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한국 약용 연체동물의 유전자원 현황

박지은[1,2], 임지윤[3], 송대권[1,2], 김용태[1], 신현준[1], 이준상[2], 이용석[1,2], 이영구[3]

[1]순천향대학교 자연과학대학 생명과학과, [2]순천향대학교 한국자생동물자원활용융복합연구소,
[3]순천향대학교 부천병원

Current Status of Genetic Resources of Medicinal Mollusks in Korea

Jie Eun Park[1,2], Ji Yoon Lim[3], Dae Kown Song[1,2], Yong Tae Kim[1], Hyun Jun Sin[1], Jun Sang Lee[2], Yong Seok Lee[1,2] and Young Koo Lee[3]

[1]Department of Biology, College of Natural Sciences, Soonchunhyang University, Asan, Chungnam 31538
[2]Korea Native Animal Resources Utilization Convergence Research Institute, Soonchunhyang University, Asan, Chungnam 31538
[3]Department of Orthopedic Surgery, Soonchunhyang University Bucheon Hospital, Republic of Korea

ABSTRACT

The Nagoya Protocol on access to genetic resources went into effect in 2014 emphasizing activities for securing biological resources by cataloging the fitness traits essential for survival in the wild habitats. In this regard, although active research is ongoingly related to applications in human disease and medicine, research at the organism level is still insufficient. In particular, there are no studies pertaining to medicinal mollusks in Korea. In order to improve pertinent literature in this area of study, an attempt has been made to compile past literature and decipher the current status of genetic resources of related species. Taking the leads from the reviewed literature, researchers would be benefitted who wish to conduct related follow-up studies in the future.

Keywords: Medicinal Mollusks, genetic

서 론

유전자원 활용을 통해 발생하는 이익의 공정한 공유를 목적으로 하는 나고야 의정서가 2014년 10월 12일 발효된 이후, 각 국가가 자생 생물과 관련한 유전자원을 적극적으로 확보하고 이와 관련된 정보를 우선적으로 선점하는 것이 매우 중요해지고 있다 (환경부, 2011). 이러한 국제적 현황에 대비하기 위하여 대한민국에서는 2007년 '국가 생명자원 확보·관리 및 활용 마스터 플랜'을 수립하였으며, 관련하여 다양한 국가소속의 전문기관을 설립하고 운영하는 등의 노력을 해오고 있다 (국가과학기술위원회, 2007). 하지만 2016년 국가과학기술심의회에서 발간한 '생명연구자원의 전략적 관리 및 활용 제고방안'에 따르면 바이오 의료 사업 발전의 영향으로 활용 가치가 큰 질병 관련 유전체 자원, 줄기세포자원, 메타 게놈 자원 등의 생명연구자원은 급속도로 축적되었으나, 자국의 생명자원 주권 강화에 필수적인 자생생물자원의 유기적인 관리와 발전 방향 수립은 상대적으로 미진한 것으로 조사되었다 (국가과학기술심의회, 2016).

다각적인 접근을 통해 생물 자원의 발굴과 관리가 필요한 다양한 생물 중 연체동물과 관련한 국내 관리 법령을 살펴보면 기본적인 신종·미기록종을 포함한 야생 생물자원의 확보는 환경부 산하 기관인 국립생물자원관리 수행하는 것으로 되어 있다. 하지만 이 중 해양생물자원의 확보는 해양수산과학부에서 총괄하는 것으로 명시되어있다 (국가과학기술위원회, 2012). 2021년 업데이트 된 국가생물종목록에 등록된 연체동물문에 해당하는 생물은 총 1,990종인 것으로 확인되었다

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Corresponding author: Yong Seok Lee
Tel: +82 (41) 530-3040, e-mail: yslee@sch.ac.kr
Corresponding author: Young Koo Lee
Tel: +82 (32) 621-6705, e-mail: brain0808@hanmail.net
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(http://www.kbr.go.kr/stat/ktsnfiledown/downpopup.do). 하지만 일본은 비 해산 패류와 두족류를 제외하고도 6,682종을 기록하고 있는 것으로 미루어 보아, 아직 많은 국내 종이 발굴되지 않은 것으로 판단된다 (국립생물자원관, 2012).

위와 같은 국내 연구 현황과는 달리 해외에서는 연체동물을 활용한 다양한 연구 사례들이 발표되고 있다. 2021년 중국에서 연구한 논문에 따르면 민간요법으로 많이 사용된 Haliotidae (전복과) 에 속하는 다양한 종의 생리활성물질을 HPLC로 분석하여 유용물질의 표준 지표를 확인하고, 향후 의약품으로 가공될 때 관리할 수 있는 기준 값을 확립하는 연구가 진행되었다 (Qing Zhao, 2022). 또한 미국 코네티컷 대학에서는 결핵균 (*Mycobacterium tuberculosis)* 항생물질을 스크리닝 하기 위하여 54종의 해양무척추동물의 추출물을 대상으로 효능평가를 진행하였다 (Acquah *et al*., 2022). 이렇듯 매우 다양하고 방대한 방법으로 생물자원을 활용하기 위한 연구가 활발하게 진행되고 있는 것을 확인할 수 있었다.

본 연구에서는 한국에 자생하는 약용으로 활용 가능한 연체동물의 목록을 최신화 하고 유전자원의 확보현황 및 후속연구의 진행현황을 종합적으로 정리하고자 수행되었다. 이러한 노력은, 향후 한국 자생 연체동물과 관련한 다양한 연구가 진행되기 위한 초석이 될 것으로 생각된다.

본 론

1. 한국 약용 연체동물 목록 최신화

한국 약용 연체동물과 관련하여 과거 연구된 문헌을 조사하기 위해 NTIS, RISS, KISTEP, Science ON 등에 등록된 논문, 보고서, 특허, 국가정책 및 동향 정보를 확인하였다. 문헌조사를 위해 사용한 키워드는 '연체동물', '천연물', 'Mollusks', 'Mollusca', 'Molluscs', 'Biological resource' 등 현재 사용하고 있는 관용어와 학술용어를 모두 포함할 수 있도록 하였다. 하지만 관련하여 종합적인 연구가 이루어졌거나, 지속적인 연구 결과가 도출된 문헌을 찾을 수 없었다. 다만 과거 아시아권 나라에서 민간요법으로 사용되었던 약용 연체동물에 대해 고문서들의 수집 및 연구로 도출된 결과를 발표한 논문을 확인할 수 있었다. 해당 논문은 2000년 발간된 '한국의 약용 패류'로 (정평림, 2000), 이 논문에서 작성한 종 목록을 기반으로 하여 한국 자생 약용연체동물 목록을 최신화 하였다 (Table 1). 목록을 최신화 하는 과정에서 현재의 분류체계와 일치하지 않는 부분을 수정하였으며, 이를 위해 사용된 논문을 모두 정리하였다 (Table 2).

2. 한국 약용 연체동물 관련 유전체 연구 현황

Table 1. 에 기술된 종들에 대한 유전체 연구 현황을 보다 객관적으로 확인하기 위해 NCBI에 등록된 연체동물 관련 SRA 데이터와 비교하였다. 2022년 3월 기준 NCBI에 연체동물문 (Mollusca) 과 관련하여 등록된 SRA Experiments는 총 35,386건으로 나타났다. 이는 연체동물문을 지칭하는 다양한 동의어들과 관련된 데이터를 모두 수집하여 중복된 결과를 삭제한 것이다. 이러한 결과는 전체 SRA Experiments인 9,931,947건에 중 약 0.35%에 해당하는 양으로 연체동물과 관련한 연구가 전 세계적으로 부족한 것을 시사한다. 그 중 한국 약용 연체동물 관련 SRA Experiments는 총 2,842건으로 전체 SRA Experiments의 약 0.029%에 해당하는 것을 확인할 수 있다. 또한 이와 관련하여 축적된 base pairs는 약 10 tera base pairs (10,701,783,417,153 bases pairs) 로 SRA database에 축적된 63,402 tera base pairs (63,402,809,122,369,236 base pairs) 의 약 0.17%에 해당하는 매우 적은 수준의 정보량인 것을 확인할 수 있다 (https://trace.ncbi.nlm.nih.gov/Traces/sra/sra.cgi).

총 2,842건으로 확인된 한국 약용 연체동물 관련 유전정보가 NCBI에 얼마나 등록 되어있는지를 확인하여 Table 1에 표기하였다. 총 4가지 부분에 대하여 기술하였으며 이는 SRA experiments, Gene, Protein, Nucleotide 수를 각각 나타낸 것이다. 각각의 내용에 대해 많이 연구된 종은 모두 다른 것을 확인할 수 있었다. SRA experiments의 경우 *Mytilus edulis*, *Haliotis discus*순으로 많이 연구되어 등록된 것을 확인할 수 있었다. Gene의 경우 대부분 CO1, ITS등의 정보가 등록되어 있었으며 *Bellamya quadrata*, *Haliotis discus* 순으로 많았다. Protein의 경우 *Mytilus edulis*, *Haliotis diversicolor* 순으로 많은 양의 정보가 등록되었으며, Nucleotide의 경우 *Meretrix meretrix*, *Haliotis diversicolor* 순으로 많이 등록된 것을 확인하였다. 등록된 정보가 많은 것으로 확인된 종들은 모두 식용으로 많이 사용되는 연체동물이었으며 예외적으로 많은 Nucleotide 서열이 등록된 *Pisidium coreanum* (산골조개) 는 본 연구진이 NCBI에 등록한 것 외에는 다른 서열 등록이 거의 없는 것을 확인할 수 있었다.

또한 한국 약용 연체동물의 SRA 데이터를 생산하는데 사용된 NGS platform에 대해 분석해 본 결과, 가장 많이 사용되어진 platform은 Illumina인것으로 확인되었다. 이러한 결과는 Illumina를 사용해 분석하는데 소요되는 비용이 2007년을 기점으로 급격히 감소하였기 때문으로 생각된다 (https://www.illumina.com/science/technology/next-generation-sequencing/beginners/ngs-cost.html). NGS 장비중 short read 서열분석기인 Illumina, Ion Torrent, LS454 등의 경우 데이터 생산단가가 매우 저렴하고 분석시간이 짧다는 장점을 가지고 있다. 하지만 short read를 long read로 조합하기 위한 assembly 과

Table 1. List of land and freshwater mollusks used as folk remedies in the East, according to the modified recent classification system. This table includes genetic information statistics registered in NCBI as of 2022.03

Family	Scientific name	Species name	SRA	Gene	Prot-ein	Nucle-otide
Clausiliidae (입술대고둥과)	*Euphaedusa* (*Euphaedusa*) *aculus aculus* (Benson, 1842)	-	-	-	12	19
	Euphaedusa (*Tauphaedusa*) *tau* (O.Boettger, 1877)	-	-	-	23	40
Camaenidae (외줄달팽이과)	*Bradybaena ravida* (Benson, 1842)	-	-	-	15	38
	Bradybaena similaris (Férussac, 1822)	-	10	-	26	61
	Cathaica fasciola (Draparnaud, 1801)	-	-	-	-	-
Viviparidae (논우렁이과)	*Bellamya quadrata* (Benson, 1842)	-	7	74	184	230
	Cipangopaludina chinensis (Gray in Griffith & Pidgeon, 1834)	긴논우렁이	12	37	122	210
Unionidae (석패과)	*Lanceolaria grayii* (Gray, 1833)	칼조개	-	13	52	60
Solenidae (죽합과)	*Solen gouldi* Conrad, 1868	-	-	13	52	60
Cyrenidae (재첩과)	*Corbicula fluminea* Müller, 1774	재첩	173	37	692	1,103
	Corbicula japonica Prime, 1867	일본재첩	37	37	465	534
	Corbicula largillierti (Philippi, 1844)	-	-	-	2	12
Sphaeriidae (산골조개과)	*Pisidium coreanum* Kwon, 1990	산골조개	2	-	1	5,658
Cypraeidae (개오지과)	*Cribraria cribraria* (Linnaeus, 1758)	-	9	13	1,435	2,619
	Cypraea tigris Linnaeus, 1758	-	-	-	21	12
	Naria erosa (Linnaeus, 1758)	은하수 개오지	-	-	-	-
	Naria helvola (Linnaeus, 1758)	처녀개오지	-	-	11	14
	Erronea cylindrica (Born, 1778)	-	-	-	6	8
	Erronea errones (Linnaeus, 1758)	-	-	-	12	16
	Mauritia arabica (Linnaeus, 1758)	아라비아 개오지	-	-	-	-
	Monetaria annulus (Linnaeus, 1758)	노랑테두리 개오지	-	-	30	32
	Monetaria moneta (Linnaeus, 1758)	돈개오지	-	-	12	13
	Purpuradusta gracilis (Gaskoin, 1849)	점박이 개오지	-	-	6	8
	Monetaria caputserpentis (Linnaeus, 1758)	별개오지	-	-	10	12
	Staphylaea nucleus (Linnaeus, 1758)	-	-	-	-	-
Olividae (대추고둥과)	*Oliva annulata* (Gmelin, 1791)	-	-	-	1	1
	Oliva mustelina Lamarck, 1811	대추고둥	-	-	18	28
	Oliva oliva (Linnaeus, 1758)	-	-	-	-	-
Haliotidae (전복과)	*Haliotis discus* Reeve, 1846	둥근전복	661	46	11,778	11,245
	Haliotis diversicolor Reeve, 1846	마대 오분자기	88	32	19,307	37,782
	Haliotis glabra Gmelin, 1791	-	-	-	-	1
	Haliotis ovina Gmelin, 1791	-	1	37	64	35
	Sanhaliotis varia (Linnaeus, 1758)	-	-	-	-	-

Nacellidae (애기삿갓조개과)	*Cellana toreuma* (Reeve, 1854)	애기 삿갓조개	-	-	7,724	719
Lottiidae (두드럭배말과)	*Lottia cassis* (Eschscholtz, 1833)	흰줄무늬 삿갓조개	-	-	14	17
Mytilidae (홍합과)	*Modiolus modiolus* (Linnaeus, 1758)	말홍합	1	37	336	356
	Arcuatula senhousia (Benson, 1842)	종밋	-	13	318	373
	Mytilus unguiculatus Valenciennes, 1858	홍합	-	-	43	45
	Mytilus galloprovincialis Lamarck, 1819	지중해담치	1,883	12	88,637	193,112
	Perna viridis (Linnaeus, 1758)	초록담치	74	38	512	1107
Mactridae (개량조개과)	*Coelomactra antiquata* (Spengler, 1802)	명주 개량조개	5	12	153	615
	Mactra ornata Gray, 1837	-	-	-	-	-
	Mactra quadrangularis Deshayes, 1853	동죽	3	36	5,882	251
Veneridae (백합과)	*Aphrodora kurodai* (Matsubara, 2007)	흰누렁 둥근백합	-	-	-	-
	Cyclina sinensis (Gmelin, 1791)	가무락조개	34	-	5,341	369
	Marcia japonica (Gmelin, 1791)	-	-	-	18	20
	Meretrix lamarckii Deshayes, 1853	민무늬백합	8	13	266	341
	Meretrix lusoria (Röding, 1798)	백합	1	14	12,145	914
	Meretrix meretrix (Linnaeus, 1758)	무명조개	6	12	345	38,586
Mesodesmatidae (퇴조개과)	*Atactodea striata* (Gmelin, 1791)	-	-	-	1	5
Arcidae (돌조개과)	*Anadara maculosa* (Reeve, 1844)	-	-	-	-	-
	Potiarca pilula (Reeve, 1843)	-	-	-	10	6
	Scapharca broughtonii (Schrenck, 1867)	피조개	94	-	348	605
	Scapharca globosa Reeve, 1844	-	-	-	15	22
	Anadara kagoshimensis (Tokunaga, 1906)	새꼬막	4	-	99	151
	Tegillarca granosa (Linnaeus, 1758)	꼬막	198	12	7,013	3,369
	Tegillarca nodifera (Martens, 1860)	-	-	-	8	20
Cardiidae (새조개과)	*Maoricardium mansitii* (Otsuka, 1937)	-	-	-	-	-
	Vepricardium sinense (G.B.Sowerby II, 1839)	-	-	-	-	-

정이 반드시 필요하며 이러한 과정에서 반복염기서열의 일부를 획득하지 못할 수 있다는 단점이 있다. 이러한 단점을 보완하기 위한 NGS 장비로는 Single Molecule Real-Time (SMRT) sequencing 방식을 사용하는 Pacbio RS-II 및 Oxford nanopore가 있는데 이 중 Pacbio 장비는 해독서열의 정확성이 높은 편이지만 nanopore 장비의 경우는 아직까지는 정확도가 다소 떨어진다는 또 다른 단점을 가지고 있다. 그러므로 최근에는 short read 기반 platform과 long read 기반 platform을 혼합 활용하여 해독한 염기서열의 정확도를 높이는 방법이 사용되고 있다. (Mahmoud *et al*., 2019). 이러한 연구 트랜드는 Table 3에서도 확인할 수 있다.

3. 약용 연체동물 관련 국내외 연구 동향

최근 해외에서는 육산 연체동물보다는 해양 연체동물과 관련하여 다양한 연구가 진행되고 있으며 관련하여 다수의 논문과 리뷰가 출간되고 있다 (Klein *et al*., 2019; Romano *et al*., 2022; Velayutham and Arockiaraj, 2022). 또한 해양 연체동물이 환경적 자극에 의해 생산하는 2차 대사산물에 대한 심도 있는 연구를 통해 의약품화를 진행하고자 하는 연구가 활발하게 진행 중이다. 그 중 대표적인 예로 Mytildae (홍합과) 에 속하는 생물의 족근에서 발견할 수 있는 접착단백질 (Mussel adhesive protein, MAP) 에 관하여 다양한 조직 공학 및 생물 의학 응용 분야에서 활용될 수 있도록 가공하는 연구가 진행되고 있다 (Cha *et al*., 2008; Lee *et al*., 2011). 이러한 단백질을 해양 연체동물로부터 직접적으로 필요한 양을 모두 추출할 수는 없기 때문에 대량배양을 위한 연구 또한 함께 진행되고 있다. 흥미로운 생리 활성 화합물을 생산하는 또 다른 연체동물은 Conidae (청자고둥과) 에 속하는 생물들로,

Table 2. List of contents changed by current taxonomic criteria and related references

2000.06 LIST		2022.03 LIST	
Family	Species	Family	Species
Clausiliidae (입술대고둥과)	*Euphaedusa aculus aculus*	Clausiliidae (입술대고둥과)	*Euphaedusa* (*Euphaedusa*) *aculus aculus* (Benson, 1842)
	E. tau		*Euphaedusa* (*Tauphaedusa*) *tau* (O.Boettger, 1877)
Bradybaenidae (달팽이과)	*Bradybaena similaris*	Camaenidae (외줄달팽이과)	*Bradybaena similaris* (Férussac, 1822)
	B. ravida		*Bradybaena ravida* (Benson, 1842)
	Cathaica fasciola		*Cathaica fasciola* (Draparnaud, 1801)
Viviparidae (논우렁이과)	*Cipangopaludina chinensis*	Viviparidae (논우렁이과)	*Cipangopaludina chinensis* (Gray in Griffith & Pidgeon, 1834)
	Bellamya quadrata		*Bellamya quadrata* (Benson, 1842)
Unionidae (석패과)	*Lanceolaria grayana*	Unionidae (석패과)	*Lanceolaria grayii* (Gray, 1833)
	Solen gouldi	Solenidae (죽합과)	*Solen gouldi* Conrad, 1868
Corbiculidae (재첩과)	*Corbicula fluminea*	Cyrenidae (재첩과)	*Corbicula fluminea* Müller, 1774
	C.largillierti		*Corbicula largillierti* (Philippi, 1844)
	C.nitens		*Corbicula* (*Corbicula*) *nitens* (Phiippi, 1844)
	C.japonica		*Corbicula japonica* Prime, 1867
	C.sandai		*Corbicula sandai* Reinhardt, 1878
	Corbiculina leana		*Corbicula fluminea* Müller, 1774 (재첩) 과 동종이명으로 삭제
Sphaeriidae (산골과)	*Pisidium* spp.	Sphaeriidae (산골조개과)	*Pisidium coreanum* Kwon, 1990
Cypraeidae (개오지과)	*Monetaria*(*Monetaria*) *moneta*	Cypraeidae (개오지과)	*Monetaria moneta* (Linnaeus, 1758)
	M. (*Ornamentaria*) *annulus*		*Monetaria annulus* (Linnaeus, 1758)
	Cypraea tigirs		*Cypraea tigris* Linnaeus, 1758
	Erosaria erosa		*Naria erosa* (Linnaeus, 1758)
	E.helvola		*Naria helvola* (Linnaeus, 1758)
	Cribraria (*s.s*) *cribraria*		*Cribraria cribraria* (Linnaeus, 1758)
	Monetaria (*Ornamentaria*) *nnulus*		*Monetaria annulus* (Linnaeus, 1758) 와 중복으로 삭제
	Purpuradusta gracilis		*Purpuradusta gracilis* (Gaskoin, 1849)
	Staphylaea (*Nucleslaria*) *nucleus*		*Nucleolaria nucleus* (Linnaeus, 1758)
	Erronea (*s.s*) *cylindrica*		*Erronea cylindrica* (Born, 1778)
	Cypraea tigirs		*Cypraea tigris* Linnaeus, 1758 와 중복으로 삭제
	Erronea (*s.s*) *erronea*		*Erronea errones* (Linnaeus, 1758)
	Mauritia (*Arabica*) *arabica*		*Mauritia arabica* (Linnaeus, 1758)
	Monetaria(*s.s*) *moneta*		*Monetaria moneta* (Linnaeus, 1758) 와 중복으로 삭제
	M. (*Ornamentaria*) *annulus*		*Monetaria annulus* (Linnaeus, 1758)와 중복으로 삭제
	Ravitrona caputserpentis		*Monetaria caputserpentis* (Linnaeus, 1758)

Olividae (대추고둥과)	*Oliva* (*Carmione*) *musterina*	Olividae (대추고둥과)	*Oliva mustelina* Lamarck, 1811
	O. (*Neocylindrus*) *annulata*		*Oliva annulata* (Gmelin, 1791)
	O. (*Oliva*) *oliva*		*Oliva oliva* (Linnaeus, 1758)
Haliotidae (전복과)	*Nordotis discus*	Haliotidae (전복과)	*Haliotis discus* Reeve, 1846
	Sulculus diversicolor		*Haliotis diversicolor* Reeve, 1846
	S. glabra		*Haliotis glabra* Gmelin, 1791
	Sanhaliotis varia		*Sanhaliotis varia* (Linnaeus, 1758)
	Ovinotis ovina		*Haliotis ovina* Gmelin, 1791
Patellidae (삿갓조개과)	*Cellana toreuma*	Nacellidae (애기삿갓조개과)	*Cellana toreuma* (Reeve, 1854)
Acmaeidae (흰삿갓조개과)	*Chilazacmea striata*	Lottiidae (두드럭배말과)	*Lottia cassis* (Eschscholtz, 1833)
Mytilidae (홍합과)	*Mytilus coruscus*	Mytilidae (홍합과)	*Mytilus unguiculatus* Valenciennes, 1858
	M.edulis		*Mytilus galloprovincialis* Lamarck, 1819
	perna viridis		*Perna viridis* (Linnaeus, 1758)
	Modiolus (*Modiolus*) *modiolus*		*Modiolus modiolus* (Linnaeus, 1758)
	Musculista senhousia		*Arcuatula senhousia* (Benson, 1842)
Mactridae (개량조개과)	*Mactra antiquata*	Mactridae (개량조개과)	*Coelomactra antiquata* (Spengler, 1802)
	Mactra veneriformis		*Mactra quadrangularis* Deshayes, 1853
Veneridae (백합과)	*Meretrix meretrix*	Veneridae (백합과)	*Meretrix meretrix* (Linnaeus, 1758)
	Cyclina sinensis		*Cyclina sinensis* (Gmelin, 1791)
	Meretrix lusoria		*Meretrix lusoria* (Röding, 1798)
	M.lamarckii		*Meretrix lamarckii* Deshayes, 1853
	Pitar (*Pitaris*) *japonicum*		*Aphrodora kurodai* (Matsubara, 2007)
	Katelysa(*Hemitapes*) *japonica*		*Katelysia japonica* (Gmelin, 1791)
	Atactodea striata		*Atactodea striata* (Gmelin, 1791)
	Mactra (*s.s.*) *ornata*		*Mactra ornata* Gray, 1837
Arcidae (꼬막조개과)	*Scapharca broughtonii*	Arcidae (돌조개과)	*Scapharca broughtonii* (Schrenck, 1867)
	S.subcrenata		*Anadara kagoshimensis* (Tokunaga, 1906)
	Tegillareca granosa		*Tegillarca granosa* (Linnaeus, 1758)
	Anadara maculosa		*Anadara oceanica* (Lesson, 1831) 와 동종이명으로 삭제
	Potiarca pilula		*Potiarca pilula* (Reeve, 1843)
	Scapharca globosa		*Anadara globosa* (Reeve, 1844)
	Tegillareca nodifera		*Tegillarca nodifera* (Martens, 1860)
Carditidae (주름방사륵조개과)	*Maoricardium mansitii*	Cardiidae (새조개과)	*Maoricardium mansitii* (Otsuka, 1937)
	Vepricardium sinense		*Vepricardium sinense* (G.B.Sowerby II, 1839)

Table 2. Continued

Family	Species	Reference
Clausiliidae (입술대고둥과)	*Euphaedusa* (*Euphaedusa*) *aculus aculus* (Benson, 1842)	(Benson, 1842; Yen, 1939)
	Euphaedusa (*Tauphaedusa*) *tau* (O.Boettger, 1877)	(Boettger, 1877; Heude, 1882; Heude, 1884; Cowie *et al.*, 1991)
Camaenidae (외줄달팽이과)	*Bradybaena similaris* (Férussac, 1822)	(Férussac, 1819; Pfeiffer, 1850; Pfeiffer, 1853; Martens, 1861; Rensch, 1937; Fischer-Piette and Vukadinovic, 1974; Minato, 1988; Fischer-Piette and Salvat, 1994; Vermeulen and Whitten, 1998; Bieler and Slapcinsky, 2000; Naggs and Raheem, 2000; Maassen, 2001; Seki *et al.*, 2002; Herbert and Kilburn, 2004; Gerlach, 2006; Griffiths and Florens, 2006; Rosenberg and Muratov, 2006; Bank and Menkhorst, 2008; Brook, 2010; Herbert, 2010; Ramakrishna and Dey, 2010; Uchida *et al.*, 2013; Inkhavilay and Panha, 2019; Espinosa and Robinson, 2021; Marzuki and Mohd-Azlan, 2021)
	Bradybaena ravida (Benson, 1842)	(Benson, 1842; Sysoev and Schileyko, 2009; Hwang and Wu, 2020)
	Cathaica fasciola (Draparnaud, 1801)	(Philippi, 1845; Möllendorff, 1899; Yen, 1939)
Viviparidae (논우렁이과)	*Cipangopaludina chinensis* (Gray in Griffith & Pidgeon, 1834)	(Griffith and Pidgeon, 1833)
	Bellamya quadrata (Benson, 1842)	(Benson, 1842; Lea, 1856; Reeve, 1862; Lea, 1866; Heude, 1882; Heude, 1889; Yen, 1939; Qian Z.-X and He, 2014)
Unionidae (석패과)	*Lanceolaria grayii* (Gray, 1833)	(Griffith *et al.*, 1833; Lea, 1834; Simpson, 1900; Rolle, 1904; Moskvicheva, 1973; Zatravkin M.N, 1984; Do *et al.*, 2018; Zieritz *et al.*, 2018; Graf and Cummings, 2019; Bolotov *et al.*, 2020)
Solenidae (죽합과)	*Solen gouldi* Conrad, 1868	(Clessin, 1842; Philippi, 1847; Gould, 1861; Erm, 1998; Liu, 2008)
Cyrenidae (재첩과)	*Corbicula fluminea* Müller, 1774	(Müller, 1774; Philippi, 1844; Prime, 1864; Clessin, 1874; Westerlund, 1883; Ishibashi and Komaru, 2003; Streftaris *et al.*, 2005; Obata *et al.*, 2006; Mackie, 2007; Coan and Valentich-Scott, 2012; Sakai *et al.*, 2014; Van Ryckegem *et al.*, 2014; Huber, 2015; InvertEbase, 2015)
	Corbicula largillierti (Philippi, 1844)	(Philippi, 1844; Prime, 1864; Prime, 1867; Huber, 2015)
	Corbicula (*Corbicula*) *nitens* (Phiippi, 1844)	(Philippi, 1844; Huber, 2015)
	Corbicula japonica Prime, 1867	(Prime, 1864; Clessin, 1874; Sowerby, 1876; Martens, 1877; Reinhardt, 1877; Pilsbry, 1901; Pilsbry, 1907; Lindholm, 1928; Kursalova V.I, 1971; Kimura *et al.*, 2004; Glaubrecht *et al.*, 2007)
	Corbicula sandai Reinhardt, 1878	(Reinhardt, 1878; Obata *et al.*, 2006; Glaubrecht *et al.*, 2007)
	Corbicula fluminea Müller, 1774 (재첩) 과 동종이명으로 삭제	
Sphaeriidae (산골조개과)	*Pisidium coreanum* Kwon, 1990	(Kwon, 1990; Graf *et al.*, 2019)
Cypraeidae (개오지과)	*Monetaria moneta* (Linnaeus, 1758)	(Linnaeus, 1758; Gmelin, 1791; Röding, 1798; Rochebrune, 1884; Schilder, 1927; Steadman and Cotton, 1943; Verdcourt, 1954; Ch, 1992; Liu, 2008; Lorenz, 2017)
	Monetaria annulus (Linnaeus, 1758)	(Linnaeus, 1758; Rochebrune, 1884; Verdcourt, 1954; Cheung, 1991; Liu, 2008; Zenetos *et al.*, 2010; Lorenz, 2017)
	Cypraea tigris Linnaeus, 1758	(Linnaeus, 1758; Melvill, 1888; Pilsbry, 1909; Dodge, 1953; Burgess, 1970; Kay, 1979; Burgess, 1985; Branch, 2002; Steyn and Lussi, 2005; Meyer and Tweedt, 2017)
	Naria erosa (Linnaeus, 1758)	(Linnaeus, 1758; Lamarck, 1810; Lorenz, 2017)
	Naria helvola (Linnaeus, 1758)	(Linnaeus, 1758; Lorenz, 2017)

	Cribraria cribraria (Linnaeus, 1758)	(Linnaeus, 1758; Steadman *et al.*, 1943)
	Monetaria annulus (Linnaeus, 1758) 와 중복으로 삭제	
	Purpuradusta gracilis (Gaskoin, 1849)	(Gaskoin, 1849; Gofas *et al.*, 2001)
	Nucleolaria nucleus (Linnaeus, 1758)	(Linnaeus, 1758; Gmelin, 1791; Röding, 1798; Perry, 1811; Burgess, 1985; Moretzsohn, 2011; Lorenz, 2017)
	Erronea cylindrica (Born, 1778)	(Born, 1778; Liu, 2008)
	Cypraea tigris Linnaeus, 1758 와 중복으로 삭제	
	Erronea errones (Linnaeus, 1758)	(Linnaeus, 1758; Brazier, 1872; Melvill, 1888; Iredale, 1935; Steadman *et al.*, 1943; Liu, 2008; Lorenz, 2017)
	Mauritia arabica (Linnaeus, 1758)	(Linnaeus, 1758; Burgess, 1970; Heiman, 2004; Liu, 2008)
	Monetaria moneta (Linnaeus, 1758) 와 중복으로 삭제	
	Monetaria annulus (Linnaeus, 1758) 와 중복으로 삭제	
	Monetaria caputserpentis (Linnaeus, 1758)	(Linnaeus, 1758; Gmelin, 1791; Philippi, 1849; Schilder and Schilder, 1938; Cheung, 1991; Lorenz, 2017)
Olividae (대추고둥과)	*Oliva mustelina* Lamarck, 1811	(Lamarck, 1811; Liu, 2008)
	Oliva annulata (Gmelin, 1791)	(Gmelin, 1791; Kilburn, 1980; Morton and Morton, 1983; Tursch B and Greifeneder, 1986; Liu, 2008)
	Oliva oliva (Linnaeus, 1758)	(Linnaeus, 1758; Röding, 1798; Duclos, 1835; Reeve, 1850; Ducros de Saint Germain, 1857; Steyn *et al.*, 2005; Liu, 2008)
Haliotidae (전복과)	*Haliotis discus* Reeve, 1846	(Reeve, 1846; Geiger and Poppe, 2000; Geiger and Owen, 2012; Lutaenko *et al.*, 2013)
	Haliotis diversicolor Reeve, 1846	(Reeve, 1846; Dunker, 1877; Geiger *et al.*, 2000; Liu, 2008; Geiger *et al.*, 2012)
	Haliotis glabra Gmelin, 1791	(Gmelin, 1791; Röding, 1798; Reeve, 1846; Geiger *et al.*, 2000; Geiger *et al.*, 2012)
	Sanhaliotis varia (Linnaeus, 1758)	(Linnaeus, 1758; Röding, 1798; Reeve, 1846; Pilsbry, 1890; Iredale, 1929; Drivas and Jay, 1987; Geiger *et al.*, 2000; Liu, 2008; Geiger *et al.*, 2012)
	Haliotis ovina Gmelin, 1791	(Gmelin, 1791; Geiger *et al.*, 2000; Liu, 2008; Geiger *et al.*, 2012)
Nacellidae (애기삿갓조개과)	*Cellana toreuma* (Reeve, 1854)	(Reeve, 1854; Nakano and Ozawa, 2007; Liu, 2008; Kase T and Haga, 2013; Yokogawa, 2015; Sasaki, 2017)
Lottiidae (두드럭배말과)	*Lottia cassis* (Eschscholtz, 1833)	(Nakano *et al.*, 2007)
Mytilidae (홍합과)	*Mytilus unguiculatus* Valenciennes, 1858	(Valenciennes, 1858; Gould, 1861; Lischke, 1868; Huber, 2010; Huber, 2015)
	Mytilus galloprovincialis Lamarck, 1819	(Poli, 1795; Lamarck, 1819; Gray, 1825; Philippi, 1836; Danilo and Sandri, 1856; Reeve, 1857; Tapparone Canefri, 1874; Monterosato, 1884; Bucquoy E and Dollfus, 1887; Locard, 1889; Monterosato, 1891; Pallary, 1903; Coe, 1945; Powell, 1958; Lubet, 1959; Britton, 1990; Rawson *et al.*, 1996; Hayazake and Tanabe, 1999; Ubukata, 2000; Ishida *et al.*, 2005; Molnar *et al.*, 2008; Huber, 2010; Cosel and Gofas, 2019; Zbawicka and Wenne, 2019; Valentich-Scott P and Zelaya, 2020)
	Perna viridis (Linnaeus, 1758)	(Linnaeus, 1758; Gmelin, 1791; Lamarck, 1819; Burch and Seed, 2000; Wood *et al.*, 2007; Liu, 2008; Molnar *et al.*, 2008; Huber, 2010; Lutaenko *et al.*, 2013)
	Modiolus modiolus (Linnaeus, 1758)	(Linnaeus, 1758; Pennant, 1777; Da Costa, 1778; Röding, 1798; Fleming, 1828; Récluz, 1843; Jeffreys, 1862; Cailliaud, 1865; Marshall, 1893; Dautzenberg, 1895; Cheung, 1991; Turgeon, 1998; Gofas *et al.*, 2001; Janssen *et al.*, 2007; Liu, 2008; Huber, 2010; Halanych *et al.*, 2013)

	Arcuatula senhousia (Benson, 1842)	(Benson, 1842; Tapparone Canefri, 1874; Fong, 1998; Huber, 2010; Katsanevakis *et al.*, 2012; Corriero *et al.*, 2015; Marchini *et al.*, 2015)
Mactridae (개량조개과)	*Coelomactra antiquata* (Spengler, 1802)	(Reeve, 1854; Chan and Caley, 2003; Huber, 2010)
	Mactra quadrangularis Deshayes, 1853	(Reeve, 1854; Huber, 2010)
Veneridae (백합과)	*Meretrix meretrix* (Linnaeus, 1758)	(Linnaeus, 1758; Schumacher, 1817; Fischer-Piette and Fischer, 1941; Steyn and Lussi, 1998; Branch, 2002; Liu, 2008; Huber, 2010; Nel and Taylor, 2012)
	Cyclina sinensis (Gmelin, 1791)	(Gmelin, 1791; Dillwyn, 1817; Römer, 1860; Chan *et al.*, 2003; Liu, 2008; Ujino and Matsukuma, 2009; Huber, 2010)
	Meretrix lusoria (Röding, 1798)	(Röding, 1798; Lamarck, 1818; Sowerby, 1851; Tomlin, 1923; Ujino *et al.*, 2009; Huber, 2010; Torii *et al.*, 2010)
	Meretrix lamarckii Deshayes, 1853	(Philippi, 1842; Kondo *et al.*, 2001; Liu, 2008; Ujino *et al.*, 2009; Huber, 2010)
	Aphrodora kurodai (Matsubara, 2007)	(Matsubara, 2007)
	Katelysia japonica (Gmelin, 1791)	(Gmelin, 1791; Röding, 1798; Gray, 1825; Adams and Reeve, 1848; Deshayes, 1853; Kueh, 1987; Liu, 2008; Huber, 2010)
	Atactodea striata (Gmelin, 1791)	(Gmelin, 1791; Wood, 1828; Reeve, 1854; Jousseaume, 1888; Ansell and Morton, 1987; Gofas *et al.*, 2001; Kondo *et al.*, 2001; Takada *et al.*, 2002; Galil, 2007; Liu, 2008; Huber, 2010; Katsanevakis *et al.*, 2012)
	Mactra ornata Gray, 1837	(Dautzenberg, 1929; Huber, 2010)
Arcidae (돌조개과)	*Scapharca broughtonii* (Schrenck, 1867)	(Reeve, 1843; Schrenck, 1867; Erm, 1998; Huber, 2010)
	Anadara kagoshimensis (Tokunaga, 1906)	(Philippi, 1842; Lischke, 1869; Tokunaga, 1906; Bernard *et al.*, 1993; Huber, 2010; Zenetos *et al.*, 2010; Katsanevakis *et al.*, 2012)
	Tegillarca granosa (Linnaeus, 1758)	(Linnaeus, 1758; Lightfoot, 1786; Gmelin, 1791; Iredale, 1939; Liu, 2008; Huber, 2010)
	Anadara oceanica (Lesson, 1831) 와 동종이명으로 삭제	
	Potiarca pilula (Reeve, 1843)	(Reeve, 1843; Huber, 2010)
	Anadara globosa (Reeve, 1844)	(Deshayes, 1839; Reeve, 1843; Huber, 2010; Lutaenko and Volvenko, 2013)
	Tegillarca nodifera (Martens, 1860)	(Liu, 2008; Huber, 2010)
Cardiidae (새조개과)	*Maoricardium mansitii* (Otsuka, 1937)	(Otsuka, 1937; Voskuil and Onverwagt, 1991; Liu, 2008)
	Vepricardium sinense (G.B.Sowerby II, 1839)	(Sowerby and Sowerby, 1832; Liu, 2008)

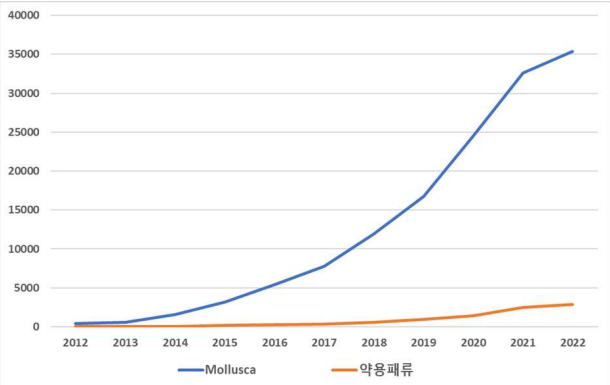

Fig. 1. Summarize information on the mollusks registered in the NCBI SRA database and the species listed in Table 1. This shows that research on Korean medicinal mollusks is very necessary.

conotoxin이라는 신경독성을 나타내는 펩타이드를 먹이활동을 위해 생산한다 (Fu *et al.*, 2018). 이 conotoxin은 현재까지 조사된 것만 약 80,000가지 이상의 종류를 가진 것으로 알려져 있다 (Robinson and Norton, 2014). 이 물질들은 생체 내의 다양한 이온 채널에 결합하여 신경 자극 전달을 방해함으로써 길항작용을 하는 것으로 알려져 있다 (Bjørn-Yoshimoto *et al.*, 2020). 대표적인 물질은 omega-conotoxin MVIIA로 ziconotide (Prialt®) 라는 의약품으로 개발되었으며, 이는 심각한 만성 통증을 관리하는데 사용되고 있다.

위와 같이 생물의 유전자원을 활용하여 다양한 연구를 진행하기 위해서는, 정확하고 다양한 유전정보를 보유하는 것이 매우 중요하다. 또한 방대한 연구 데이터를 처리할 수 있는 소프트웨어 및 하드웨어 기술이 발달함으로 인해, 생물자원은 단순

Table 3. NGS platform used to produce SRA data of Korean medicinal mollusks. Data about 2022 is data accumulated over three months from January to March, 2022

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	TOTAL
CAPILLARY									1			1
ILLUMINA		5	17	80	64	118	229	276	476	1,060	342	2,667
ION TORRENT					1			36				37
LS454	45	2		28	1	1	1					78
OXFORD NANOPORE								1	1	2		4
PACBIO SMRT						1		30	18	6		55
TOTAL	45	7	17	108	66	120	230	343	496	1,068	342	2,842

히 R&D에서 생산되는 연구결과의 일부인 것이 아니라 향후 R&D의 방향성을 결정하는 핵심 요소로 그 중요성이 격상되고 있다. 이러한 트렌드에 맞춰 미국, 일본, 유럽 등의 다양한 주요 국가에서는 생물자원에 대한 기존 DB간의 연계 강화를 단계적으로 추진하고자 하고 있다. 이에 대한민국에서도 각 부처가 독자적으로 관리하고 있던 생물자원과 관련된 정보를 통합하여 관리하고, 연구 · 산업 현장에서 생물 자원의 활용을 적극적으로 지원하기 위한 정책 변화가 관찰되고 있다 (국가과학기술자문회의심의회의, 2020).

결 론

이번 연구를 통해 현재까지 연구되어진 한국의 약용 연체동물 관련 결과들을 종합한 결과, 한국의 약용 연체동물은 총 17과 (family), 60 종으로 조사되었다. 해당 종에 대한 유전자원 현황을 종합적으로 분석해 보았을 때, NCBI SRA database에 등록된 데이터 기준 0.17%의 데이터가 해당되는 것을 확인할 수 있었다. 이러한 유전자원들은 대부분 식용으로 많이 이용되는 생물종에 국한되어 있는 것을 확인할 수 있었다.

최근 해외에서는 적극적인 해양생물자원의 발굴 및 활용을 통해 의약, 생태 등 다양한 분야에 영향을 미칠 수 있는 연구결과가 도출되고 있다. 이러한 연구 동향에 발 맞춰 다양한 연구를 진행하기 위해서는 양질의 유전자원이 국가기관의 관리 하에 집중적으로 축적되어야 할 필요성이 있다고 판단된다. 향후 약용 연체동물을 연구하고자 하는 연구자들을 위해 구축되어 있는 유전자원은 매우 부족하다는 사실을 이번 연구를 통해 확인할 수 있었다. 이러한 현황을 개선하기 위해서는 한반도에 서식하는 다양한 육산 및 해양 연체동물에 대한 발굴 및 유전자원의 적극적인 확보가 매우 중요하다고 판단된다.

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