017 that began the search for the butterfly, reproduced by courtesy of Greg KERR (© Greg KERR). — **Fig. 2:** *P. natewa*, holotype male. **2a:** upper surface; **2b:** under surface; **2c:** labels. — Set specimens approx. natural size, labels not at same scale; scale bar = 1 cm.

Discussion

Excluding the erroneous records referred to in the quote at the head of this paper, only one papilionid species has previously been recorded from Fiji: the endemic *Papilio schmeltzi* Herrich-Schäffer, 1869, which has been extensively studied by the second author (Chandra et al. 2013a, b). Only one other species of Papilionidae is previously known from the region east of Vanuatu: *P. godeffroyi* Semper, 1866, which is endemic to the Samoan islands. The presence of a second papilionid species on Fiji, especially of such a distinctive form quite unlike anything previously recorded from the region, is truly remarkable.

Background to discovery of *P. natewa*

Operation Wallacea, an international organisation devoted largely to scientific education of teenage students from schools all over the world, began a project on the Natewa Peninsula on the island of Vanua Levu, Fiji, in 2017. Various scientific and natural history subjects were included in the project, but although some diversity and associated butterfly studies were carried out, none of the scientists involved had any specialist knowledge of butterflies, which were identified locally using some basic literature sources. Attention was initially drawn to the fact that an unidentified butterfly was present on the peninsula when Greg Kerr, an experienced ornithologist and highly accomplished photographer, photographed a butterfly (Fig. 1) nectaring on a flower of *Stachytarpheta urticifolia* (Verbenaceae), a common invasive weed originating in South America that has spread successfully throughout much of the Pacific Region. The florets of *Stachytarpheta* have become an important nectar source for butterflies, as have the flowers of other invasive species (e.g. *Mimosa pudica*, *Mikania micrantha* etc.). For the record, the photograph, reproduced here by kind permission of Greg Kerr, was taken at 8:09 hrs local time on the 11. vi. 2017, using sophisticated equipment that allowed exposure at 1/680th second with a 500 mm lens (ISO 3200).

So far as Operation Wallacea organisers were aware, a specimen of this unidentified butterfly had not been captured at the close of the 2017 project. This turned out to be erroneous; following subsequent contact by the first author it was discovered that a specimen was captured by ecologist Greg Chamberlain towards the end of the 2017 field visit and remained with other butterflies unidentified in a box remaining in Fiji. Copies of Kerr's photograph were distributed internationally to selected butterfly specialists, including the first author. Because its general appearance and reported occurrence on Fiji seemed incredible, there was at first some discussion regarding the possibility that the picture might have been tampered with. It was originally understood that the picture had been taken by a student; the butterfly did not fit the form of any known species, or any similar species in the region, and it was hard to accept that such a remarkable butterfly could remain undiscovered on Fiji. There was – and remains – no obvious geographical source from which the precursor of such a species could have evolved.

Greg Kerr was contacted by the first author and it was instantly clear that the picture was genuine; the butterfly was observed in the forest or nectaring at *Stachytarpheta* on fewer than 10 occasions, but by several different observers in 2017. Contact with Greg Chamberlain, Operation Wallacea ecologist in Fiji in 2017, established that a further photograph of a damaged ♂ of the unknown butterfly had also been taken whilst nectaring at *Stachytarpheta*.

At the close of the 2017 Operation Wallacea project, this was how it stood, although some of this was not widely known until significantly later:

- a female specimen in excellent condition was photographed by Greg Kerr on 11th of June;
- an adult male was photographed by Greg Chamberlain;
- unknown to the remainder of the Operation Wallacea group, a female specimen was captured by Will Earle in late July or early August 2017 and preserved.

Fieldwork and ecology: 2018

The second author was invited in November 2017 to be part of the Wallacea team from June to July 2018. In February 2018, the first author was invited to go to Fiji in July/August with Operation Wallacea in the hope of discovering more information regarding the unknown swallowtail species. Reports in the early part of Project Wallacea in June/July 2018, when the butterfly was reported several times by a number of observers, suggested a very fast flying forest butterfly that did not linger on flowers when nectaring and often returned to the forest after doing so. This seemed unusual behaviour for a papilionid butterfly but was subsequently confirmed.

Entomologist Richard Markham (and one of the students) first saw the butterfly on the access road to the Wallacea forest camp, about one kilometre before the camp from the Vunimokosoi Village side in July 2018. It was seen twice within a few minutes, around noon. The butterfly emerged briefly from the forest, which at this location consists of dense 'swamp forest', at 'low-treetop' height perhaps 10 m above the ground – on the first occasion, flying rapidly for a few metres parallel with the track and then disappearing in the tree tops. On the second occasion, a specimen flew directly across the track and disappeared even more rapidly. Despite 'staking out' large clumps of *Stachytarpheta* subsequently, the butterfly was not noted again at this locality.

On the 7th of July, the second author, together with Richard Markham and 'butterfly group guide' Maika Vuto saw a specimen in hill-top forest approximately 2.5 km from the Wallacea forest camp. It was seen to emerge from the forest about 3–4 m above the ground, advanced as if to feed on the flowers but flew on immediately (perhaps avoiding a *Myzomela* [bird], which was already feeding on the flowers), passing directly across

the track and disappearing into the forest. Richard and Maika observed similar behaviour, on another clump of *Stachytarpheta* about 200 m from there, but on this occasion the butterfly fed very briefly from two flowers before flying on. The second author caught a specimen of the butterfly on the 10th of July, nectaring on *Stachytarpheta* along the track from the Wallacea forest camp to Natewa Village, about 1.5 km from camp in an area of degraded forest with pine and mahogany, and a second specimen (one of the paratypes) in the same general area on the 15th of July.

The first author arrived in the Operation Wallacea forest camp on the 16th of July 2018 and saw the butterfly only twice that month in widely separated localities; on each occasion it was no more than a fleeting glance of a large, white, barred tailed butterfly flying through forest close to wide forest paths. Other staff and guides at the Wallacea forest camp reported that the butterfly flew "very fast" and was seen, often only briefly, flying in the forest rather than in open areas or (commonly, but perhaps this was where it was most noticeable) nectaring at *Stachytarpheta* flowers, where it seldom remained on the same flower for more than a few seconds.

When the first author arrived in camp, sightings of the butterfly in general were sporadic and infrequent and it was apparent that the true habitat of the butterfly remained a mystery. The only commonality linking localities where the butterfly had been seen both in 2017 and early in 2018 was that they were close to secondary and/or primary forest growth and that there were stands of *Stachytarpheta* flowers present — on which many of the individuals had been seen to nectar, usually fleetingly.

The butterfly seems to be fundamentally a forest species. Many — actually a very high proportion — of sightings of the butterfly suggested that it very often left the forest environment specifically in order to feed from the flowers of *Stachytarpheta,* and that remaining close to a stand of the plant for an extended period might provide a good opportunity for capture. The theory was sound, but unfortunately butterfly density was low in places where it was seen, and *Stachytarpheta* density so high almost everywhere there was open ground near the forest, that it was impossible to guess where and when a butterfly might appear.

It was not until the 31st of July 2018 that what is believed to be a true habitat was discovered. In preparing for the arrival of a group of students on a track not previously visited, within walking distance of the forest camp, the first author made eight sightings of the butterfly, capturing one. The following day, in the same area, a further 13 sightings were made and several specimens collected. The track in question was originally a logging track dating from the 1980s which had been 're-opened' by Wallacea personnel in 2017 in the sense that waist to shoulder high vegetation then covering the area had been cut, allowing a narrow central access for a "transit" used for differing scientific project purposes. In conversation with a local chief and ex-forester, the first author learned that as soon as the 2017 Wallacea group had left the area, the track was fully opened again to 4WD vehicles using a bulldozer, allowing village access to land on which to construct gardens. In 2018, the track was about 1500 m in length leading from a wider road to a rocky stream and was bordered on both sides by occasional small gardens planted with taro and other crops. In effect, although the track was bordered immediately by secondary growth, the depth of that growth was quite narrow and beyond that the area was bordered by undisturbed primary forest on all sides, in most cases presumably to a significant depth.

The following observations were made by the first author based on 21 personal sightings over two days, combined with data supplied by others. Although some specimens were captured, others were merely observed, and their habits recorded. In many respects it behaved like other papilionid butterflies, in particularly species of *Graphium* (e.g. *G. sarpedon* Linnaeus, 1758, *G. agamemnon* Linnaeus, 1758) widespread further west. However, it differed in one significant respect. The butterfly clearly favoured a forest environment over open areas. It was notable that it invariably stayed on *Stachytarpheta* flowers at the side of the path (in places ca. 3–4 m wide) from where it had emerged from the forest and returned to the forest on that same side; it was never seen at *Stachytarpheta* on the central reservation, despite an abundance of healthy flowers there. Individuals occasionally flew for a short distance (up to 20–40 m), with a 'bouncing' flight typical of *Graphium,* along the side of the path, keeping close to the contours of secondary forest vegetation at the edge; it was not seen flying along the path itself (*i.e.,* using it as a 'highway') other than the few occasions when it was seen to cross the path obliquely and although flight was erratic individuals covered a lot of ground with few wingbeats. When feeding, it maintained 'quivering' movement of forewings typical of *Graphium;* as with other relatively heavy butterflies, this might be to reduce the probability of knocking the rather sensitive *Stachytarpheta* florets off the stem. Individuals often visited 2–4 flowers at the same stand, sometimes starting with a flower on the 'forest side' of a stand of flowers or a flower near the centre of a clump, where it was virtually unreachable with a net. One female was observed nectaring at a flower of *Mimosa pudica* at ground level in a relatively open area at the end of the transect; this was the only specimen seen at a flower other than *Stachytarpheta*.

Individual butterflies were seen from 9:20 h to ca. 15:25 h and although sunshine or shade seemed not to be very significant, the butterfly may prefer shaded places or the shady side of the path. No butterflies were seen after 13:15 hours on the second day in this habitat, although the first author stayed on the ground until ca. 16:00 h. The butterfly apparently emerged from the forest with the sole purpose of obtaining nectar from the abundant *Stachytarpheta*, and individuals generally returned immediately and directly to the forest post-nectaring.

Higher taxonomic placement of *Papilio natewa*

With its narrow, elongated wings and long hindwing tails reminiscent of *Pathysa* Reakirt, 1865, *Papilio natewa* could also, as already noted, be superficially mistaken for a species of *Graphium* Scopoli, 1777, rather than a *Papilio*. However, several features of the new species (separated veins 11 and 12; unscaled antennae, fluted hindwing margin as opposed to androconial fold and well developed uncus) suggest the new taxon belongs with *Papilio* rather than within the tribe Leptocircini. No doubt further studies will clarify this placement.

Although the position of *P. natewa* within the Papilionini is uncertain, it broadly shares characters with various species groups within the genus *Papilio*. In common with many groups within Papilionini, the sexes are fundamentally monomorphic. Another feature common to several groups within *Papilio* (including certain members of the 'subgenera' *Heraclides* Hübner, 1819, and *Princeps* Hübner, [1807], is the series of cream yellow longitudinal cell bars on the underside of the forewing. Additionally, a black striped, yellow abdomen is common to several *Papilio* species-groups (e.g., those of *demoleus* Linnaeus, 1758, and *machaon* Linnaeus, 1758). To some degree, all of these groups have a tornal spot on the hindwing upperside, similar to that of *P. natewa*.

The prominent hindwing underside apical ocellus of *natewa*, consisting of a blue crescent bordered orange distally, is also pronounced in the *demoleus* and *lormieri* Distant, 1874, groups (although it is acknowledged that these two species-groups are considered to be in separate clades, according to the calibrated phylogenetic tree of Zakharov et al. 2004). The prominent row of postmedian hindwing underside spots is unique to *P. natewa* but is also mildly developed in the *demoleus* and *lormieri* groups, as is the cream discocellular patch between black bars on the forewing underside.

While some phenotypic features suggest resemblance to certain *Papilio* groups, in particular perhaps the *demoleus* group, *P. natewa* has a unique set of characters, suggesting that placement in its own species group ('section') within *Papilio* may be appropriate. Its long, exaggerated 'sword' tails, proportionately longer in comparison to the length of the hindwing than in any known *Papilio* species, are highly unusual. It is also noted that the sub-basal black bar on the hindwing underside is positioned at a very low angle to the inner margin whereas, in general, *Papilio* groups with hindwing underside bars have them situated significantly closer to the base and intersecting the inner margin at a much higher angle.

Following research on *P. schmeltzi* both published (Chandra et al. 2013a, b) and in progress, the second author obtained results from both mitochondrial and nuclear DNA sequencing of *P. natewa*. This is yet to be fully interpreted and incorporated in a phylogeny, but preliminary results suggest distinction from, but some affinity with, *P. anactus* Macleay, 1826 from eastern Australia. Prominent ventrolateral spikes in the male genitalia of both *P. anactus* and *P. natewa* support this view.

How did a unique taxon with seemingly no close relatives reach or evolve on Fiji?

If *P. natewa* is truly related to the *machaon* or *demoleus* groups, which are themselves potentially related (as suggested by Caterino et al. 2001), then it is plausible that a *P. natewa* ancestor may have had similar overwhelming dispersive ability. Together, the *machaon* and *demoleus* groups have a near cosmopolitan distribution (that is continually expanding, see for example Guerrero et al. 2004, Morgun & Wiemers 2012). It is not inconceivable that an ancestor may have historically spread widely, into distant parts of the globe, even the remote Pacific islands. As already noted, there are other papilionids in remote Pacific islands (*Papilio schmeltzi* and *P. godeffroyi* on Fiji and Samoa, respectively).

Why is *P. natewa* restricted to the Natewa Peninsula?

The question posed here is in a sense rhetorical: the butterfly has only recently been discovered and may yet be found to occur elsewhere on Fiji or even further afield. But the Fijian islands are known to support a significant number of endemic taxa, including several endemic invertebrate genera (e.g., the damselfly genus *Nesobasis* Selys, 1891 and the cicada genus *Fijipsalta* Duffels, 1988). Considering the remote location of the Fiji Archipelago, and that the oldest reliably dated rocks on Vanua Levu are ca. 6.5–8 Ma, ample time for the evolution of distinct lineages, evolution on the Peninsula is not at all far-fetched, although it is noted that most of the island was not subaerial before 3–4 Ma (Seeley & Searle 1970, Robinson 1974, Yan & Kroenke 1993, Rodda 1994).

Other endemics are present on the Natewa Peninsula, which is only narrowly connected to the main island of Vanua Levu. The Natewa Silktail, *Lamprolia klinesmithi* (Ramsay, 1876) (Rhipiduridae), is a bird species present on the Peninsula, but apparently absent from the rest of Vanua Levu (Andersen et al. 2017). Conversely, the bird taxa *Myiagra azureocapilla* Layard, 1875 (Monarchidae) and *Gymnomyza viridis* Layard, 1875 (Meliphagidae) are present on mainland Vanua Levu and the island of Taveuni, but apparently absent from the Natewa Peninsula (Andersen et al. 2017). Smith (1991) noted that ca. 5% of plant species on the Natewa Peninsula are endemic.

It is reasonable to suggest that the geological history of the Natewa Peninsula (also known as the Cakaudrove or Thakaundrove Peninsula) is, at least in part, responsible for this pattern of endemism and exclusion. The Natewa Volcanics (consisting of volcanic breccias, flows, clastics) are basalt and basic andesite rocks (Woodhall 1998) of Miocene to Pliocene age (Whelan et al. 1985). Though the Natewa Volcanics are widespread on the remainder of Vanua Levu, as well as on the Natewa Peninsula,

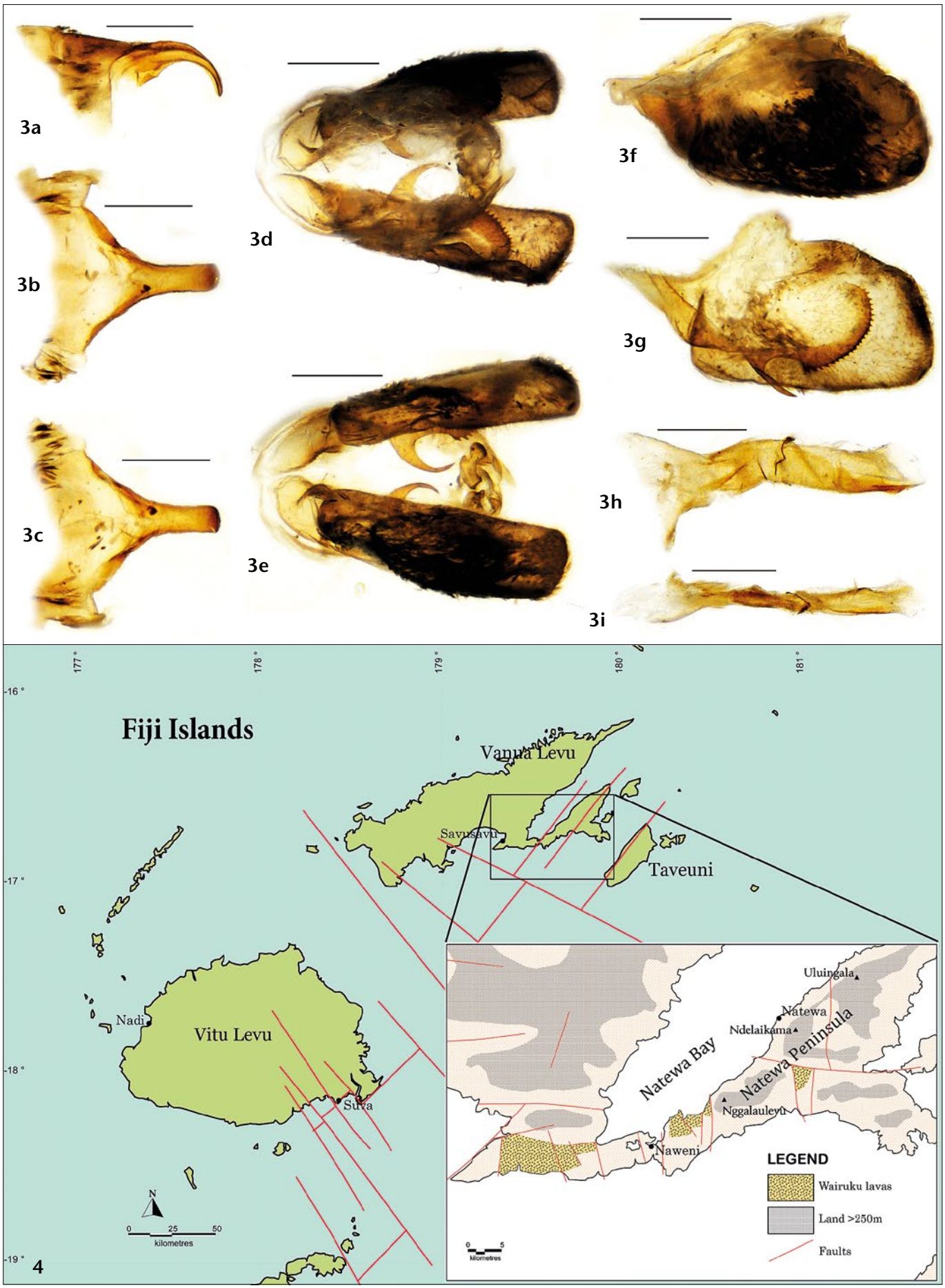

Fig. 3: *P. natewa*, genitalia (from male paratype). **3a:** sociuncus, lateral view; **3b:** ditto, dorsal view; **3c:** ditto, ventral view. **3d:** genitalia, dorsal view (sociuncus and phallus removed); **3e:** ditto, ventral view; **3f:** right valva, tegumen and vinculum, lateral view; **3g:** left valva, lateral view. **3h:** phallus, lateral view; **3i:** phallus, dorsal view. Scale bars = 1 mm. — **Map** of the Fiji Islands and the Natewa Peninsula (inset), illustrating main crustal elements (Hunter Fracture Zone) and other important geological features referred to in the text.

they represent discrete volcanic belts. The Peninsula is composed of a series of eroded volcanoes with overlapping flanks, along a lineament including Nggalaulevu, Ndelaikama and Uluinggala volcanoes (Woodrow 1976). The common NE–SW structural trend (strike) of the Natewa Volcanics on both 'mainland' Vanua Levu and the Natewa Peninsula implies that they were emplaced along similar, yet widely spaced fissures and were almost certainly well separated spatially in the Miocene, in much the same way that Taveuni Island is in relation to the Natewa Peninsula today (see Map).

The Natewa Peninsula is connected to the remainder of Vanua Levu *via* an isthmus that is a mere 1.55 km wide at its narrowest point in the vicinity of Naweni Village. The area is low-lying and comprises a number of salt lakes. Geological maps of Woodrow (1976) show that the isthmus comprises younger volcanic flows (the Wairuku pillow lavas) of middle to lower Miocene age that now seal the gap between what is now the Natewa Peninsula (but was an island), and the remainder of Vanua Levu. It is highly likely that the Natewa Peninsula was isolated as an island for an extended period during the early Miocene. In more recent times since the gap was closed by the formation of the isthmus, primary forest species such as *P. natewa,* which seems to favour slightly higher elevations (ca. 250 m or above), may not be able or willing to easily or routinely cross this low-lying area, thus resulting in continued isolation.

Fiji is positioned close to the junction of three plate boundaries (Triple Plate Junction), where major movement and rotation of terranes has taken place (Herzer et al. 2011). There is a major lineament in the Natewa Bay separating the Natewa Peninsula from the remainder of Vanua Levu (Shorten 1990, Lafoy 1992) that is part of the major NE fracture system, the Taveuni trend, which in turn reflects the strike of the broader Hunter Fracture Zone (Colley & Flint 1995). It is quite possible that there was some influx of biota from a far outlying island or terrane, brought in closer proximity by movement along these structures.

Why has *P. natewa* remained undetected?

If the geological history outlined above offers some plausible explanation regarding how such a species was able to evolve in isolation and remain isolated, the equally interesting question of how such a large and distinctive butterfly could remain undetected over centuries remains. The answer is not known, but its apparently secretive habits and unwillingness to remain in open spaces may have some bearing. It may also be the case that the restricted distribution of the butterfly is governed in turn by the distribution of its hostplant, which remains unknown – although regional plant diversity apparently reaches a peak on the Natewa Peninsula (Wragg et al. 2015).

As indicated at the outset of this paper, it is remarkable that such a distinctive species could remain undetected on a relatively well-studied island group like Fiji. But the answer lies in all the circumstances outlined above. *P. natewa* is a forest butterfly, apparently with habits that keep it in the forest itself for much of its life; it would need to have been seen by a specialist – or at least by someone who recognized its significance, and it is noted that even when a relatively large number of people were actively looking for the butterfly in approximately the right area for some months over a period of two years in 2017 and 2018, sightings were few. The Natewa Peninsula is controlled by a series of Mataqali (land owning village communities) and access has historically been denied to outsiders. Following indirectly from the presence of Operation Wallacea on the peninsula in 2017 and 2018, and directly from the photograph taken by Greg Kerr, *P. natewa* has been brought to our attention. Without these serendipitous events we would not have been aware of its presence there.

The fact that all specimens seen, including females, appear similar in all significant respects, with no notable variation, suggests that the gene pool is small, as might be expected of a species from an isolated, restricted and remote piece of land. If it is found to be restricted to the Peninsula, *P. natewa* may be the most range-restricted of any papilionid species.

Data available at present illustrates an urgent need to conserve primary forest habitat on the Natewa Peninsula and it is a fact that many land-based vertebrate species have already been lost or populations decimated by the ravages of mongoose, rat and cane toad. With the founding of the Nambu Conservation Trust, initiated by Gilbert Vakalalabure from Natewa village with the support of Operation Wallacea, a positive start has been made on conserving what appears to be a unique and distinctive region.

Acknowledgements

A number of people were involved in the discovery and photography of this species in 2017 and in observations and subsequent capture the following year. In particular, Gilbert Vakalalabure, Natewa village, set up the local Nambu Conservation Trust and facilitated access to and travel on land belonging to the local Mataqali (village community), members of which actively supported research into the butterfly on their Custom Land on the Natewa Peninsula. Research would not have been possible without the vision and administrative support of Operation Wallacea, in particular Tim Coles, Director, and Martin Speight, Science Director. Ornithologist Greg Kerr is particularly thanked for the superb photograph of the butterfly, which triggered serious interest in this project, and for his agreement for the use of the photograph subsequently, including in this paper. Greg Chamberlain is thanked for discussion on the specimen captured in 2017; Will Earle provided photographs taken in 2017 and discussed sightings of the butterfly. The scientific team and guides of Operation Wallacea in both 2017 and 2018, in particular entomo-

logist Richard Markham, and guide Maika Vuto (who collected several specimens in 2018), are thanked for their interest and personal observations, and students from a number of international schools are thanked for the important part they collectively played. The second author thanks the Fiji National University, Suva, for supporting her attendance on the Operation Wallacea project in 2018. The Ministry of Education, Heritage and Arts, Government of Fiji, Suva, is thanked for allowing research on the Natewa Peninsula by named associates of Operation Wallacea, including the first author. Margreet S. Soqomaiwasa, at the Geological Resources Department in Suva, worked tirelessly over two days to assist the third author in identifying numerous relevant geological maps and reports related to the Natewa Peninsula and surrounding areas.

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Received: 10. ix. 2018

 ISSN 0723-9912