OUKA
The University of Osaka
Institutional Knowledge Archive

Title	Integrative systematics of two lophotrochozoan group: A panoptic approach to Octopus and Dicyemid taxonomy
Author(s)	Purkayastha, Abhijeet
Citation	大阪大学, 2026, 博士論文
Version Type	
URL	https://hdl.handle.net/11094/107164
rights	
Note	やむを得ない事由があると学位審査研究科が承認したため、全文に代えてその内容の要約を公開しています。全文のご利用をご希望の場合は、大阪大学の博士論文についてをご参照ください。

The University of Osaka Institutional Knowledge Archive : OUKA

https://ir.library.osaka-u.ac.jp/

The University of Osaka

Form 3

Abstract of Thesis

Name （**Abhijeet Purkayastha**）	
Title	**Integrative systematics of two lophotrochozoan group: A panoptic approach to Octopus and Dicyemid taxonomy** **(2つの冠輪動物群の統合的分類学：タコ類とニハイチュウ類の分類における包括的なアプローチ)**

Abstract of Thesis

Cephalopods, including squids, cuttlefishes, octopuses, and nautiluses, are among the most ecologically and economically important marine invertebrates worldwide. This study provides a comparative overview of cephalopod biodiversity, ecology, population biology, fisheries, trade, pathology, and management in India and Japan, two countries that represent contrasting but highly significant cephalopod-producing regions within the Indo-Pacific. Indian waters currently support more than 210 recorded cephalopod species, while Japanese waters harbor over 230 species distributed across diverse coastal, oceanic, and deep-sea habitats. In both countries, cephalopods occupy important ecological roles as active predators and prey, contributing substantially to marine food-web dynamics and nutrient transfer. Despite sharing similar biological characteristics such as rapid growth, short life spans, and semelparous reproduction, cephalopod populations exhibit distinct regional patterns shaped by oceanographic conditions, habitat availability, and fishing pressure. India remains a major producer and exporter of cephalopods, with squid fisheries dominating landings and export revenues. In contrast, Japan has experienced long-term declines in domestic catches and increasingly relies on imports to satisfy consumer demand. The review also highlights major differences in parasite diversity and pathological studies, with Japan possessing one of the world's most thoroughly documented cephalopod parasite faunas, whereas knowledge from Indian waters remains limited. Overall, this comparison demonstrates the importance of integrating biodiversity research, fisheries science, trade dynamics, disease monitoring, and ecosystem-based management to ensure the long-term sustainability of cephalopod resources under changing environmental and climatic conditions.

Octopus longispadiceus is a poorly understood octopod species distributed in the Sea of Japan and adjacent Korean waters, with its taxonomic position remaining uncertain owing to limited molecular and population-level studies. This study integrates phylogenetic reconstruction, species delimitation, population genetics, and historical biogeography to clarify the evolutionary status of the species. Analyses based on COI, COIII, 16S, and concatenated mitochondrial datasets recovered *O. longispadiceus* as a strongly supported monophyletic lineage encompassing populations from Japan and the Korean Peninsula. The candidate taxon *Octopus* sp. 1 was nested within this clade, indicating conspecificity rather than species-level distinction. Species delimitation using ASAP and LIMES supported recognition of *O. longispadiceus* within a stable taxonomic framework and identified an optimal partition balancing taxonomic congruence and resolving power. Haplotype analyses revealed high genetic diversity, numerous unique haplotypes, and moderate geographic structuring, suggesting historical connectivity among regional populations despite localized differentiation. Ancestral area reconstruction suggested that diversification within the lineage was shaped primarily by regional isolation, range fragmentation, and limited dispersal rather than extensive long-distance colonization with speciation approx. 8-10 million years ago. Collectively, the results demonstrate that *O. longispadiceus* represents a genetically cohesive yet geographically structured species with a complex demographic history. These findings provide important insights into the phylogeography, evolution, and taxonomy of North Pacific octopods and establish a foundation for future investigations using genome-scale datasets.

The taxonomy of deep-sea octopods within Enteroctopodidae remains problematic due to historical misidentifications, incomplete descriptions, and unresolved generic boundaries. The present study provides the first comprehensive redescription and systematic reassessment of *Octopus fujitai* Sasaki, 1929, based on newly collected specimens from the central Sea of Japan. Detailed morphological examinations, morphometric analyses, anatomical investigations, and molecular phylogenetic approaches were employed to evaluate its

taxonomic status. The species is characterized by a smooth skin surface lacking papillae, an ovoid mantle, long slender arms with well-developed lateral keels, a large hectocotylus bearing a broad ligula with distinct transverse grooves, and the presence of a minute ink sac in some female specimens. Phylogenetic analyses using mitochondrial and nuclear markers consistently recovered the species within a strongly supported North Pacific clade comprising *Muusoctopus leioderma, M. sibiricus*, and related taxa. Species delimitation analyses and haplotype network reconstruction further supported its genetic distinctiveness while revealing a recent evolutionary divergence from closely related species. Biogeographic analyses suggested that the Northwest Pacific lineage represents a relatively recent radiation associated with secondary adaptation between shallow and deep-water habitats. The combined morphological and molecular evidence confirms the validity of the species and supports its transfer from Octopus to *Muusoctopus*, herein recognized as *Muusoctopus fujitai*. This study contributes to resolving longstanding taxonomic uncertainties within Enteroctopodidae and highlights the importance of integrative taxonomy for deep-sea cephalopod systematics.

Dicyemids are the most common parasites inhabiting the renal appendages of benthic cephalopods. Although they occur worldwide and closely follow the distribution of their hosts, their diversity remains poorly documented, particularly in deep-sea environments. The present study reports two new candidate species of *Dicyemennea* collected from the renal appendages of the deep-sea octopus *Muusoctopus fujitai* from Toyama Bay, Sea of Japan. Based on the host specificity, the species reported appears to be different from the other known species through a combination of morphological characters, including calotte shape, body size and peripheral cell arrangement. *Dicyemennea* sp. 1 is a large, slender species reaching approximately 3.5 mm in length and possesses a cap-shaped calotte, whereas *Dicyemennea* sp. 2 is medium-sized with a short, broad body and an irregularly shaped calotte. Only a single developmental stage for both species were generally present in the renal appendages, with *Dicyemennea* sp. 1 being numerically dominant. The strict host specificity observed in both species is consistent with the well-established pattern of dicyemid-cephalopod associations. Despite nearly 300 described deep-sea octopus species worldwide, only 17 dicyemid species have previously been reported from true deep-sea hosts, most from Antarctic and Arctic waters. These findings highlight the vast, unexplored diversity of deep-sea dicyemids and provide new insights into host specificity, parasite diversity, and the coevolution of cephalopods and their renal endosymbionts.

Dicyemids are highly specialized organisms in the renal appendages of cephalopods and represent one of the most enigmatic groups of marine metazoans. Despite more than a century of research, their taxonomy, diversity patterns, ecological significance, and evolutionary relationships remain poorly understood. This study provides a comprehensive synthesis of the global diversity, ecology, host associations, molecular systematics, and biogeography of dicyemids associated with cephalopods. A dataset comprising 151 described dicyemid species and 82 cephalopod hosts was compiled from published literature and analyzed using ecological, biogeographic, and molecular approaches. Diversity analyses revealed a strong concentration of species richness within the Northwest Pacific Ocean, while polar and tropical regions supported comparatively lower diversity. Alpha, beta, and zeta diversity metrics demonstrated pronounced spatial turnover and limited species overlap among oceanic regions, reflecting strong host specificity and regional endemism. Atmospheric-cell analyses further showed a temperate-centered distribution, with approximately 75% of records occurring within the Northern and Southern Ferrel Cells. Molecular species delimitation using mitochondrial COI sequences recovered fewer genetic entities than traditionally recognized morphospecies, suggesting that current taxonomy may overestimate species diversity and that several nominal taxa likely represent species complexes or morphological variants. Environmental analyses indicated that host ecology, oxygen availability, salinity, and benthic habitat characteristics exert greater influence on dicyemid richness than broad physical gradients such as temperature and depth. Collectively, these findings highlight the intimate evolutionary association between dicyemids and cephalopods, reveal substantial cryptic diversity, and establish a global framework for understanding the ecology, evolution, and biogeography of this unique symbiotic lineage. The study also identifies major geographic and taxonomic knowledge gaps and provides priorities for future genomic, ecological, and conservation-oriented research.

様式 7

論文審査の結果の要旨及び担当者

氏　名	（ Abhijeet Purkayastha ）	
	（職）	氏　名
論文審査担当者	主 査　教授	古屋　秀隆
	副 査　教授	志賀　向子
	副 査　教授	昆　隆英

論文審査の結果の要旨

Integrative systematics of two lophotrochozoan group: A panoptic approach to Octopus and Dicyemid taxonomy

2つの冠輪動物群の統合的分類学：タコ類とニハイチュウ類の分類における包括的なアプローチ

頭足類（タコ類・イカ類・コウイカ類）は、海洋生態系において重要な捕食者であり、水産資源としても高い経済的価値を有する軟体動物である。また、頭足類は多様な共生生物の宿主としても知られ、その腎嚢内にはニハイチュウ類と呼ばれる特異な内部共生動物が生息している。頭足類とニハイチュウ類は長い進化の過程で共生関係を築いてきたと考えられ、その多様性や進化、生態を明らかにすることは、海洋生物学および共生進化の理解に重要である。本学位論文では、頭足類およびニハイチュウ類を対象として、分類学、生態学および進化学の観点から総合的な研究を行った。日本とインドは頭足類の種多様性が世界的に大きく、ホットスポットとも呼ばれている。その両海域における頭足類相およびその利用状況を比較し、頭足類とニハイチュウ類の分類学的研究および系統・生物地理学的解析をも通して、両者の多様性と進化、生態に関する包括的な知見を示している。

本学位論文では、最初に日本とインドの頭足類相を比較し、両国が高い種多様性を有する一方で、水産資源の利用状況や寄生生物研究の進展に違いがあることを明らかにした。特に、インドでは頭足類資源の重要性が高まる一方、寄生生物学的研究は十分に進んでおらず、今後の研究の必要性を示した点は、水産資源管理や海洋生物学の観点からも意義が大きい。

分類学的研究では、クモダコ*Octopus longispadiceus*について形態学的・分子系統学的解析を行い、本種が独立した有効種であることを実証するとともに、日本海を中心とした分布域における遺伝的変異と進化的位置を明らかにした。また、トヤマダコ*Octopus fujitai*について再検討を行い、本種を*Muusoctopus*属へ移し、*Muusoctopus fujitai*として再分類することを提唱した。形態学的特徴と分子データを統合したこれらの研究は、北太平洋産深海性タコ類の分類体系の整備に大きく貢献する成果である。

さらに、富山湾深海産*Muusoctopus fujitai*の腎嚢からニハイチュウ類2種の未記載種を発見・記載し、日本における深海性タコ類からの初めての記録を報告した。本研究は、深海環境には未記載種が数多く存在する可能性を示し、深海生物多様性研究の発展に重要な知見を提供している。加えて、世界の頭足類に共生するニハイチュウ類151種を対象に形質をまとめ、北西太平洋が世界的な多様性ホットスポットであること、多くの種が高い宿主特異性と地理的限定性を示すことを明らかにした。

以上より、本論文は博士（理学）の学位論文として十分価値あるものと認める。