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Scientific names of the two *Pieris napi* (Linnaeus, 1758)-related species of Japan

(Lepidoptera, Pieridae)

by

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Abstract: Scientific names of the two *Pieris napi*-related species of Japan, commonly named as Ezo-sujiguroshirochou (Hokkaido- species) and Yamato-sujiguroshirochou (Hondo-species) biologically defined by Shirôzu (2002), are reviewed based on appropriate interpretation of the current ICZN. *Pieris nesis* Fruhstorfer, 1909 is given to Hondo (Mainland) population of Hondo-species, and *Pieris pseudonapi* Verity, 1911 **stat. nov.** is appropriate to apply for Hokkaido-species. And South Hokkaido population shall be treated as a subspecies of *Pieris nesis* Fruhstorfer, 1909.

Keywords: Androconia, ICZN, Japan, Morphology, Phylogenetic linage, *Pieris dulcinea*, *Pieris erutae, Pieris napi*-related species group, *Pieris nesis*, *Pieris pseudonapi*, Species, Systematic

Introduction: In this paper, taxonomic definition of the two distinct *Pieris napi*-related species of Japan, namely as Ezo-sujigurosirochou (Hokkaido-species) and Yamato-sujiguroshirochou (Hondo-species) follows Shirôzu (2002). Shirôzu (2002) defined the boundary line of the two species as around Ishikari lowland in Hokkaido (fig. 1), based on molecular phylogeny, such as karyotype linages by Maeki & Kawazoe (1994) and phylogenetic analyses of mtDNA genes. Hondo-species distributes even in South Hokkai do-species in addition to Hondo (Mainland = Honshu, Shikoku and Kyushu), while Hokkaido-species distributes only in East Hokkaido. The definition above does not mean that the two species are reproductively separated.
Since then, scientific names of the two species have been in confusion mainly in Japan. Although Eitschberger (1983) applied *P. nesis* Fruhst. for Hondo population of Hondo-species, Shirôzu (2002) treated it as South Hokkaido population of Hondo-species, and applied *P. n. japonica* Shirôzu,1952 for Hondo population. Recently, Oda (2015) treated *P. nesis* Fruhst. as Hokkaido-species based on statistical analyses of wing forms and venations in three species from Hokkaido (Hondo-species from S. Hokkaido, Hokkaido-species from E. Hokkaido and *P. melete* Ménétriès, 1857) comparing to the type specimens of *P. nesis* Fruhst. in NHM London.
As for Hokkaido-species, Shirôzu (2002) initially named *P. dulcinea pseudonapi* Verity, but later changed to *Pieris dulcinea pseudonapi* Eitschberger, 1983 in Shirôzu (2006). Shirôzu (2011) further changed the name to *Pieris dulcinea tomariana* Matsumura, 1928, that was followed by Inomata et al. (2013) and is considered valid in Japan.
Those confusions might be caused by inappropriate interpretations of ICZN (International Code of Zoological Nomenclature). This paper reviews the scientific names of the two *Pieris napi*-related species of Japan, based on appropriate interpretation of the current ICZN Version-4, along with recent papers in morphological or phylogenetic analyses of those nominal taxa.

Chapter-1. Hondo-species: Confusions in scientific name of Hondo-species are chiefly caused by uncertain type locality of *Pieris nesis* Fruhstorfer, 1909 stated in the original description. "Habitat: North-Japan 2 ♂♂, 2 ♀♀. Sapporo (Dr. Matsumura leg.)" in Fruhstorfer (1909), might have misled many entomologists to believe that the type locality was Sapporo in Hokkaido instead of North-Japan (incl. northern part of mainland Japan). In fact, the lectotype (figs. 2, 3) in NHM London indicates that the place of collection is vaguely "Japan".
1. 1: Type locality of *Pieris nesis* in accordance with ICZN: As the term "type locality" is defined by ICZN Art. 76.1 as the geographical place of capture, collection or observation of the lectotype, "Japan" printed on a label of the lectotype (fig. 2) should be treated as the type locality.
The lectotype designated by Eitschberger (1983) from two syntypes is considered valid in accordance with ICZN Art.74 as follows; [1] to have treated taxon *nesis* as a distinct species, [2] to have nominated one specific taxon *nesis*, [3] to have designated the holotype from two type specimens (♂, ♀) in ex- Fruhstorfer collection deposited in BMNH, which could be considered as a part of syntypes. [4] Although Eitchberger (1983) misused the word "holotype" for the designation of name-baring type, "holotype" can be interpreted as "lectotype" under Art.74.5.
Recommendations 76A were also taken into consideration, as follows; 76A.1.1. Data accompanying the original material: None, 76A.1.2. Collector's notes: The late Dr. Shonen Matsumura, the collector of four syntypes (2 ♂♂, 2 ♀♀), indicated that taxon *nesis* Fruhst. was distributed in both Hokkaido and Honshu (Mainland) in Matsumura (1929) (fig. 4), 76A.1.3. Morphological characteristics in the original description perfectly match to the lectotype specimen (Tadokoro, 2015-1), and the habitat of syntypes 2 ♂♂, 2 ♀♀ in Fruhstorfer (1909) can be read as North-Japan (Northern part of Hondo as well as Hokkaido), which does not conflict to the label of the lectotype as "Japan".
As the type locality is not limited to "Hokkaido" but vaguely in "Japan", the nominal taxon *P. nesis* Fruhst. shall be given to the most appropriate population matching to the lectotype, judging from impartial morphological comparison of three populations (Hondo, S. Hokkaido and E. Hokkaido) of the *P. napi*-related species of Japan.

1.2. Materials and methods: Photographs of the lectotype *P. nesis* Fruhst. (fig. 2) were provided by NHM, London. Morphological characteristics of the lectotype are compared with those of three populations summarized in Fujimori (2012). Fujimori (2012) divided the *P. napi-related* species of Japan into three populations, such as Hondo, South Hokkaido and East Hokkaido populations, according to the taxonomic definition in Shirôzu (2002). Total numbers of specimens observed in Fujimori (2012) were 2.174, including 974 from Kinki district in Hondo, 547 from S. Hokkaido and 653 from E. Hokkaido. And all data were classified by genders and generations. As the lectotype of *P. nesis* Fruhst. has been identified as a ♂ in spring generation by Eitschberger

and Tadokoro (2015 b), all comparisons are made within the same group. In Fujimori (2012), morphological data of ♂ in spring generation were 655 in total, including 249 from three places of Kinki district in Hondo, 149 from four places in S. Hokkaido and 257 from ten places in E. Hokkaido.
Androconia (figs 5, 6) were extracted from the lectotype by the author (Tadokoro, 2015 b) and measured by optical microscope in 400 magnifications with micro meters. Dimensional data of androconia in Fujimori (2012) consist of 100 androconia for each population, randomly extracted 10 androconia from each of 10 typical specimens in spring form. The population from Kinki district (Osaka area) is considered to represent Hondo population (of Hondo-species) in morphological characteristics.

1.3. Morphological Comparisons: Forewing length, wing markings and form of androconia in three populations summarized in Fujimori (2012) are compared with the lectotype of *P. nesis* Fruhst. Hondo and S. Hokkaido populations belong to Hondo-species, while E. Hokkaido population belongs to Hokkaido-species, as per the definition in Shirôzu (2002).
1. Forewing length (FL): Dimensional ranges and averages. (n: nos. of population) (fig. 2).
   Hondo: Range 22-30 mm, Av. 26.7 mm. (n=249)
   S. Hokkaido: Range 21-28 mm, Av. 25.0 mm. (n=149)
   E. Hokkaido: Range 19-26 mm, Av. 22.9 mm. (n=257)
   Pieris nesis Fruhst. (FL=25.5mm) is within the ranges of all populations, but out of standard range of E. Hokkaido population (Standard range 22-25mm = 86% of 257).
2. Wing markings: Occurrence ratios (n: same as above) (fig. 2).
   ①Triangular black marking in apex (upf):
   Hondo: 86%, S. Hokkaido: *less than 12%, E. Hokkaido: *less than 4%.
   ② Black spot in space-3 (upf):
   Hondo: 55%, S. Hokkaido: 6%, E. Hokkaido: 6%.
   ③ Black scales in underside forewing cell (unf):
   Hondo: 71%, S. Hokkaido: *less than 17%, E. Hokkaido: *less than 18%.
   For ① and ③, the word "*less than" is added to Hokkaido populations as the degrees of blackness in the specimens shown in Fujimori (2013) do not reach to the equivalent level as lectotype. Occurrence ratio that three morphological characteristics ①, ② and ③ appeared at the same time, is extremely low in both S. Hokkaido and E. Hokkaido populations. Occurrence ratios above indicate that *P. nesis* Fruhst. match to the Hondo population in wing markings.
3. Wing form and Venations:
   Fujimori (2012) states that no significant difference is observed in wing form and venations in three populations.
4. Form of androconia: Dimensional ranges of average minimum neck widths in each specimen, and grand averages (fig. 5).
   Hondo: Range of averages 24.4-36.5μm, Gr. average 29.6μm. (n=100).
   S. Hokkaido: Range of averages 22.3-28.8 μm, Gr. average 25.7 μm. (n=100).
   E. Hokkaido: Range of averages 20.6-29.1 μm, Gr. average 24.5 μm. (n=100).

Fujimori (2012) states that there is no significant difference in the form of androconia between South Hokkaido and East Hokkaido populations, but significant difference is observed between South Hokkaido population and Hondo population.in the minimum neck width (fig. 5).
The minimum neck width of *P. nesis* Fruhst. (Av. 32.5 μm, Range 30.3-34.1 μm. n=10) (fig. 6) is within the range of Hondo population, but out of ranges of both South Hokkaido and East Hokkaido populations. *Pieris nesis* Fruhst. belongs to Hondo population, judging from the average minimum neck widths of androconia.

1.4. Appropriate scientific name of Hondo-species: Judging from impartial morphological comparisons between lectotype of *P. nesis* Fruhst. and three populations of the *P. napi*-related species of Japan as summarized in Fujimori (2012), *P. nesis* Fruhst. is indicated as Hondo population of Hondo-species (Yamato-sujiguroshirochou), as previously suggested by Eitschberger (1983) and Tadokoro (2015 b). The nominal taxon *P. napi japonica* Shirôzu,1952, described from the northern part of Hondo, is a junior synonym of *P. napi nesis* Fruhstorfer, 1909.

Chapter-2. Hokkaido-species: Confusions in scientific name of Hokkaido-species are initially caused by complex system of classifications in Verity (1905-1911), where the taxon *pseudonapi* Verity 1911 from East Hokkaido was treated as an unavailable infrasubspecific name, as previously suggested by Kudrna & Geiger (1985). In this paper, availability of the taxon *pseudonapi* Verity, 1911 is reviewed in accordance with the current ICZN Version-4. And the appropriate specific name of Hokkaido-species is discussed based on the recent phylogenetic analyses of the *Pieris napi*-relates species group.
2. 1. History of taxon *pseudonapi* Verity, 1911: Nominal taxon *pseudonapi* was described in January 1911 in the legend of plate LIX, figs. 13-17 in Verity's "Rhopalocera Palaearctica" as ***Pieris melete*** var. ***pseudonapi*** (fig. 7) from Ichikishiri (fig. 1). Verity later classified the taxon *pseudonapi* as a race of the nominal subspecies *Pieris melete melete* in his "Index systematique" issued in October 1911, where the names are clearly ranked as 'species - subspecies - race - form (morph) - aberration' [Verity (1905-1911)]. Matsumura (1928), Bollow (1932) and Talbot (1932) treated *pseudonapi* as a subspecies of *Pieris melete* Ménétriès, 1857.
In the late 20th century, Eitschberger (1983) concluded that *pseudonapi* was included in the *Pieris napi*-related species group instead of *P. melete* Mén. and treated it as a subspecies (Hokkaido population) of *Pieris dulcinea* Butler, 1882 (Fig. 8). However, Kudrna & Geiger (1985), in defaming the systematics of Eitschberger (1983), suggested '*Pieris melete melete pseudonapi* Verity, 1911 was an unavailable infrasubspecific name proposed for race.

2. 2. Nomenclatural history of Hokkaido-specie: Leech (1892-1894) introduced *Pieris napi* (Yesso) (fig. 9) from Hokkaido. Since then, *Pieris napi* Linnaeus, 1758 had been used as the sole specific name of the *P. napi*-related species in Japan, until Shirôzu (2002) declared that there were two distinct species in Japan based on phylogenetic analyses of mtDNA genes by Shinkawa et al. (2001) (fig. 10). Shirôzu (2002) initially named the newly defined Hokkaido-species as *Pieris dulcinea pseudonapi* Verity, by following Eitschberger (1983). But soon after, Shirôzu (2006) changed the name to *Pieris dulcinea pseudonapi* Eitschberger, 1983 by replacing the author's name and the year of description. I assume that Shirôzu (2006) tried to follow the suggestion by Kudrna & Geiger (1985) that Verity was not the appropriate author. Shirôzu (2011) further changed the name to *Pieris dulcinea tomariana*

Matsumura, 1928, after learning that the population from Kunashiri-island (the southernmost Kuril-islands and the type locality of the taxon *tomariana*) was included in the Hokkaido-species in phylogenetic. Inomata et al. (2013) followed Shirôzu (2011). The scientific name *Pieris dulcinea tomariana* Matsumura, 1928 is curiously treated as appropriate scientific name of Hokkaido-species in Japan today.

2. 3. Availability of taxon *pseudonapi* Verity, 1911 in accordance with ICZN: *Pieris melete* var. *pseudonapi* Verity, 1911 (fig. 7) was described in January 1911. According to ICZN Art. 45.6.4, this name can be interpreted as subspecific, and therefore available. However, later in the same year, Verity published "index systématique" where he listed it as *Pieris melete melete pseudonapi*, thus as a quadrinomial, and clearly infrasubspecific. Therefore, Verity's overall treatment of the taxon *pseudonapi* suggests that he proposed it as an infrasubspecific entity, and thus unavailable for nomenclatural purposes. On the other hand, Art. 45.6.4.1 states that if such an infrasubspecific name as *pseudonapi* was adopted before 1985 as the valid name of a subspecies, it should be deemed to be subspecific from its original publication. Matsumura (1928) treated *pseudonapi* as a valid subspecies, and by that action made it available under Art. 45.6.4.1, although Matsumura (1928) did not discuss it when simultaneously describing a new subspecies as *tomariana*. Bollow (1932) and Talbot (1932) treated it as a subspecies of *Pieris melete* Mén. as well. Based on interpretations above, taxon *pseudonapi* Verity, 1911 is considered as available in accordance with the current ICZN Version-4. It is apparent that Art. 45.6.4.1 was added to the current ICZN after 1985, and therefore the suggestion by Kudrna & Geiger (1985) was correct, as it had been published before the current ICZN Version-4 was issued in 2000. However, Shirôzu (2006, 2011) should have named Hokkaido-species as *Pieris dulcinea pseudonapi* Verity, 1911 as Shirôzu (2002) initially proposed, according to the current ICZN Version-4 already issued.

2. 4. Specific name based on recent phylogenetic analyses: Shirôzu (2002) selected *Pieris dulcinea* (Butler, 1882) (fig. 8) as the specific name of Hokkaido-species based on phylogenetic analyses of mtDNA genes by Shinkawa et al. (2001) (fig. 10), where the *P. napi*-related species group in Palearctic region was divided into three significant phylogenetic lineages, such as *P. napi* (L.) from Europe to Mongolia, *P. dulcinea* (Btlr.) from Asian region, and *P. nesis* Fruhst. from mainland Japan. Recently, Shinkawa et al. (2010) and Tadokoro et al. (2014) (fig. 11) indicate that Hokkaido-species (taxon *pseudonapi*) has its own phylogenetic lineage distinct from *P. dulcinea* (Btlr.) and *P. erutae* Poujade, 1888, while ssp. *kamtschadalis* and ssp. *saghalensis* are included in *P. dulcinea* (Btlr.) in phylogenetic. If *P. erutae* Pouj. from SW China, *P. dulcinea* (Btlr.) from Ussuri, and *P. hulda* Edwards, 1869 from Alaska are treated as distinct species, Hokkaido-species (taxon *pseudonapi*) ought to be treated as a distinct species as well. Tuzov (1997) also considers that the *Pieris napi*-related species from Japan is not included in *Pieris dulcinea* from Ussuri, Russia.

2.5. Appropriate scientific name of Hokkaido-species: Appropriate scientific name of Hokkaido-species is indicated as *Pieris pseudonapi* Verity, 1911 **stat. nov.** based on recent phylogenetic analyses of mtDNA genes (fig. 11).

Pieris pseudonapi Verity, 1911 **stat. nov.** (Type locality: Ichikishiri, E. Hokkaido, Japan)

Pieris napi (Yesso): Leech, 1894 (partim - from Nemuro) (fig. 9).
Pieris melete var. *pseudonapi*: Verity, 1911 (fig. 4).
Pieris melete melete pseudonapi: Verity, 1911 (Index): Kudrna & Geiger, 1985.
Pieris napi pseudomelete gen. aest. *aestiva*: Verity, 1911.
Pieris melete pseudonapi: Matsumura, 1928: Bollow, 1932: Talbot, 1932
Pieris napi pseudomelete: Matsumura, 1928 (partim - from E. Hokkaido).
Pieris napi pseudomelete f. *aestiva*: Bollow, 1932
Pieris melete f. *pseudonapi*: Matsumura, 1929.
Pieris napi f. *pseudomelete*: Matsumura, 1929 (partim - from E. Hokkaido).
Pieris napi f. *nesis*: Matsumura, 1929 (partim - from E. Hokkaido)
Pieris napi nesis: Bollow, 1932 (partim - from E. Hokkaido): Talbot, 1932 (partim - from E. Hokkaido, f. aest *aestiva*): Shirôzu, 1952 (partim - from E. Hokkaido): Maeki et al., 1994: Kuroda et al. 2010: Kitahara et al. (partim - from E. Hokkaido).
Pieris napi race *dulcinea* f. *aestiva*: Warren, 1961.
Pieris dulcinea pseudonapi: Eitschberger, 1983 (partim - from E. Hokkaido): Shirôzu, 2002, 2006: Ziegler, 2019 (partim - from E. Hokkaido)
Artogeia napi pseudonapi: Inomata, 1990 (partim - from E. Hokkaido).
Pieris nesis: Tuzov, 1997 (partim - from E. Hokkaido): Tadokoro et al., 2014.: Oda, 2016.
Pieris dulcinea tomariana: Shirôzu, 2011: Inomata et al., 2013.
Artogeia napi nesis: Matsuda, 2009 (partim- from E. Hokkaido).
Artogeia nesis: Shinkawa et al., 2010.

Chapter-3. Hondo-species from South Hokkaido: Scientific name of South Hokkaido population in Hondo-species has never been discussed in Japan, as it has been treated as the nominotypical subspecies of *P. nesis* Fruhst. by Shirôzu (2002, 2006, 2011) and Inomata et al. (2013) until today. As *P. nesis* Fruhst. is indicated as Hondo population of Hondo-species in this paper, S. Hokkaido population ought to be treated as a subspecies of *P. nesis* Fruhst., due to its distinct morphological characteristics from nominotypical Hondo population.

Reproductive Isolation: Kuroda (2010) reported that no reproductive isolation was indicated between E. Hokkaido population (*P. pseudonapi* in this paper) and S. Hokkaido population (*P. nesis* ***yesso*** in this paper), judging from cross-breeding experiments by cage paring. Kuroda (2010) and Kuroda et al. (2010) also reported that imperfect reproductive isolation was observed between E. Hokkaido population (*P. pseudonapi* in this paper) and Hondo population (*P. nesis nesis* in this paper), where F1 ♀ hybrid had no fertility although F1 ♂ hybrid has normal reproductivity. Recentry, Kitahara et al. (2018) reported that similar imperfect reproductive isolation was indicated between Central Sakhalin population (*P. dulcinea sakhalinensis* in this paper) and Hondo population (*P. nesis nesis* in this paper), but the degrees of reproductive isolation between them was more than the one between E-Hokkaido population (*P. pseudonapi* in this paper) and Hondo population (*P. nesis nesis* in this paper), judging from reproductive capabilities of F2 and F3 ♀ born by back cross-breeding of F1 ♂ hybrid. Based on the cross-breeding experiments above, Kuroda (2010) and Kitahara et al. (2018) concluded that Hokkaido populations (S. Hokkaido and E. Hokkaido) should be included

definition of species by reproductive isolation.

Conclusion: The *Pieris napi*-related species group is deemed to be in the process of speciation, and taxonomic statuses of three populations in Japan are subject to the definitions of "species". If the author classify the species by phylogenetic lineages like in this paper, three populations shall be treated as two distinct species as follows:

Hondo population: *Pieris nesis nesis* Fruhstorfer, 1909

South Hokkaido population: *Pieris nesis* subspec.

East Hokkaido population (Ezo-sujigurosirochou): *Pieris pseudonapi* Verity, 1911 **stat. nov.**

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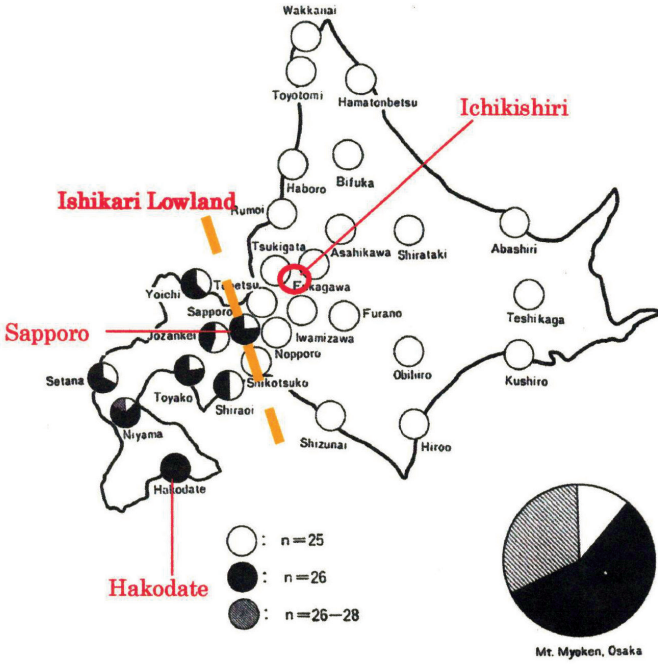
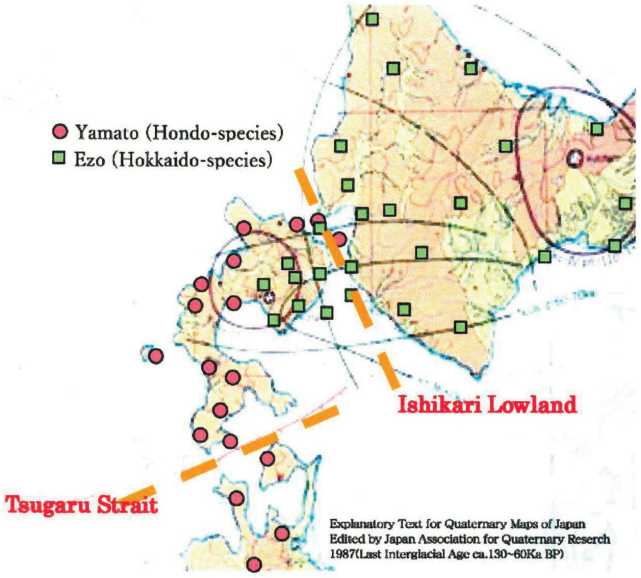
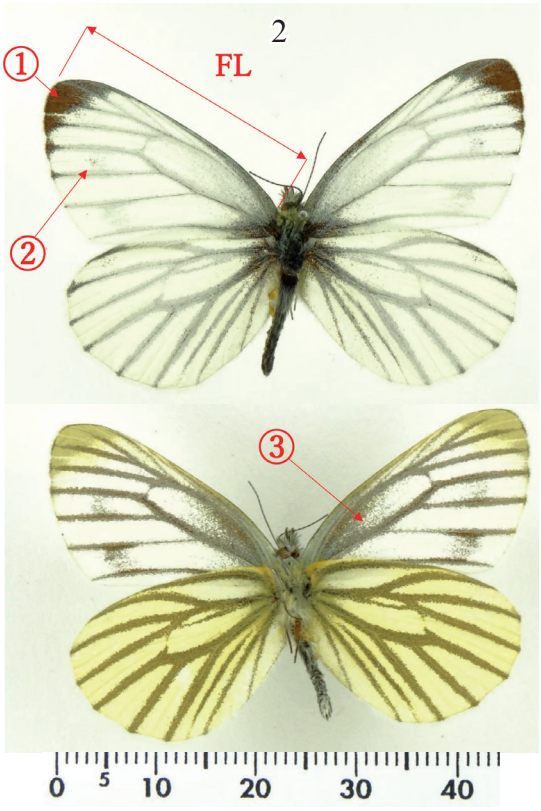


Karyotype lineages [Maeki & Kawazoe (1994)]



Phylogenetic lineages by mtDNA [Tadokoro *et al.* (2014)]

Fig. 1: Two *Pieris napi*-related species in Hokkaido, Japan.



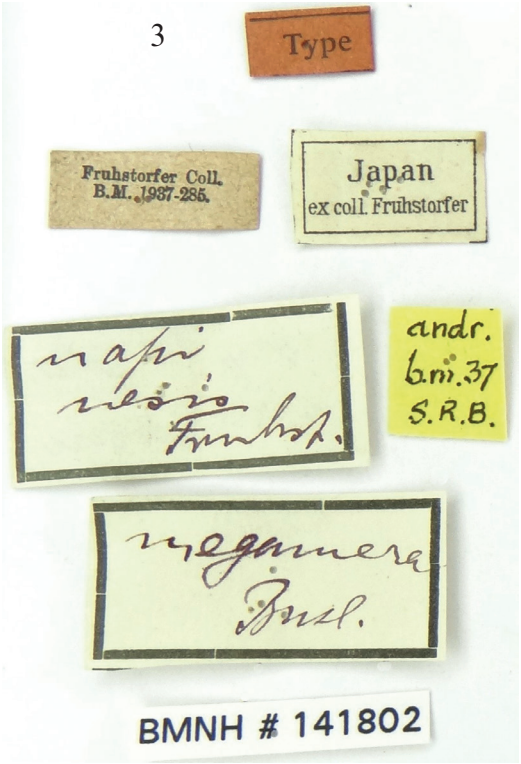


Fig. 2, 3: *Pieris nesis* Fruhstorfer, 1909,(2) lectotype ♂ (gen. vern.), (3) and all labels, © NHM, London

4

6 日 本 産 蝶 類 分 布 表

PIERIDAE	樺太 Seghalien	北海道 Hokkaido	本州 Honshu	四國 Shikoku	九州 Kiushu	朝鮮 Korea	沖繩 Okinawa	臺灣 Formosa	本書に記載せる蝶	粉蝶科
55. **P. melete** Mén.		×	×	×						ウスモンシロテフ
f. aglaope Motsch.			×	×	×	×			Pl. IV, f. 2, ♀	
,, dulcinea Butl.								×		
,, juba Fruhs.				(Tsushima)						
,, pseudonapi Verit.		×								
,, tomariana Mats.		×								
56. **P. napi** L.									Pl. IV, f. 7, ♀	スヂカロテフ
f. frigida Scudd.			×							
,, kamtschadalis Bangh.	×									
,, napaeae Esp.	×									
,, nesis Fruhs.		×	×							
,, pseudomelete Verit.		×								
,, saghalensis Nak.	×									

Fig. 4: Distribution table of the butterflies in Japan (MATSUMURA, 1929)

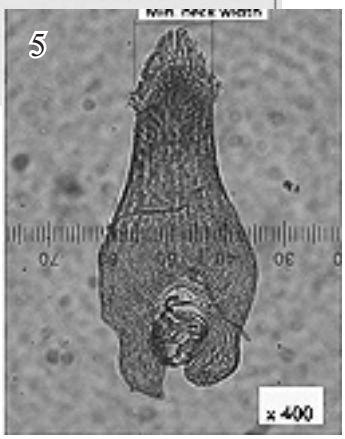


Fig. 5: Minimum neck width of androconium.

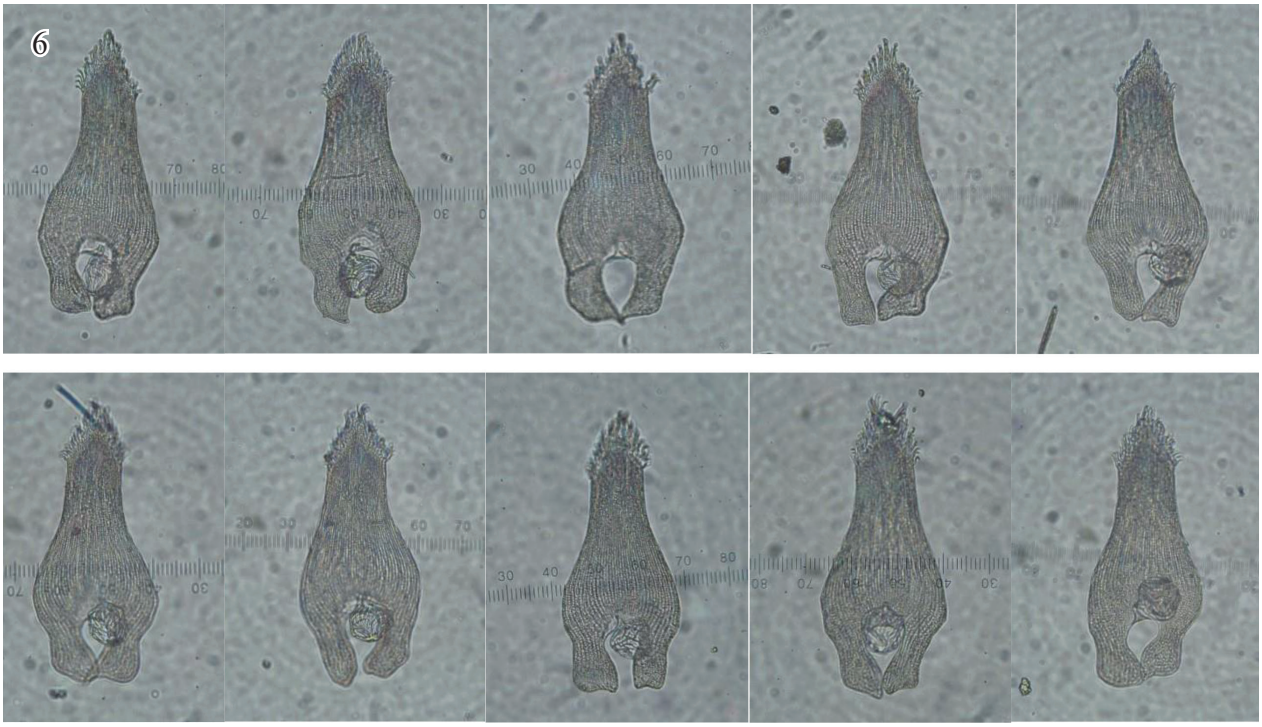
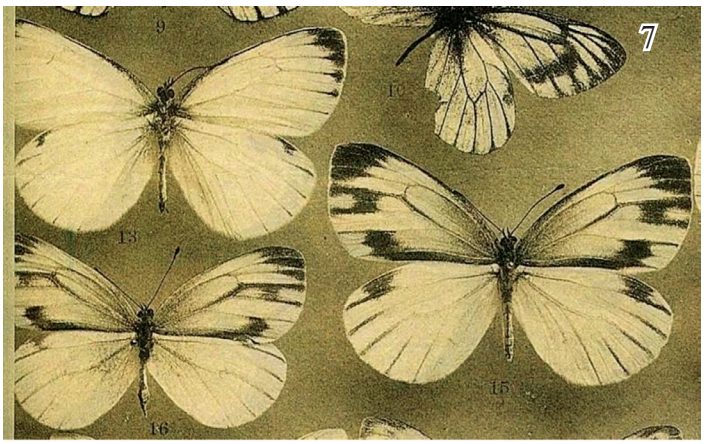
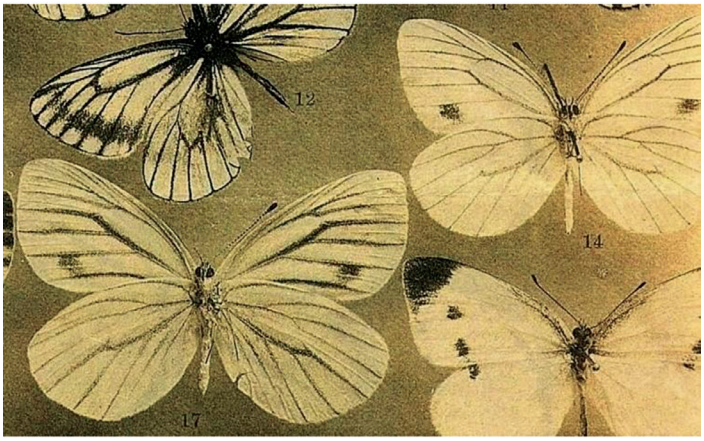


Fig. 6: Androconia of *Pieris nesis* FRUHSTORFER, 1909, lectotype ♂.





13. *P. melete*, Mén. var. *pseudonapi*, Verity ♂ (Ichikishiri, Yesso, Japon)
14. Id. ♂ Revers (Ichikishiri, Yesso, Japon)
15. Id. ♀ (Ichikishiri, Yesso, Japon)
16. Id. ♀ (Ichikishiri, Yesso, Japon)
17. Id. ♀ Revers (Ichikishiri, Yesso, Japon)

Fig. 7: *Pieris melete pseudonapi* Verity, 1911 (pl. 59: 13-17).

Fig. 8: *Pieris dulcinea* (Butler, 1882), holotype (♂, gen. aest) © NHM, London.

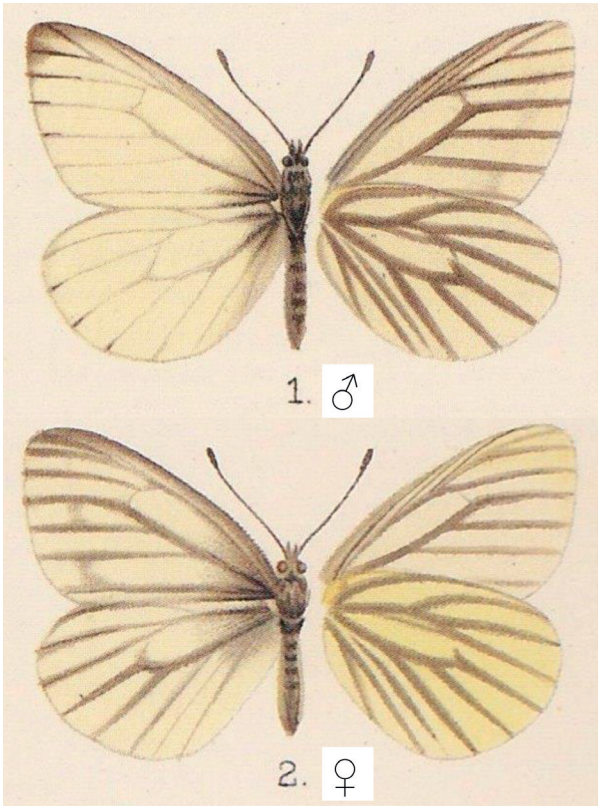
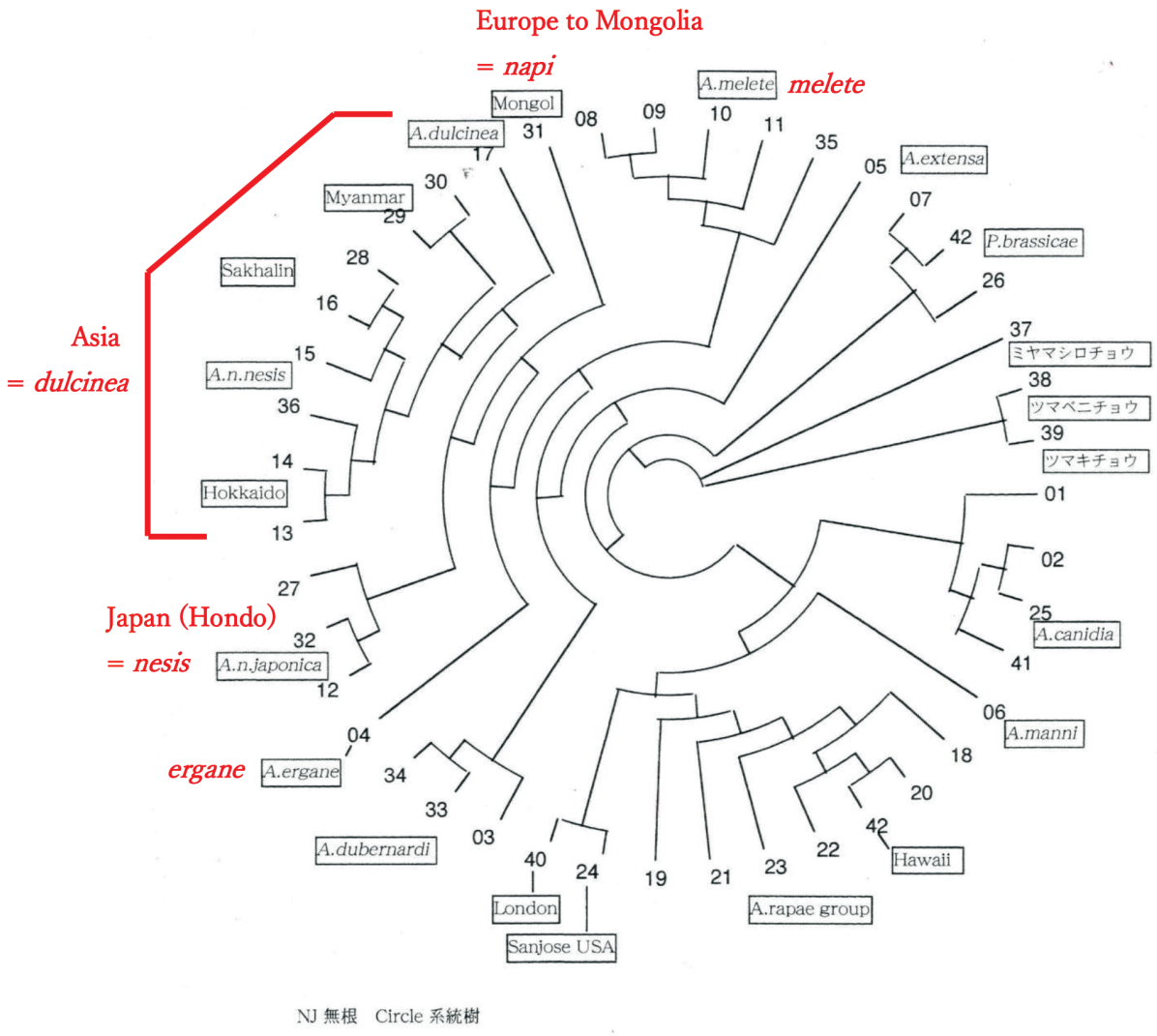


Fig. 9: *Pieris napi* (Linnaeus, 1758) (Yesso), ex Leech (1893 pl. 43: 1, 2).

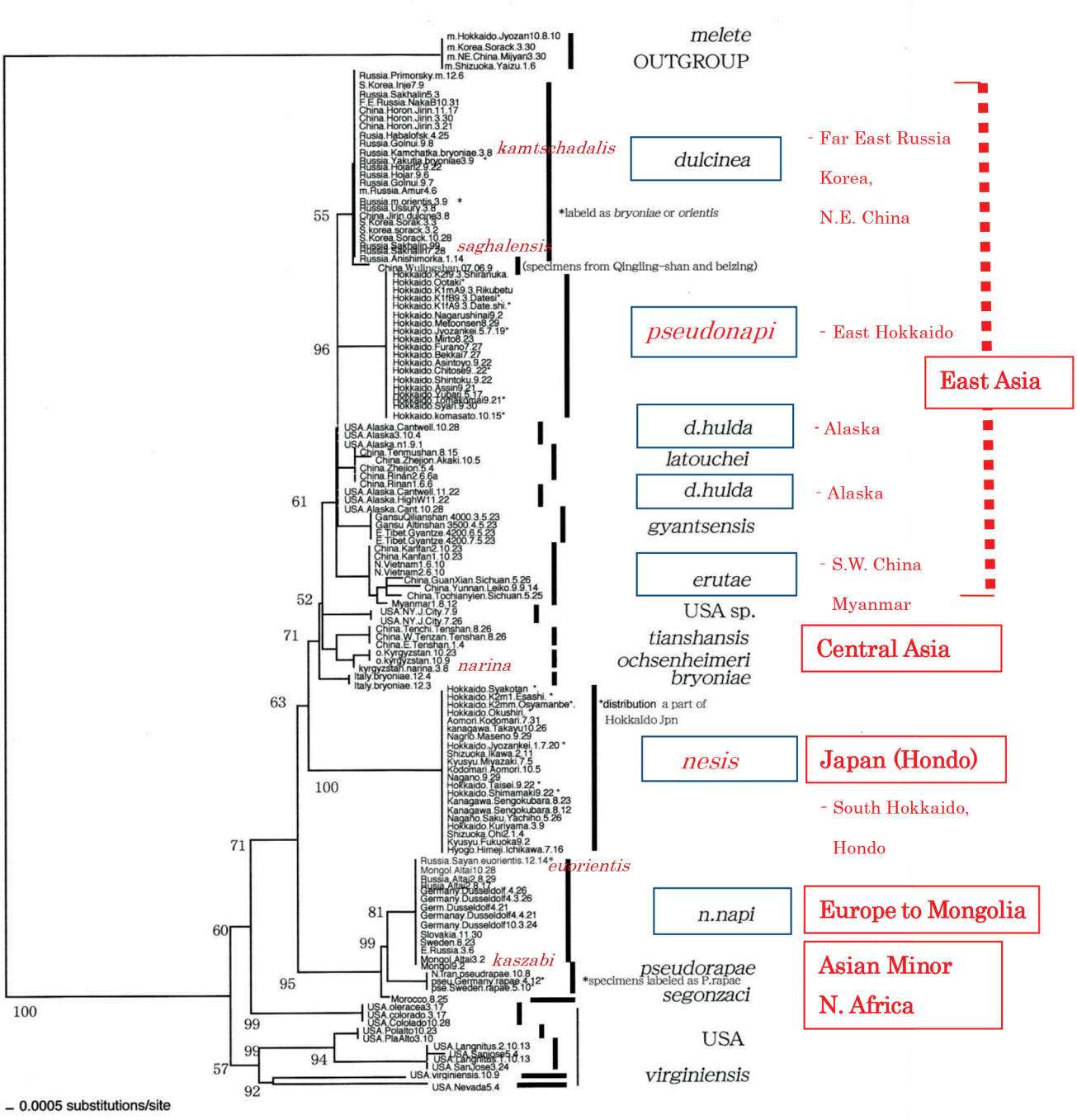


NJ 無根　Circle 系統樹

Remarks

1. Drawn by Shinkawa, T. (mtDNA-ND5 900 bp.)
2. Red Notes : Added or revised by the author

Fig. 10: NJ Circle for the genus *Pieris* [after SHINKAWA, 2001].



napi group ND5 naighbor-jointing method(NJ)tree T.Shinkawa 2012.8

Remarks

1. Drawn by Shinkawa, T. (mtDNA-ND5, 810 bp.)
2. Red Notes: Added or Revised by the author

Fig. 11: NJ Tree for the *Pieris napi*-related species [Tadokoro et al., (2014)].