2版

様　式　Ｃ－１９、Ｆ－１９－１、Ｚ－１９　（共通）

# 科学研究費助成事業　　研究成果報告書

令和　元 年　　６ 月 ２９ 日現在

機関番号：１６４０１

研究種目：基盤研究(B)（海外学術調査）

研究期間：2015～2018

課題番号：１５Ｈ０５２３５

研究課題名（和文）亜寒帯バイカル湖のカジカ類の湖底1600mまでの適応放散を分子・生活史から探る

研究課題名（英文）Researching adaptive radiation to 1600 m-bottom of the Baikal sculpins in subarctic lake by their molecules and life histories

研究代表者

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交付決定額（研究期間全体）：（直接経費）　　12,700,000円

研究成果の概要（和文）：南湖盆と央湖盆の境の水深300-500 mの水域で，結氷期前の9月と融氷期後の6月に調査を行った．DOは両期とも表層～湖底まで十分高く，この水域を多くの深底性カジカ類が成育場としていた．C. grewingkiiふ化仔魚の耳石で孵化輪と日周輪が認められた．
深底種Asprocottus 5種のmtDNAに基づき系統解析では，本属内で急速な種分化または種間交雑の可能性があった．Comephorus属の精子は体内環境に適応進化していた．雄は小さい鉤状の交尾器を有していた．体外受精型である沿岸4種の精子は湖水で運動性を有し，精子の形態や運動性が繁殖様式の進化に伴って適応進化したことが明らかになった．

研究成果の学術的意義や社会的意義
耳石日周輪の調査から，バイカルカジカの個体発生の速度は極めて遅いのに対して，mtDNA解析では，種分化の速度は極めて速いことが明らかになった．このことは，生物の個体発生と系統発生は，時間的に不の関係にあり，これまでの生物学の原理を刷新する可能性を秘めている．さらに，バイカルカジカの種分化は，同じ古代湖であるタンガニイカ湖と比べて極めて新しく，過去の温暖化による不凍結期によって，数度リセットされた可能性が示唆され，現在の地球温暖化を再考する場合，重要な参考資料となり得る．多くのカジカ深部種が，央湖盆の比較的浅部を成育場としていた事実は，本湖の環境保護ならびに種保全を考える上で意義深い．

研究成果の概要（英文）：We investigated shallower waters (300-500 m d) between southern and central regions in seasons before freezing (September) and after thawing (June). Thermoclines were found to 100 m-depth in June, and it was vertically well-mixed in September. DO was enough to bottoms in both seasons. Many species of deep-sculpins were used as their nurseries over this area in June. Otoliths could be collected from hatched larvae of pelagic sculpin, and daily increment and hatch-check could be recognized. Molecular phylogeny of Asprocottus species was reconstructed based on a ca. 1500bp fragment of m-DNA. No haplotypes from these formed monophyletic groups that corresponded to species boundaries, suggesting introgression through hybridization and/or incomplete lineage sorting due to rapid speciation. Compared sperm traits among three non-copulatory species and one copulatory species, sperm traits may have evolved adaptively in association with the evolution of copulation and viviparity.

研究分野：海洋生物学

キーワード：バイカル湖　カジカ類　適応放散　種分化　古代湖

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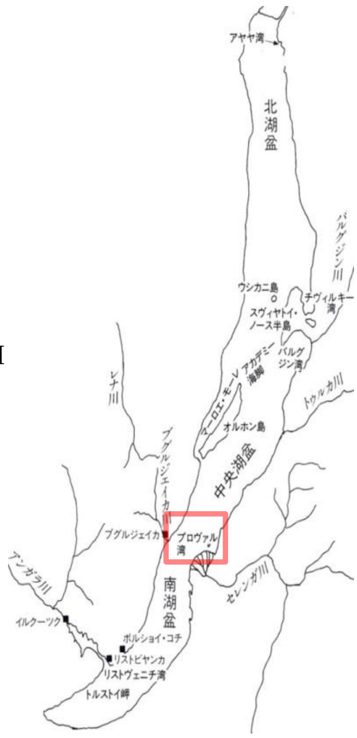
㯬FGY H[garbled] Ù 3000 SºS HHaØ 1640 mHFþ ÈFFÒ HW 1HHFĞFÓ5FþFÔ /%Ë ÈFÝFFĞG5‰$G FĞGŠF÷È5‰$GFFĞG H$ŠG/²Fþ 75-80%Fþ PÑ 4Ç G)TFF6Ô . FFĞ , ÉþHG0GcGxG9FþGMG:GY GŽG9 FfH Fþ(Ù 100 mÝ FF$(6ÛÂFGFþ5G , FŸŠGG9G2GoG• HGvGAG6Ga8® GFG98®FFFÔ . ÏFû H• FÈÛ6%6FÒG9GFG98®GvGAG6Ga8® Fÿ , ÈdFÛGFFFa:ÂSFÜGGGFÔ HGG2G9Gy F÷FÿH 3 G9GFG9Š Abyssocottus ø Comephorus 12 “ 33 Fþ G9GFG9BÈÝ(8® ÈGBFç HFFþ þ 31 FÿFŵFFÒ HFĞGFþG9GFG98®FF‰ FĞFö , H 28 H , 4KºH 3 H , FÚG4KºH 2 HFþ 3 FþGyGŠ GeFFĞG HFFĞ HFÊöFþ(xFFÔþ 1 FÜFþ ÈdFûFç HFF ÏFFÝGF4:ÂSFç HFþ"FFï FÛFFÒFž9FĞG HFþFÖø HFĞ4KºFF4Kº , FÚGMØ HþÝG4KºG HF÷ÿþÛ(FçFø FFĞGFÜ ,FĞG"FG(FDÿGGFÔÔ . Fö HFĞGFþ)2º GGFØGGFFÒ .




W 1. 2015-2018 ºHÏFl$ FûFçGG2G9Gy p, %4ŠþeH

2. %ÊFþ‰ $

G9GFG98®FFöxdFÛ4ŠGF%FG 28 ' HÂFFF%FG4Kº 3 ' H FÚGp4Š5‰$4FFM3G4Kº 2 FÛBG H%ÊFÿ H> DNA F(GFG mt-DNA Fþ× ØÛŽFÔG2G9GyG9GFG98®G(-G0ŽGFFGFû HFĞGaGMGQVÝ HFÚG$FÛ G)GFFÂGÊ/Ô HGGyGŠeFFFFþGFÔ4:Âç HFÔÚG)2F:Fç H%‡ $GFÔ2sFFFþG0ŽGFG% $GG H

3. %ÊF‰

(1) 9GFG98®G7Ÿ

G9GFG98® *Comephorus* “ *HCottocomephorus* 2009-2012 ºØFþ* FGGÂFÊGFFÜFÝHÒH 2015-2018 ºØFÏFÝF4:ÂSG4FG9GFG98®GÂ FÊGFGFHF)YFĞGG/FHFF 2015H2016 ºØFzFû%G0GG:GwFG/Fï FÜ9GFG98®GFçGFFFÊFGH 2017H2018 ºØF! %Fø%FĞF(FGGIGzG• G:FþUGyGMFÈÜÝ 300-500 m F$FÈ1Fþ1FçHW 1HH1Fÿ 2017 ºØ FF‰$Fþ 9 vFH 2018 ºØF%‰$Fþ 6 vFÊgG3QFH

(2) ‰Fþ9

GG2G9GyG9GFG98®)FĞG 6 vFĞIGzGG:FþUGyGMFG" FçH ÈFFH ÈÖxdF÷ *Paracottus kneri* Ú *Cottocomephorus grewingkii* 16 ¥FçHGVGxGeGEG#GFç3Â FçGFÛHe%F‰G4GvFçHW 2HH16 ¥FFþG(H+((6H(Ù 6 mmHF‰F3ÂFÔGH%FFç0$FÜFFÔH

(3) mt-DNA FF0– 0Ž

ÝFÈÛGFĞG *Asprocottus* “ 6 Fþ Æ *A. korjakovi* 5 FFÊH mt-DNA Fþ 12S rRNA 4GÊG 16S rRNA 4GÊFFþÙ 1500bp FFÝ

W 2. *Cottocomephorus grewingkii* (ca. 9 mm TL) F‰¼ .

*Abyssocottus korotneffi* 2 • H*Cottinella boulengeri* 2 • GÝÊÔ *A. abyssalis* 8 • H*A. herzensteini* 3 • H*A. parmiferus* 2 • H*A. platycephalus* 8 • H*A. pulcher* 3 • FÛ" GGFGGeGGMG2GeFFÊÔ3Ajœ 2F(þ-0Ž/'õõï H

(4) GG2G9GyG9GFG98ÉÉG/¥(FÞ 6FþÊ$Q

%ÊFFÿ3)ÆþFŵ(FÞþ%wFGa$GFFçÔG2G9GyG9GFG98®ÝÔÞÎ È*

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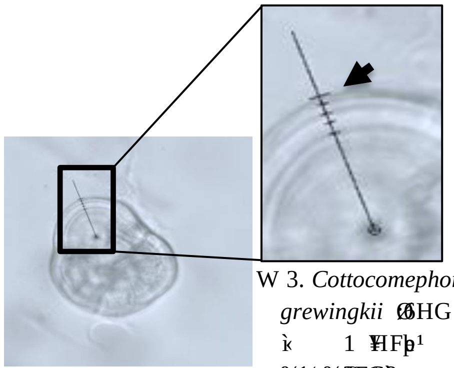
2015H2016 ºØ÷ Fþ! %ÆþG0GG:Gw] FFÿ HÊ9 GFG98®$FçGFFÊÔ'H M%o 2017H2018 ºØ FFÿ! %Fø%FþFÿFGGIGzGG:FþUGyGM FÈÜŽ 300-500 m Fþ$FÊ1* Fþ1FFçï HW 1HH1Fÿ 2017 ºØFÿ‰$Fþ 9 v FH 2018 ºØFÿ%‰$Fþ 6 vFÊÔgG3QFH

Ûþ 9 vFFÿ²™Fÿ 10ºC SFFÈÔFÜŽ 100 m GFFþ8$Fâ FÜGGH 100 m FÛ ÜGF÷ (Ù 3.5ºC FÂFÈÔH 6 vFFÿ²FÛ ÜGF÷ 3.3ºC SMF÷ ²FÊþ ÈFÔH PÃGH DOHFy‰FG/²™ FÛ 500 m Fþ ÜGF÷ 12-14 mg/l Fø(9FÊH M+$ÊŽ/VFÔHFFFÜŽ 1600 m GFFþ@FG9GFG98®4:ÂG/'ÈFÔH

9HavGFFH 5 " 9 FďG9GFG98®$HFþE 2 " 3 Fÿ 4 K õFË‰ç H/² 1HHFÈþ FÜFþ ďö G9GFG98BFÒFø G&'HFGFÌgv6F3QGFõ/%‰$FÿÛGFÈ& :6FÈ9FÊ)ÊFďG9GFG98®ÿFÜFFÔFGG& ççÔH FFþFÔH FÉÝFÜ¸%F$4ŠBFç FÔÛFÿ• FÊ+¤ FøGFØVFÈÝÔ

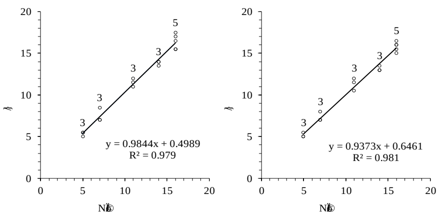


W 3. *Cottocomephorus grewingkii* ØHG ì 1 ¥Fþ¹ %¼%3FGƷo .

(2) GG2G9GyG9GFG98®%Ø

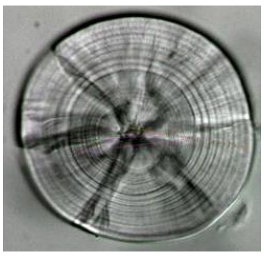
*Cottocomephorus grewingkii* F G ‹ 1 ¥ FØFþ %G09FçÝ H GFÊ%Fú AþƷoAFÜGGG HFFÊÙ 4 FƷo(FÜB FGFFÊÔHW 3HHGì 5H7H1H4H6 ¥FGe%F%Fý 3o(K0KGFø HFÊGF¥FÊÔG8K0KƷo(KÜ

M+FçHW 4HHFGGG HGG2G9GyG9GFG98®ÉÔG H¥F‡Ʒo(FÜ ØoFFÒFFG&FFÝï H



W 4. *Cottocomephorus grewingkii* FþG ì K%¼ (e : e %¼ ; ' : &%¼ )FĝBFGFƷo(X .

3QFGFHwÊÞFG4G9GFG98®ÒGrGlGG9GmFþ ‹.. dØH /6× 10.9 mmHFþ%F%G09FGFø H4FÊþo õÜ 0.96 µm FFÒHW 5HH%ÊFÊçï *C. grewingkii* Ø F HÞÊ 1.02 µm FFÒ HÉÞ9GFG98®þ ďe (G9GFG9p8ºH 2.81 µmHG4GRGIGmG9GG9µm) GGGwFÊÔ FïH



W 5. wÂG7Ÿâ GFFþGrGlGG9Gm‹ dØ (10.9 mm BL) Fþ%¼ . %® 3FGƷoG&Fé . Bar = 20µm

/² 1. GG2G9GyHaFø%6FþGIGzGG:GUGyGMFÉÔ)YFGG ďG9GFG98&FþG7Ký‰$H 9vHFø%‰$FÊQ

| ¦ | | 2017º 9v | 2018º 6v |
|---|---|---|---|
| *Abyssocottus* | *korotneffi* | 1 | 22 |
| *Asprocottus* | *abyssalis* | 4 | 2 |
| *A.* | *platycephalus* | 3 | 20 |
| *Comephosus* | *dybowski* | 4 | 6 |
| *C.* | *baicalensis* | 1 | |
| *Cottocomephorus* | *inermis* | | 5 |
| *Limnocottus* | *bergianus* | | 1 |
| *L.* | *griseus* | 1 | 3 |
| *L.* | *pallidus* | 1 | 8 |
| Total | | 15 | 67 |

(3) mt-DNA Fŧŧß *Asprocottus* “ 5 Fþ̂ )+66

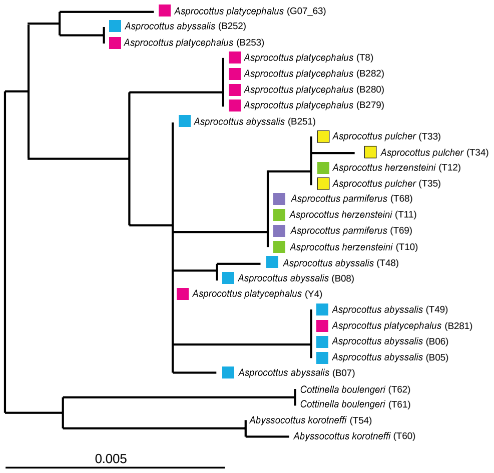
FFþGeGGMG2GeFÜ )+ĿGǥBFGFFFyFFH9FþGeGGMG2 GeFÜGǥFû FúG( )+ŻÜGFï HW 6HB Fŧŧ þ)GFFFFyHM FþGeGGMG2GeGwFG[ : *A. abyssalis* ŧ *A. platycephalus*H*A. herzensteini* ŧ *A. parmiferus*H*A. herzensteini* ŧ *A. pulcher*H Ⱦ H*Asprocottus* “ Ɇ Ɇ

'ĞÜ H *A. herzensteini*H*A. parmiferus*H*A. pulcher* ŧ 3 FFGGF( )+ĿGǥBFFï FŧŧĜH 5 FþFGFŧ63)ÆH aFFGGmGVGAGGWGxG0( )+FFŧĜŧH GGyGŠeFFÒFFŧǥ@GFH

S3Èþ ¥ ƀoFþFĜHGG2G9GyG9GFG9FFþGÇ F4FĜ5FFçFH mt-DNA 0ŽFH(F3ÇGF3FĜFŧĤ GFĤFFFHFFþFŧFH( )+ ŧH6ŧÝFþ %& 6õ6ŧÒHFGGFFĜN#GĘFG+GGFŧÒHFå GFHGG2G9GyG9GFG9FþFyHFæFFÒGMGG:GYG2G9 FGF6FFçH4ŧFþFGGY þ‡ FGFŧŧØxGIGQVFGFFǥ@GHFF..GĬGm50FgƷ(φGĜH

(4) GG2G9GyG9GFG9FFGG(Ĥþì

GG2G9GyG9G8GGyH3)ÆþFw(F Æ(HþGwFG+(ÝF0bFGGFFþĜ H w(ÆFÜFĜ/ÆFçFFFŧŧĜ HGG2G9GyG9GFG98FþĜ4FFFFGG H 2017 º 9 v HaÝ ŧþ9GFG9FFÒ *Comephorus* Ɇ H ç H ŧ Ɇ B Ý 1• FŧŧĜöGF(Ĝ4K3þFBHçï H(ĤÆŧ@FþGF4 6ã FñH FþFFFĤĤŧFŧG H(ĤÆF4:ĤFçFĜFFǥGFï HM‰ H(ŧFÿ 43 µm FØ9GFG98Fþ• HǂFŧFŧFFŧFÜ H8ŧÿºFÆ(GGGGFç/¥(- FþǥGFçŧĜï HGFï H/FŠĤþ9FĜ H7FFĤGÜGFĤþFþwFFĜFFGGFĤbFç FïHFFþFFŧĜÿ H• Ø9GFG9FGFþÝÜGFĜFÜ HgĤFFþwFþGFFFŧï HFFþGFĜû HFã GGFƷF‰GGFŧĤĤŧĜGG2G9GyG9GFG9ĤþFFçFGFĤŧŧŧÝĜ H2018 º 6 v H8Ø F¥w(ºG9GFG9FFÒ *Leocottus kesslerii*H*Cottocomephorus grewingkii*H*Paracottus knerii* Ɇ Gç H G HF Ɇ F Ý ØØ *Comephorus dybowskii* Ɇ GG G HG G 4 FŧŧĜĤþ gĤ4 ö G‘GFþÝ H)ÿGFGĤ4 6gĤÝFFŧï H/Æ(- ºFþ *C. dybowskii* ŧ Ɇ M ‰H¥ŧ 3 FþĤÿÈ÷ FGFG 4 6Ŧó FïH(ŧ4ŠþǥFFGG GxºFFĜFÜ HFþ8FÆ(º F÷Fß HFGFÿ H(ŧþÒ8bÆGG¬ FFKFFGFŧØGFï HM‰ H/Æ(ºFþĤþ4ŸFÆw(ºGGG6Fß H(Ĥ4K3Ø3FŧFï H FGFÿ HºF4FĤ(ĤþFGGFŧĜ+ŧÜ FÒ HV HG9GFG9 ' F÷H(ĤǥĜ4 · ŧ)FF4:ĤFçFFŧĤFĤŧï H




W 6. mt-DNA Fŧŧß *Asprocottus* “ 5 FþĜ )+66ĤþFþÝGAGŠWH ĤþFþ0FǥĤŧŧFFû (FFGFĜHGGGGŠyFÿ Jukes-Cantor GpGUGyFŧŧG8¥H

5. zFŧ1=e¼

FŧŧĤ1=eFĤ0£ 5 ŧH


(1) Sideleva VG, Naseka AM, Nowak M, Palandacic A. The finding of holotype and redescription of *Cottus microstomus* Hechel 1837 (Cottidae), Ichthyol Res, 1w , 66, 249-257, 2019.

(2) Ito T, Awata S. Optimal methods to fix fish sperm for optical microscopic observation: comparisons among different fixative solutions using sperms of copulatory and non-copulatory marine fishes, Ichthyol Res, 1w , 66, 307–315, 2019.

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(1) .(Å HW( H( H3\ H(í H Valentina SH ó# H/¥w(FÛ/Æw(GH GG2G9GyG9GF G98FÉG(Êì H¥68® H¿ 2018.

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(1) W( H%ÊFÛ0bFwÂ , ACADEMIA, 168, 50-62, 2018.

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ɛ̧　(YOKOYAMA Ryota), ʂ(í　(GOTO Akira), SIDELEVA G Valentina