NTNU
Norwegian University of
Science and Technology

Master's thesis

2019

Nathalie Skahjem

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NTNU
Norwegian University of
Science and Technology
NTNU University Museum
Department of Design

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A molecular and morphological study of Bivalvia (Phylum: Mollusca) in Norwegian waters, with emphasis on Pectinidae Rafinesque, 1815

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A molecular and morphological study of Bivalvia (Phylum: Mollusca) in Norwegian waters, with emphasis on Pectinidae Rafinesque, 1815

Nathalie Skahjem

Nordic master's programe in biodiversity and systematics (NABiS)
Submission date: May 2019
Supervisor: Torkild Bakken

Norwegian University of Science and Technology

ABSTRACT

Species are considered the basic units within biology. This states the importance of both species delimitation, finding the number of species and the boundaries between them, and taxonomy, naming, describing and classifying species. In this study both morphological and molecular taxonomy are used to attain knowledge about Bivalvia (Phylum: Mollusca) with emphasis on the marine family Pectinidae (Subclass: Pteriomorphia). Bivalvia is a large aquatic group of animals comprising about 9100 species worldwide, around 230 in marine habitats in Norway. Pectinidae, with 271 species worldwide, is a well-known commercially exploited family. They are distributed all over the world, and found in all marine depths and habitats. DNA barcoding, a molecular method for species identification, using coxI was done on 190 bivalve specimens from Norway, mainly Trøndelag. Out of the 190 specimens, 110 were successfully sequenced. 14 of these sequences, belonging to Pectinidae, together with 17 pectinid sequences downloaded from GenBank, were used in species delimitation analyses. Two different methods were used, one distance based (ABGD) and one tree-based (mPTP). Both yielded the same nine species as morphology, suggesting that simple species delimitation methods work very well on Pectinidae, and perhaps Bivalvia in general. The bivalve collection at the NTNU University Museum was thoroughly studied with the aim of learning to identify all bivalves found in Norway. An updated species list over marine species found in Norwegian waters was made, and some difficult taxa are discussed including preliminary identification keys and character tables as identification aid. Species descriptions were made of all 12 species of Pectinidae found in Norwegian waters. An identification key to all pectinid species found in Norwegian waters is provided.

SAMMENDRAG

Art regnes for å være den grunnleggende enheten innenfor biologi. Dette understreker viktigheten av både avgrensning av arter, å finne antall arter og grensen mellom disse, og taksonomi, å navngi, beskrive og klassifisere arter. I dette studiet ble både morfologisk og molekylær taksonomi benyttet for å tilegne kunnskap om muslinger (Rekke: Mollusca, Klasse: Bivalvia) med fokus på den marine familien kamskjell (Pectinidae, Underklasse: Pteriomorphia). Muslinger er en stor akvatisk dyregruppe bestående av totalt ca. 9100 arter, omtrent 230 av de marine artene finnes i Norge. Kamskjell, totalt 271 arter, er en velkjent familie bl.a. ettersom den utnyttes kommersielt. De er utbredt over hele verden, og lever i alle marine habitat og dybder. DNA strekkoding, en molekylær metode for artsidentifisering, med bruk av coxI ble utført på 190 musling-individer fra Norge, hovedsakelig fra Trøndelag. Blant de 190 vevsprøvene, ble 110 sekvensert med suksess. 14 av disse sekvensene tilhører Pectinidae, og ble sammen med 17 nedlastede sekvenser fra GenBank, brukt i analyser for artsavgrensning. To ulike metoder ble brukt, en basert på genetiske distanser (ABGD) og en basert på fylogenetiske trær (mPTP). Begge metodene, i tillegg til identifisering ved bruk av morfologi, resulterte i en inndeling av ni arter. Dette tilsier at selv enkle metoder for artsavgrensning er tilstrekkelig for å finne grensen mellom arter innen Pectinidae, muligens innenfor Bivalvia generelt. Muslingsamlingen ved NTNU Vitenskapsmuseet ble nøye studert med mål om å være i stand til å identifisere de ulike muslingene som lever i Norge. Det ble laget en oppdatert artsliste over marine arter som er funnet i Norge, i tillegg til noen preliminære identifiseringsnøkler og karaktertabeller til bruk i artsidentifisering av vanskelige grupper. Det ble også laget artsbeskrivelser av alle 12 kamskjell-arter som er registrert funnet i Norske farvann. En identifiseringsnøkkel til Pectinidae funnet i Norske farvann er inkludert.

ACKNOWLEDGEMENTS

This master's thesis in biodiversity and systematics was written at the Department of Natural History at NTNU University Museum. I want to thank Torkild, my supervisor, for all feedback, guidance and help. Thank you for lending me relevant literature, and for always giving a quick reply to all my emails. Thank you for valuable comments on the written thesis. I would like to say thank you to Torkild and Karstein Hårsaker for letting me borrow material from the collection at NTNU University Museum, and for helping me find the material I needed, and to Tom Alvestad, Jon Anders Kongsrud and Katrine Kongshavn at the University Museum of Bergen. Torkild, Mäel Grosse and Aina Mærk Aspaas have my greatest appreciations for working with me in the microscopy lab. I am very grateful for all the hours you spent with me taking tissue samples of bivalves and teaching me how to take pictures using the stereoscopes. This thesis could not have been completed without all the knowledge I gained from all the courses arranged by ForBio Research School in Biosystematics and the Nordic Academy of Biodiversity and Systematic Studies (NABiS). I'm very thankful towards Andreas, for helping me to take pictures, for editing all of them, for testing my key to pectinid species and for sending me huge amounts of relevant literature. Thank you, Mäel, for all the discussions about our projects and for helping me with the molecular analyses. I want to show my gratitude towards the late Jon-Arne Sneli, a great thank you for your advice on bivalve identification, tips on relevant literature and for lending me valuable notes from your own research. Lastly, I want to thank my siblings, Joachim and Josephine, for proof-reading parts of my thesis, and for testing my key to Pectinidae.

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ABBREVIATIONS

ABGD	Automatic Barcode Gap Discovery
AIC	Akaike Information Criteria
BLAST	Basic Local Alignment Search Tool
BOLD	Barcode of Life Data System
CCDB	Canadian Centre for DNA Barcoding
coxI	Cytochrome Oxidase Subunit 1
ITS1	Internal Transcribed Space 1
ITS2	Internal Transcribed Space 2
LV	Left Valve
ML	Maximum Likelihood
mPTP	Multi-rate Poisson Tree Processes
MUSCLE	MUltiple Sequence Comparison by Log-Expectation
NBIC	Norwegian Biodiversity Information Centre
NJ	Neighbor-Joining
NorBOL	Norwegian Barcode of Life
NTNU-VM	NTNU University Museum
PCR	Polymerase Chain Reaction
PI	Pallial Index
PTP	Poisson Tree Processes
RV	Right Valve
ZMUB	University Museum of Bergen

1. INTRODUCTION

Species are the basic units in biology. Although most agree on this, the definition of a species has been highly debated among biologists through time (Agapow et al., 2004, Aldhebiani, 2018). Mayden (1997) listed 22 different species concepts, models that explains the definition of a species (Aldhebiani, 2018). All these concepts focus on different aspects, defining species according to phenetically distinguishable traits, ecologically divergence, reproductive isolation etc. (De Queiroz, 2007, Mayden, 1997). De Queiroz (2007) noted that the only thing lineages need to be considered different species, are separate evolution. Using only one species concept makes it easier to compare different species, e.g. in conservation, since all species are defined using the same assumptions (Mace, 2004). De Queiroz (2007) proposed a unified species concept, defining species as “separately evolving metapopulation lineages”. In the same paper De Queiroz also stated the difference between species concept and species delimitation, the latter explained as “how to determine the boundaries and numbers of species from empirical data”.

Species delimitation can be approached by both tree based and distance based methods (Puillandre et al., 2012, Zhang et al., 2013). Automatic Barcode Gap Discovery (ABGD) can be considered a simple method as it doesn’t require a phylogenetic reconstruction or a multi-locus dataset (Puillandre et al., 2012). It is based on pairwise distances between sequences, and automatically infers the barcode gap, i.e. the gap between intra- and interspecific diversity (Puillandre et al., 2012, Vitecek et al., 2017). Poisson tree processes (PTP) is also considered a simple and robust method, but unlike distance-based methods such as ABGD, PTP is based on phylogenetic trees and uses non-ultrametric phylogenies as input (Zhang et al., 2013). PTP uses the number of substitutions to model intra- and interspecific processes and finds the transition point among them (Correa et al., 2017, Zhang et al., 2013). Multi-rate PTP (mPTP) is an improvement of the PTP model, and differs from PTP in that it includes different rates of branching events within the species (Kapli et al., 2017).

Species need not only be defined and delimited, but also named, described and classified (Winston, 1999). This naming, describing and classification of organisms are known as taxonomy (Winston, 1999, Schlick-Steiner et al., 2010) is an important field within biology that humans have used since biblical time, although modern taxonomy can be dated back to Linnaeus (Alexander et al., 2015, Godfray, 2002). Taxonomy also involves redescribing and rearranging the classifications of already described species (Thomson et al., 2018, Winston, 1999). The field of taxonomy is closely related to the field of systematics which mainly focus on the evolutionary relationship between organisms (Winston, 1999).

Taxonomy is important in many fields, including biodiversity conservation, ecology, agriculture and human health (Ellis et al., 2010, Schlick-Steiner et al., 2010, Thomson et al., 2018, Wheeler et al., 2004). It is essential to both understand and protect world's biodiversity, especially due to the current biodiversity crisis. The rapid loss of biodiversity makes it important to document, and preferably conserve, all life before it is lost (Wheeler, 2004). Without unique scientific names there would be nothing to link knowledge with the organisms (Geoffroy and Berendsohn, 2003). No species can be properly protected without first identifying the species. Identification in conservation biology helps to make a bigger picture of what is conserved, i.e. if the species in question belong to a particular taxa (Mace, 2004). During history many different names have been assigned for the same species. This may lead to not only confusion, but also referencing important information using the wrong names (Geoffroy and Berendsohn, 2003). This problem states the importance of taxonomy, but despite this the contribution to the field has declined (Wilson, 2004).

Traditionally descriptions and identification of species have been based on morphological characters (Cook et al., 2010). This don't take into consideration that unrelated species may share characteristics, while closely related species can look completely different from one another (Hillis, 1987). While molecular taxonomy deals with this (Hebert and Gregory, 2005), traditional taxonomy is still needed for fossils, newly diverged species, cases of hybridization etc. (Hillis, 1987, Jordal and Ekrem, 2005, Lou et al., 2010), as well as communication on the differences between species that can be used by all in order to recognize them (Wheeler et al., 2004).

DNA barcoding is a molecular method for species identification that use DNA sequences to distinguish different species. The method is based on the premise that the interspecific genetic variation is larger than the intraspecific in the specific sequence that is analyzed (Hajibabaei et al., 2007). The first step is to collect a specimen and extract their DNA, before polymerase chain reaction (PCR) with suitable primers (Ye et al., 2012) is used to make multitude copies of the gene of interest to make DNA sequencing possible. When sequencing is achieved, the sequence can be compared with others from a database containing sequences of known species (or higher taxa). Many different sequences can be used, although the most universally used for animals is a 648-bp region of the mitochondrial gene coxI, cytochrome oxidase subunit 1 (Hajibabaei et al., 2007, Jordal and Ekrem, 2005, Schindel and Miller, 2005).

One of the most widely used databases for DNA sequences is BOLD (Barcode of Life Data System), an informatic workbench that anyone interested can get access to (Ratnasingham and Hebert, 2007). BOLD currently contains over 7 million barcodes and almost 300 000 species (BOLDSystems, 2019). NorBol, a Norwegian network that is part of the international Barcoding of Life Initiative, has a goal of making a reference library of all species in Norway and adding it to BOLD. By May 2019, 52 281 barcodes for a total of 17 027 species had been registered (NorBOL, 2019).

DNA barcoding are known to enhance the discovery of species that are new to science (Schindel and Miller, 2005). As earlier mentioned, molecular taxonomy can be helpful when traditional taxonomy is failing, i.e. when there are no distinct morphological characters to use for identification, e.g. because of damaged specimens, misleading morphological characters like sexual dimorphism or when the organisms are so small they lack good morphologically characters (Blaxter et al., 2005, Jordal and Ekrem, 2005). DNA barcoding is also useful when wanting to find out about disease carrying species or the dispersal of important species in agriculture, and is of great advantage when analyzing trading items to check for illegal activity (Frézal and Leblois, 2008). In addition, it can be used on organisms at all life stages, i.e. both eggs, larvae and adults, and no more than a fragment of the organism is needed (NorBOL). A last great advantage compared with traditional identification is the objectivity when using molecular markers instead of human biased characters (Jordal and Ekrem, 2005).

Although there are a lot of advantages when it comes to DNA barcoding, there are also several challenges with this relatively new method for species identification. Bad quality of the DNA or insufficient knowledge about the organisms genomes can make PCR and sequencing difficult to implement (Jordal and Ekrem, 2005). Suitable primers are essential for PCR to work, but due to the many factors that need to fit for a primer pair to work on specific taxa, primer design can be both time consuming and difficult (Ye et al., 2012). It is also problematic to set a limit for how large the genetic variation has to be before different specimens should be considered as different species (Jordal and Ekrem, 2005).

In order to achieve the goal of describing all life on earth, both traditional and molecular taxonomy are needed (Will and Rubinoff, 2004). A little below 1.9 million species (Roskov Y., 2019) have so far been described, but the true number of species on earth are thought to be much higher. How much higher are debated, and the total number of extant species on earth ranges from ~2 million to over 30 million (Costello et al., 2011, Larsen et al., 2017, May, 1992). This incomplete knowledge of species diversity is especially large in the marine habitats (Winston, 1999).

One of the largest animal phyla is Mollusca, a phylum with great diversity comprising 80 000 currently described species, as well as an estimate of 80 000 undescribed species (Brusca et al., 2016). Molluscs are bilaterally symmetrical, unsegmented organisms that vary greatly in morphology, and lives in both aquatic and terrestrial habitats. The group consist of eight classes which are known to have classification troubles at both generic and species level. The classes include squids and octopuses (Cephalopoda), slugs and snails (Gastropoda), clams, mussels and their kin (Bivalvia), as well as five less known groups: Scaphopoda, Polyplacophora, Monoplacophora, Solenogastres and Caudofoveata. All molluscs have a coelom, possess a complete gut, and have a visceral mass covered by a mantle. Of all classes Gastropoda is the largest, followed by Bivalvia (Brusca et al., 2016).

There are about 9100 extant bivalve species (MolluscaBase, 2019) as well as an extensive fossil record, all living in aquatic environments. They range in size from a length of 1 mm (Fam. Condylocardiidae Bernard, 1896) up to 1 m (Fam. Cardiidae Lamarck, 1809) (Brusca et al., 2016). The group consists of four subclasses: Protobranchia, Pteriomorphia, Palaeoheterodonta and Heterodonta (Horton et al., 2019). Heterodonta is by far the most species rich, comprising 5330 marine species and 270 in freshwater. There are 106 families in total, 7 of them only in freshwater. In addition to these exclusively freshwater families, freshwater species are found in some largely marine orders such as Arcoidea, Mytiloidea and Tellinoidea (Huber, 2010). Of the 9100 extant species, around 8000 divided into 1070 genera live in marine, brackish or estuarine environments. The largest extant marine family is Veneridae Rafinesque, 1815 with 774 species, while the freshwater family Unionidae Rafinesque, 1820 contains about 500 species (Huber, 2010, MolluscaBase, 2019).

Bivalves are laterally compressed animals with a rudimentary head, and a large mantle cavity covering both the visceral mass and the blade-like foot. The mantle produces a calcareous shell (Figure 1 and 2) typically divided into two valves, a right and a left (Brusca et al., 2016, Oliver, 2016). Where the mantle is attached to the shell, a scar appears called the pallial line. This line may be either entire or have a pallial sinus (Figure 2 and 3). The pallial sinus is said to be confluent when the ventral arm is fused with the pallial line, otherwise is it described as free (Oliver, 2016).

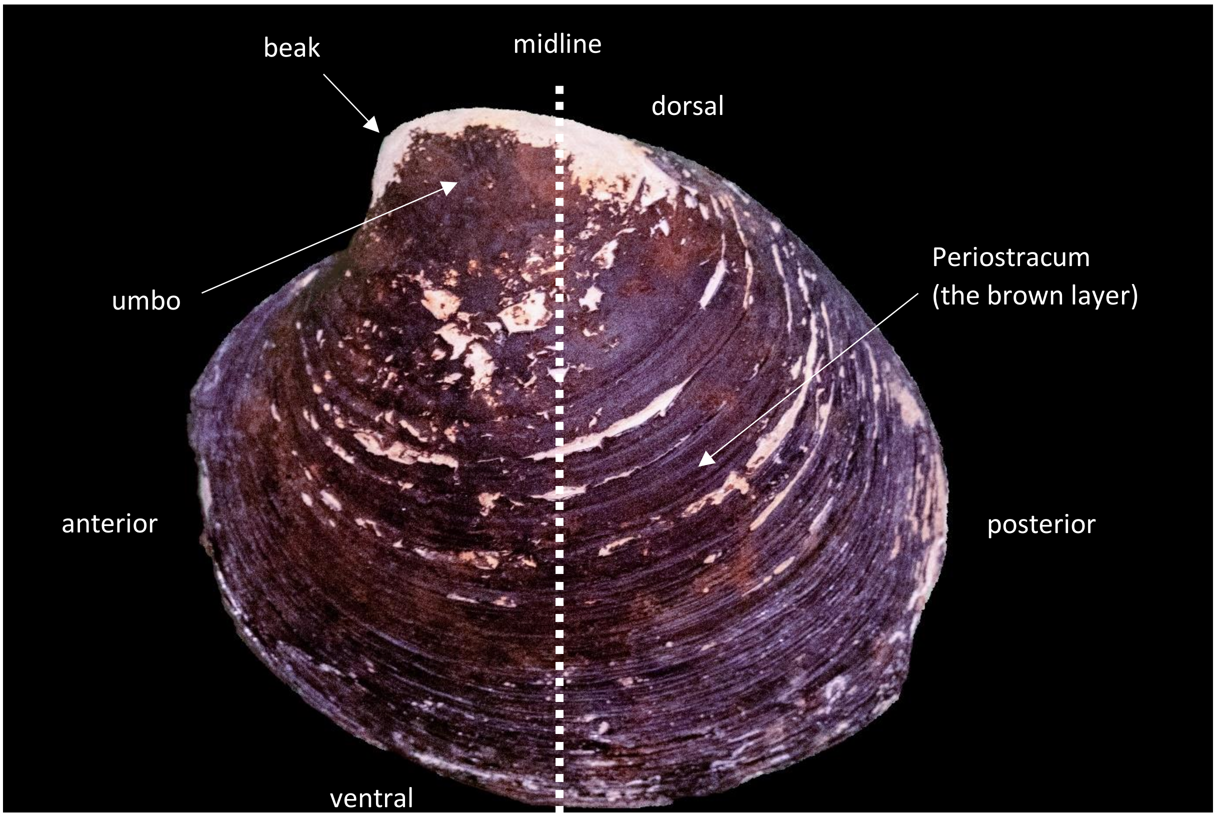

Figure 1. Axes and some external structures on a bivalve shell. Left valve of *Arctica islandica* (Linnaeus, 1767) shown. Photo: Andreas Zsoldos, Nathalie Skahjem.

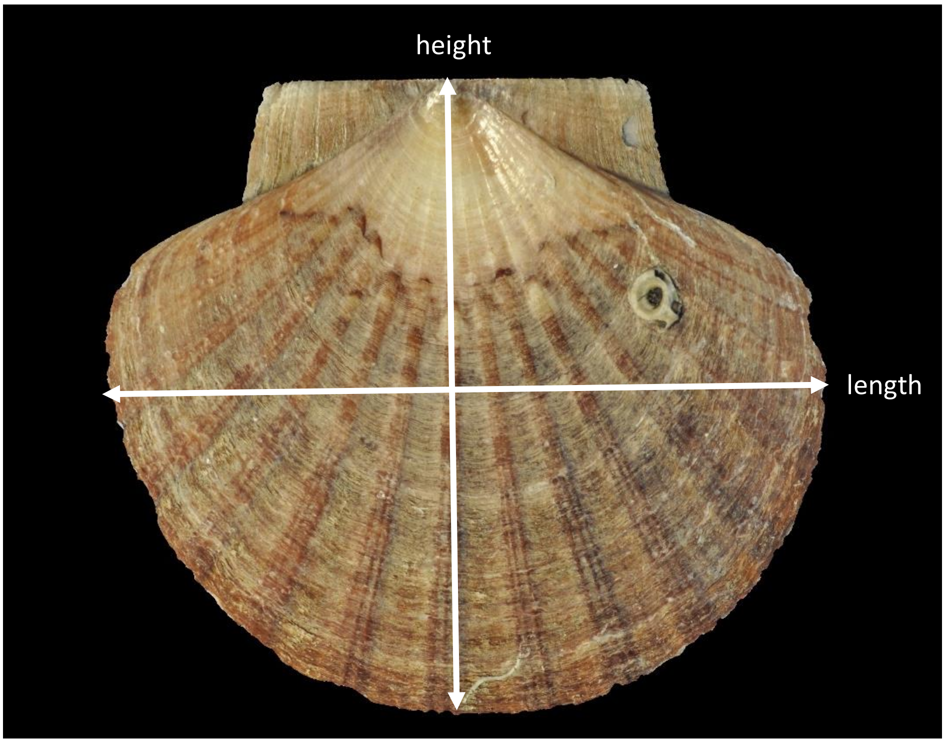

Figure 2. Length and height of a bivalve shell. Left valve of *Pecten maximus* (Linnaeus, 1758) shown. Photo: Nathalie Skahjem.

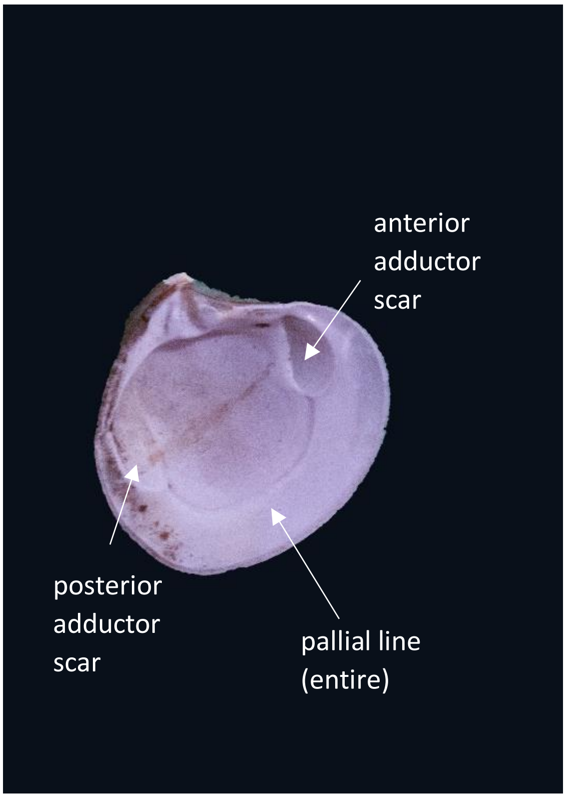

Figure 3. Adductor scars from adductor muscles, and the pallial line of a bivalve shell. Left valve of *Astarte* cf. *montagui* (Dillwyn, 1817) shown. Photo: Andreas Zsoldos, Nathalie Skahjem.

The valves are connected dorsally with ligament and/or teeth, and can be opened and closed by the use of adductor muscles (see Figure 3) (Brusca et al., 2016). Concerning the adductor muscles, a bivalve can be either dimyarian or monomyarian, depending on the number of adductor muscles present. A dimyarian bivalve have both an anterior and posterior adductor muscle that can be equal (homomyarian) or unequal (heteromyarian) (Oliver, 2016).

The ligament is an elastic component that can be either external or internal, or both. In some taxa, a calcareous structure is associated with the ligament, such as a resilifer or chondrophore (Figure 4). A resilifer is a depression on the shell where the ligament is attached, whereas chondrophore is the term for an internal resilifer that projects beyond the hinge plate (Oliver, 2016). The hinge plate lies on the inside of the dorsal margin, and is the part of the shell where the teeth are attached. A bivalve may be edentulous, i.e. lacking teeth altogether, or have teeth arranged in one of four main groups, where heterodont is by far the most common:

Taxodont (Figure 5) – numerous simple teeth arranged in a row along the hinge plate (e.g. Protobranchia)
Isodont – few teeth placed symmetrically on each side of the ligament (e.g. Anomiidae Rafinesque, 1815)
Dysodont – no true teeth, but a few small badly defined denticles on each side of the ligament (e.g. Mytilidae Rafinesque, 1815)
Heterodont (Figure 5) – two types of teeth, 1-3 cardinals radiating from the beak and 0-2 laterals on each side of the cardinals that do not radiate from the beaks, but are subparallel to the dorsal margin

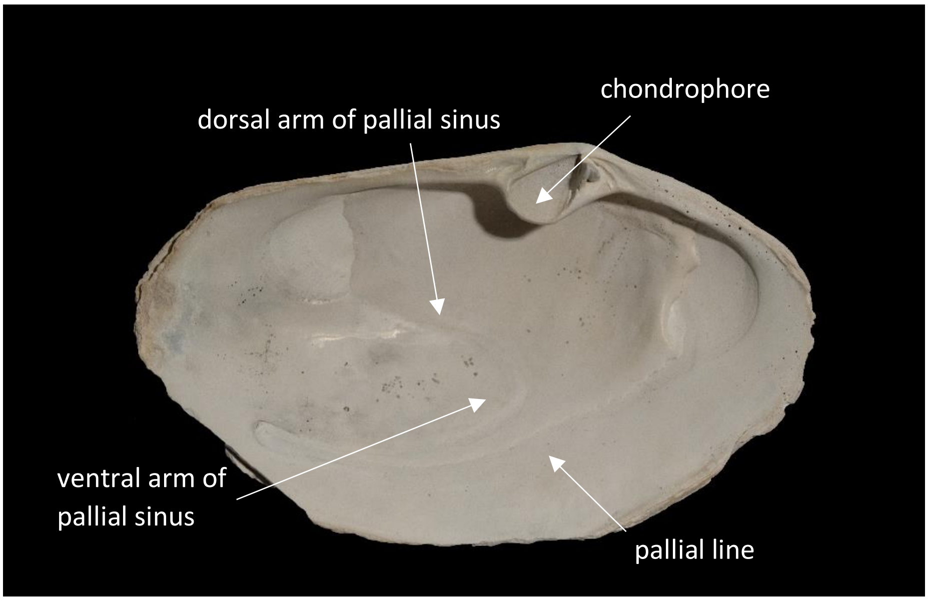

Figure 4. Chondrophore and pallial sinus of a bivalve shell. Left valve of *Lutraria* sp. shown. Photo: Andreas Zsoldos, Nathalie Skahjem.

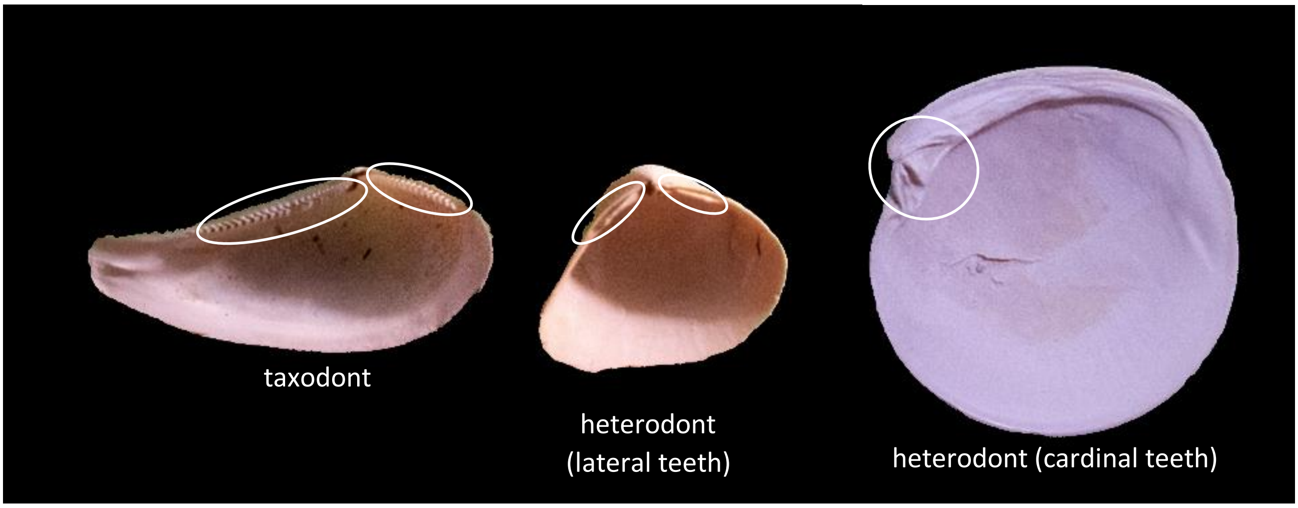

Figure 5. Taxodont and heterodont teeth in bivalve shells. Species, from left to right: *Nuculana* sp., *Spisula* sp., *Dosinia* sp. Photo: Andreas Zsoldos, Nathalie Skahjem.

The form of the dorsal margin is useful in identification as it can be e.g. straight, curved or with a keel. The opposite side of the shell, the ventral margin, can be either smooth or crenulated, i.e. with notches (Figure 6) (Oliver, 2016).

Figure 6. Crenulated ventral margin in a bivalve shell. Left valve of *Cerastoderma edule* (Linnaeus, 1758) shown. Photo: Andreas Zsoldos, Nathalie Skahjem.

Radiating ribs are one of two main forms for macrosculpture (Figure 7), the other being commarginal ridges. Ribs flows from the dorsal part of the shell to the ventral, while commarginal ridges follow the margins. In some species the ribs can be separated into primary and secondary, where the primary ribs are the first to develop. They later divide in two, and thus the smaller secondary ribs appear. A shell may also be macroscopically smooth, thereby lacking both ribs and ridges. In addition to macrosculpture, microsculpture is important in bivalve identification. This sculpture needs to be seen with magnification, and it refers to both sculpture on the periostracum (a thin layer covering most shells, see Figure 1), ribs or ridges, as well as in the interspace, i.e. the area between the ribs or ridges. Microsculpture can appear in different forms, such as linear lines, granules or a punctate pattern (Oliver, 2016).

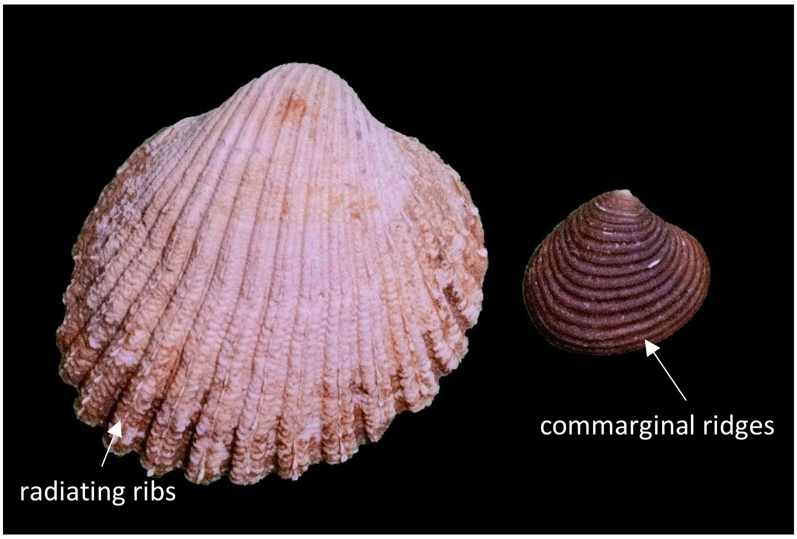

Figure 7. The two main forms of macrosculpture in bivalves. Species, from left to right: *Acanthocardia echinata* (Linnaeus, 1758), *Astarte* cf. *montagui* (Dillwyn, 1817). Photo: Andreas Zsoldos, Nathalie Skahjem.

The oldest part of the shell, called the umbo (see Figure 1), lies dorsally on each valve surrounding the remains of the post-larval shell, i.e. the beak (see Figure 1). A shell is said to be equilateral if the beak is placed on the midline, otherwise the valves are inequilateral. Same goes for the shape and sculpture of the valves, if they are identical the shell is considered equivalve, otherwise inequivalve (Brusca et al., 2016, Oliver, 2016).

To be able to recognize which valve is left and which is right, is important in bivalve identification as some characters are only present on one valve. In order to distinguish between the two valves, the posterior and anterior part of the shell must be determined. When holding a shell with the posterior part pointing towards your face and the dorsal margin upwards, the valve on your right is the right valve (RV) of the bivalve and the valve on your left is the left valve (LV) (Oliver, 2016). How to determine the posterior part of the shell varies between groups, but there are some general features that may help. An external ligament always lies posterior of the beak, as do a pallial sinus. The mouth and tip of the foot lie anterior, while anus and siphons lie posterior (Oliver, 2016). Other important structures in bivalve identification may be present along the dorsal margin. These depressed structures are called the lunule and escutcheon, and lies anteriorly and posteriorly respectively.

Unlike all other molluscs, the bivalves lack radula, a rasp-like feeding structure covered with teeth. Different ways of feeding exist among bivalves, although the vast majority attain nutrition by suspension feeding. Suspension feeding are achieved as particles are collected by the animal due to a water current generated by cilia on the ctenidia (the gills) (Brusca et al., 2016). Some groups, e.g. Thyasiridae and the genus Tridacna, live in symbiosis with chemosynthetic bacteria or photosynthetic dinoflagellates (zooxanthellae), respectively (Huber, 2010). Other feeding forms include e.g. deposit-feeding in Protobranchia and Tellinoidea, and sessile predation in some members of Poromyata. These predators have reduced and modified ctenidia as they don't use their gills for feeding (Brusca et al., 2016). In most bivalves however, the ctenidia are used for both feeding and gas-exchange. Gas-exchange is also performed over the mantle surface. Bivalves have both a heart and hemolymph, and often a pericardial cavity that surrounds both the heart and part of the digestive tract. Most taxa lack respiratory pigments, but a few has been found to have either hemoglobin or hemocyanin. Beneath the pericardial cavity are two nephridia used in excretion and osmoregulation. Bivalves have a bilateral nervous system consisting of three distinct ganglia (Brusca et al., 2016). There are sensory organs mainly along the middle lobe of the mantle that in some taxa include mantle tentacles. These tentacles are either restricted to the siphonal areas, or in swimming species, line the entire mantle margin (Brusca et al., 2016).

Bivalves may be hermaphroditic, although most are gonochoristic with paired gonads that look like one single gonadal mass. External fertilization is most common, with the development of a trochophore larva followed by a veliger larva. The veliger larva is only found among molluscs, it is characterized by its swimming organ (velum) and they can be either long- or short-lived depending on the species distribution range. Widely distributed species tend to have longer larval stages to enhance long-distance dispersal. Mixed and direct development are found in a few taxa. Species with mixed development brood the embryos through the trochophore stage, and release the embryos as veligers (Brusca et al., 2016).

They are found in all depths, from the intertidal to the deep sea, and in all marine environments (exposed and sheltered shores, coral reefs, kelp forests, hydrothermal vents, caves, cold seeps, mangroves, rivers, lakes etc.) although the majority are burrowers in soft benthic habitats (Brusca et al., 2016, Huber, 2010). Other bivalves are attached to hard substratum by byssus threads produced by a gland in the foot. Some bivalves that live in hard substrata have adopted a life style where they bore into the substratum, either by the use of serrations anterior on the shell or by the secretion of acidic mucus (Brusca et al., 2016). Other life styles include cemented to hard substrata and free-living (Huber, 2010).

Even though bivalves are distributed all over the world, there are only 30 marine species considered as truly cosmopolitan. With 2750 species the Indo-Pacific is the region with most marine species in the world. Not only is the total number of species high, the region also represents a high diversity and endemism containing 90 % of all marine families and 2000 endemic species (Huber, 2010).

Bivalve systematics are commonly based on shell characteristics such as ligament, pallial sinus and macro- and microsculpture, as well as internal anatomy of e.g. the gills, but also habitat, biogeography and molecular characters influence the systematics (Bieler and Mikkelsen, 2006, Dufour, 2005, Huber, 2010, Zardus, 2002).

It is estimated that there are good morphological data for 50 % of all species, biogeography data for 99 %, detailed habitat-data for only 10 % and DNA-data for about half the families (Huber, 2010). Bivalves have an evolutionary history of about 500 million years (Cope, 2000), with a good fossil record (Harper et al., 2000) and about 100 extinct families and 1000 extinct genera (Huber, 2010).

Species identification can be problematic, e.g. due to cryptic species (Bieler and Mikkelsen, 2006, Knowlton and systematics, 1993). Since many bivalve characters are modifications from the plesiomorphic molluscan characters, the phylogenetic placement of Bivalvia within Mollusca is also considered problematic, as is the relationship within the class (Giribet and Wheeler, 2002). Many different classifications within Bivalvia has been proposed during the 20th century, nicely summarized in Schneider (2001).

Genes like coxI seems to be insufficient to reconstruct higher relationships within Mollusca (Giribet and Wheeler, 2002). Bivalvia has in different studies been considered either monophyletic (Giribet and Carranza, 1999, Giribet and Wheeler, 2002) with synapomorphies such as the bivalve shell, absence of radula and presence of adductor muscles, pallial line and ligament (Brusca et al., 2016, Giribet and Wheeler, 2002) or polyphyletic (Adamkewicz et al., 1997, Giribet and Wheeler, 2002, Hoeh, 1998, Steiner and Müller, 1996). Giribet and Wheeler (2002) states that studies that find bivalves as polyphyletic have generally used a small sample size and/or a poor representation of the diversity found in the class. Giribet and Wheeler (2002) did therefore a thorough phylogenetic study using both morphological data, with 183 characters, and molecular data from three different genes: 18S, 28S and coxI. The sample size consisted of 62 bivalve species representing all subclasses, as well as 14 outgroup taxa belonging to Polyplacophora, Cephalopoda, Gastropoda and Scaphopoda. None of the molecular datasets alone nor the combined molecular dataset showed monophyly, while the morphological dataset found Bivalvia to be monophyletic. A combined dataset with all morphological and molecular data was made, and this showed bivalves to be a monophyletic group with Bremer support of 20.

One issue with bivalve classification is the huge number of synonyms that exist. There are around 30 000 names for the 8000 marine species, which equals an average of around 4 synonyms per species. The reasons for this are many, such as non-detailed original descriptions and not recognizing intraspecific variation (Willan, 1993), and to study too few specimens when describing a new species or to describe a species from unknown localities (Huber, 2010). Synonyms may also arise if juveniles of known species are used as types for new species, without the realization that they are juveniles (Huber, 2010). No fundamental taxonomic infrastructure exists among the bivalves. This leads to several identification problems, such as disagreement upon validity of names and making good barcode databases. Only a few bivalve taxa exist in such databases (Bieler and Mikkelsen, 2006, Mikkelsen et al., 2007). As of January 2018, 1,641 species of bivalves from a total of 115 countries are registered in BOLD (Barcode of Life Data System) 4.0. Many of these species registrations come from only 1 specimen.

One of the subclasses within Bivalvia, Pteriomorphia Beurlen, 1944, comprises many well-known og commercially used taxa, such as oysters, scallops and blue mussels (Horton et al., 2019). This group is monophyletic supported by both morphological and molecular data, and is characterized by the presence of egg cleavage with polar lobe formation (Giribet and Wheeler, 2002, Steiner and Hammer, 2000). Most species in the group lack siphons as they are epibenthic (Brusca et al., 2016). Pteriomorphia comprises around 2000 species, where 11 live in freshwater (Huber, 2010). The species belong to 25 different families (Huber, 2010) in the extant orders Mytilida, Arcida, Ostreida, Limida and Pectinida (Horton et al., 2019).

Pectinoidea Rafinesque, 1815, one of four superfamilies belonging to Pectinida, are exclusively marine and are characterized by having a triangular resilium with a nonmineralized core situated in the resilifer below the hinge line (Horton et al., 2019, Huber, 2010, Waller, 2006). Pectinoidea consists of 5 families, 68 genera and 540 species worldwide (Horton et al., 2019, Huber, 2010, MolluscaBase, 2019) with Pectinidae Rafinesque, 1815 being the largest family with 271 extant species, along with a rich fossil record (MolluscaBase, 2019, Waller, 2006). The family is characterized by having a ctenolium (a structure that keeps the byssus from intertwining) at least in the early life stages (Shumway and Parsons, 2016, Waller, 2006, Waller, 1984). Other useful characters to recognize the family includes an anterior and posterior auricle dorsally on each valve, and a byssal notch in the right anterior auricle, which is the place where the ctenolium is found (Figure 8) (Waller, 1984). In some species, the ctenolium disappears in adults removing the possibility of byssus thread production. They have both and external and internal ligament (Shumway and Parsons, 2016). Pectinids possess the most complex eyes within Bivalvia, located along the mantle margin (Morton, 2001). This eyes are considered “mirror eyes” as they have a reflective layer called the tapeum behind the retinas (Brusca et al., 2016). Most pectinids are sexually mature after one year, and they have either indirect or direct development of the young. They are hermaphrodites, but in some species there’s a difference in color between the male and female gonad, the female being darker. Pectinids are monomyarian, having only one adductor muscle. The adductor muscle consists of both striated and smooth fibers. The striated functions in quick and repetitive opening/closing of the shell during swimming, while the smooth is able to hold the shell closed during longer periods using a minimal amount of energy (Shumway and Parsons, 2016).

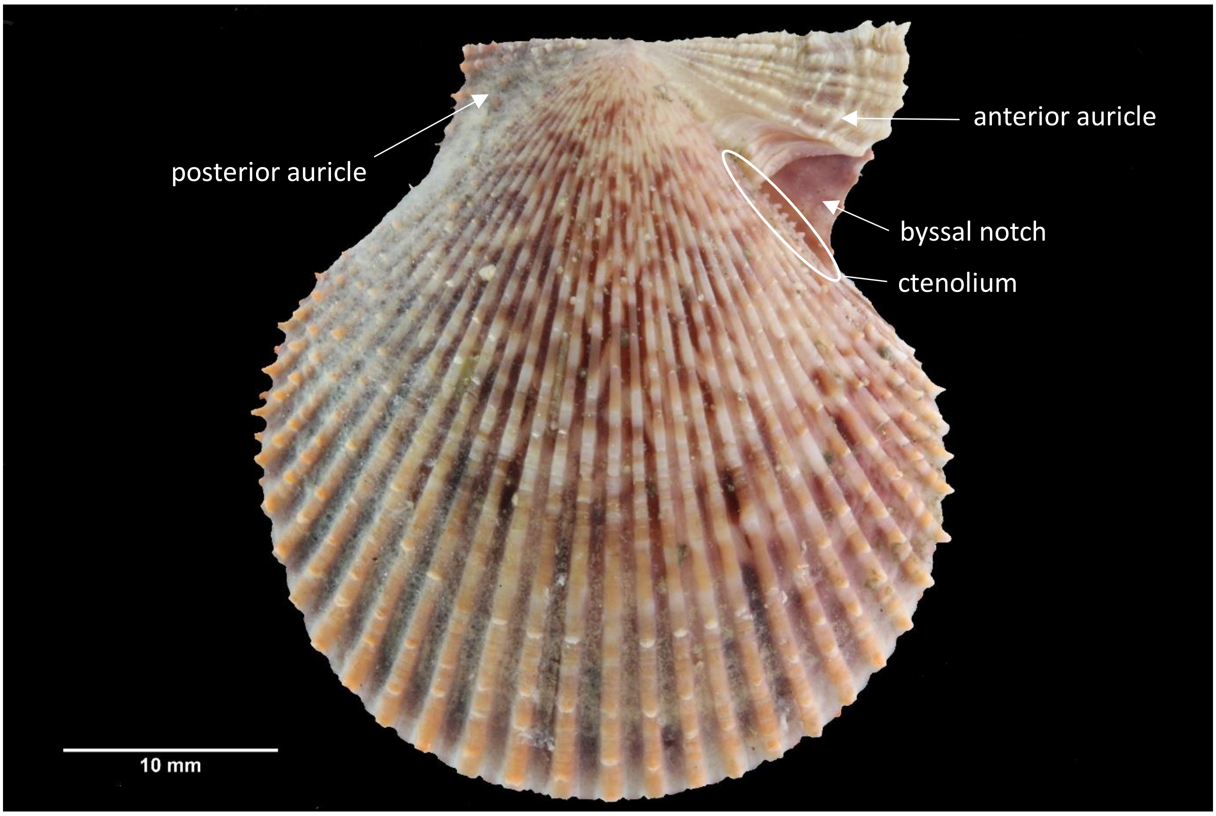

Figure 8. Key characters of Pectinidae. Right valve shown. Picture of ZMUB-55783. Photo: Nathalie Skahjem.

Pectinids live in a large variety of habitats, ranging from the intertidal zone to 7000 meters (Shumway and Parsons, 2016, Waller, 2006). They can be found in all oceans from the polar regions to the tropics. The species can be divided into six different groups concerning life habits (Table 1) (Alejandrino et al., 2011, Shumway and Parsons, 2016, Stanley, 1970).

Table 1. Different life habits within Pectinidae.

Life habit	Description	Species appearance	Example
Byssal attachment	Temporarily attached to hard substrate using byssus threads.	Chlamydoid: inequilateral, deep notch, well-developed ctenolium.	*Mimachlamys varia*
Nestling	Nestled within living Scleractinia (Subclass: Hexacorallia).	Variable.	*Pedum spondyloideum*
Cementing	Permanently attached to hard substrate by secreting new shell material. Right valve conforms to the substrate.	Chlamydoid when juvenile, variable and distorted when adult	*Talochlamys pusio*
Reclining	Passively occupying a location on soft substrate. May be partly buried in the substrate.	Aequipectinoid: equilateral, shallow byssal notch	*Aequipecten opercularis*
Recessing	Living in soft substrate, creating a saucer-shaped depression in the ground by shooting water jets from the mantle cavity.	Pectinoid: equilateral, inequivalve	*Pecten maximus*
Gliding	Active swimmers able to swim over long distances even with the valves closed. Maintain an almost horizontal position over the substrate.	Amusioid: thin shell, lightweight, smooth macrosculpture, circular, small auricles, gaping.	*Amusium* sp.

The other families within Pectinoidea, Spondylidae, Entoliidae, Propeamussiidae and Cyclochlamydidae lack a ctenolium (Horton et al., 2019, Waller, 1984). Concerning Spondylidae, this has, until recently, been thought to be a primary loss (Waller, 2006). Both Matsumoto (2003) and Barucca et al. (2004) found that Spondylidae is a sister group to Pectinidae, which supports the hypothesis of a primary loss of ctenolium. (Waller, 2006) on the other hand, studied fossils and the morphology of juvenile spondylids and found this character loss to be secondary, a finding that suggest that Pectinidae is a paraphyletic group. The species within Pectinidae has long been considered difficult to distinguish. The evolutionary relationships and phylogenies within the family are also considered problematic (Feng et al., 2011a, Shumway and Parsons, 2016). Canapa et al. (2000) found Pectinidae to be monophyletic with high support, but this study only included 7 species.

Different classifications of pectinid subfamilies have been proposed (Puslednik et al., 2008), several of them compared in Barucca et al. (2004). Originally, all pectinid species were placed into only 5 genera, based on shell form. When it was learned that shell forms were non-homological characters connected to life habit (see Table 1), these genera were considered polyphyletic and a change in the classification arose (Shumway and Parsons, 2016). Molecular markers are now used in addition to morphology, to establish a phylogeny of the family (Puslednik et al., 2008, Saavedra and Peña, 2006). Several different genetic markers have been used in molecular studies of Pectinidae: coxI, 5S, 5.8S, 12S, 16S, 18S, 28S, ITS1, ITS2 and Histone H3 (Feng et al., 2011a, Insua et al., 2003, López-Piñón et al., 2008, Mahidol et al., 2007, Malkowsky et al., 2012, Matsumoto and Hayami, 2000). Taxon sampling regarding both ingroup and outgroup, and the number of species, together with different choice of markers reveals different evolutionary relationship within Pectinidae (Shumway and Parsons, 2016).

Pectinidae is one the most diverse bivalve families (Shumway and Parsons, 2016), and is an important commercial group, as the species are used in everything from food industry to decoration (Ghys-b, Shumway and Parsons, 2016). Due to the huge variety in color and shape, shells belonging to this family are often collected by scientists and non-scientists alike, and therefore well represented in many natural history museums. The family is 245 million years old, meaning it survived two mass extinctions (Shumway and Parsons, 2016). A good fossil record gives the family high potential for evolutionary biology studies.

Many original descriptions from this group are old and includes few details as many of them are described by scientists like Linnaeus and Müller (Linnaeus, 1758, Müller, 1776a). The studying of old and/or poorly detailed descriptions makes the discovery and descriptions of new taxa hard as it is difficult to relate new and old taxa (Godfray, 2002).

AIMS

This study is a faunistic approach towards diversity and distribution within Bivalvia, with focus on Pectinidae. The Norwegian Biodiversity Information Centre (NBICa) has registered 384 species of bivalves and 19 species of pectinids in Norway. These numbers are not accurate due to nomenclature problems, and this is an issue that needs clarification, so a new list of species present in Norway (excluding synonyms and unlikely registrations) was made. Both morphological and molecular characters are used to get a better insight into bivalves living in Norwegian waters, although the main part of this project is based on morphology.

1) **DNA barcoding**: DNA barcoding of as many bivalves as possible from Norwegian waters as part of the NorBol project. The aim was mainly to see how well barcoding works for identification within this group, but also to increase the coxI library for bivalves.
2) **Species delimitation**: Both distance based (ABGD) and tree based (MPTP) species delimitation methods for Pectinidae found in Norwegian waters, was compared with each other and with morphology to get an overview of the species number within this family in Norway.
3) **Morphological analyses**:
    a. **Bivalvia**: The aim was to look at morphological characters used in identification, and learn as much as possible about bivalves in Norwegian waters and how to identify them.
    b. **Pectinidae**: A closer study was made at the family Pectinidae. Detailed descriptions including several detailed pictures were made of the 12 species found in Norwegian waters. In addition, a key was made to be used for species identification of pectinids found in Norway.

2. MATERIALS AND METHODS

Specimens used for molecular and morphological analyses were preserved in 96 % EtOH and belonged mainly to the bivalve collections at NTNU University Museum (NTNU-VM) and the University Museum of Bergen (ZMUB). In addition, fresh material was sampled from different places in the Trondheimsfjord on three occasions, to be used mainly in molecular analyses. All material was directly preserved in 96 % EtOH. The 29th and 30th of August 2017, sampling was done by dredge and grab from 1-23 m deep in Hopavågen, Sletvik. At a sampling cruise with R/V Gunnerus in the Trondheimsfjord East of Trondheim, the 7th of February 2018 sampling was done with a triangular dredge from 17-130 m. In June/July 2018, sampling was done by R/V Gunnerus in Agdenesflua (66-299 m), Brødreskift (23-48 m), Trondheimsleia (411-421 m) and Mølnbukta using a triangular dredge or an Agassiz trawl, as well as hand sampling from the littoral zone close to Sletvik field station in Agdenes. The study area for this project is waters around Norway: North Sea, Norwegian Sea, Norwegian coast and shelf, Skagerrak, Barents Sea, Norwegian basin and the Arctic Ocean (Nygren et al., 2018, OSPAR, 2010, Yashayaev et al., 2015).

2.1 DNA BARCODING

Tissue samples were taken from 190 specimens from the sampling excursions and the collection at NTNU. Specimens were chosen to represent as many as possible of the marine bivalve taxa in Norwegian waters. The specimens represented a total of 71 species from 29 different families, most specimens belonging to Pectinidae (Appendix I). A picture was taken of all specimens from a lateral view using a Leica MC170HD camera attached to a Leica M165C stereo microscope. The samples were sent to the Canadian Centre for DNA Barcoding (CCDB), University of Guelph for DNA extraction (CTAB Animal Automated Extraction), PCR and sequencing of coxI following their standard protocols (CCDB, 2017). DNA was amplified using the primer pair BivF4_t1/BivR1_t1 (Prosser). Due to a low success rate in the first run, the two plates were run two additional times, with different primer pairs, MBivF1_t1/BivR1_t1 (Prosser) and C_BivF1_t1/MBivR1_t1 (Prosser) respectively. All sequences were stored in BOLD as part of the project Norwegian marine Mollusca from NTNU University Museum (NMMVM) under NorBOL. All successful barcodes >200 bp were used to make a neighbor joining (NJ) tree with the Kimura 2 parameter model, using the Taxon ID Tree tool in BOLD (Ratnasingham and Hebert, 2007). Sequences containing stop codons or flagged as misidentifications or contaminants, were excluded from the analysis.

2.2 SPECIES DELIMITATION ANALYSES

Out of all the bivalves sent to CCDB, 43 specimens represented Pectinidae. 15 sequences were successful, but only 14 used in further analyses due to unnatural mismatch in the alignment. The 14 pectinid sequences, together with 17 coxI sequences downloaded from GenBank (Table 2)(Benson et al., 2017), as well as two outgroup sequences chosen from the samples sent to CCDB, were used in species delimitation analyses. Two species, *Mytilus edulis* and *Arca tetragona*, were chosen as an outgroup due to their taxonomic position within the same subclass (Pteriomorphia) as Pectinidae, but within different orders, Mytilida and Arcida, respectively. Only sequences from 9 of the 12 pectinid species found in Norwegian waters were available. After performing a sequence similarity search on the CCDB sequences with Basic Local Alignment Search Tool (BLAST) (Altschul et al., 1990), all sequences were aligned using MUSCLE (Edgar, 2004) in AliView (Larsson, 2014). Species delimitation was performed using two different methods, one distance based (ABGD) (Puillandre et al., 2012) and one tree-based (mPTP) (Kapli et al., 2017). ABGD ran with 10 partitions and a minimum slope increase of 1. The program utilized the FASTA-file containing all the sequences in question. For MPTP, the options --ml and --multi were used, and the input was a maximum likelihood (ML) tree made in R Studio version 3.5.1 (2018) (Appendix II). The function modelTest in the R package Phangorn (Schliep, 2010) was used to test for the best substitution model. The model TIM1+G+I had the lowest AIC and was therefore used to make the ML-tree. Bootstrap support was calculated from 100 pseudo replicates.

Table 2. Specimens used in species delimitation analysis of Pectinidae in Norwegian waters. GenBank accession number and/or voucher number shown for each specimen, together with a reference for the published sequences.

Species	GenBank accession number	Voucher number	Reference
Delectopecten vitreus 1	-	DeVi02	This study
Delectopecten vitreus 2	-	DeVi01	This study
Delectopecten vitreus 3	-	DeVi03	This study
Mimachlamys varia 1	MH178523.1	-	Breitwieser et al. (2018)
Mimachlamys varia 2	KU680883.1	-	Breitwieser et al. (2016)
Mimachlamys varia 3	KU680873.1	-	Breitwieser et al. (2016)
Mimachlamys varia 4	MH178513.1	-	Breitwieser et al. (2018)
Mimachlamys varia 5	MH178520.1	-	Breitwieser et al. (2018)
Mimachlamys varia 6	MH178517.1	-	Breitwieser et al. (2018)

Chlamys islandica 1	AB033665.1	-	Matsumoto and Hayami (2000)
Chlamys islandica 2	EU564118.1	-	Unpublished article
Pecten maximus 1	KC429102.1	BivAToL-199	Sharma et al. (2013)
Pecten maximus 2	EU418250.1	PAN_Pm/18	Unpublished article
Aequipecten opercularis 1	-	AeOp06	This study
Aequipecten opercularis 2	-	AeOp04	This study
Aequipecten opercularis 3	KR084493.1	MT04966	Barco et al. (2016)
Aequipecten opercularis 4	KR084493.1	MT04966	Barco et al. (2016)
Palliolum striatum	-	PaSt05	This study
Palliolum tigerinum 1	MG934882.1	MollOvr 8756V	Unpublished article
Palliolum tigerinum 2	-	PaTi02	This study
Palliolum tigerinum 3	-	PaTi03	This study
Palliolum tigerinum 4	-	PaTi01	This study
Palliolum incomparabile	-	NTNU-VM-67397	This study
Pseudamussium peslutrae 1	KR084637.1	MT04962	Barco et al. (2016)
Pseudamussium peslutrae 2	KR084848.1	MT05056	Barco et al. (2016)
Pseudamussium peslutrae 3	-	PsPe01	This study
Pseudamussium peslutrae 4	KR084399.1	MT01028	Barco et al. (2016)
Karnekampia sulcata 1	JF496766.1	BES MPB 092	Plazzi et al. (2011)
Karnekampia sulcata 2	-	KaSu02	This study

Karnekampia sulcata 3	-	NTNU-VM-71824	This study
Karnekampia sulcata 4	-	KaSu01	This study

2.3 MORPHOLOGICAL ANALYSES

All available bivalves at the NTNU University Museum were studied for identification purposes, looking at external and internal shell morphology. The internal anatomy of the soft parts was not studied. A Leica Wild M3B stereo microscope was used for examination as well as different literature for identification: Handbook of the Marine Fauna of North-West Europe (Hayward and Ryland, 2017), Danmarks Fauna: Bløddyr II Saltvandsmuslinger (Jensen and Spärck, 1934), British Bivalve Seashells (Tebble, 1966), and Marine Bivalve Shells of The British Isles (Oliver, 2016). The bivalves have all been collected in Norway, mainly from Trøndelag, and represent 41 families and 144 species. This equals 89 % of the families and 62 % of the species found in Norwegian marine waters. A list over all marine species registered in Norwegian waters was made based on the museum collection and the list available in NBIC.

A closer look was made at the 12 species of Pectinidae found in Norwegian waters, from the collections at NTNU University Museum (NTNU-VM) and the University Museum of Bergen (ZMUB). A total of 183 specimens were studied collected in different parts of Norway, ranging in depth from the littoral zone to 3006 m (Appendix III). Pictures were taken of selected specimens for each species, after the internal soft parts had been removed. A Leica DFC420 camera attached to a Leica MZ16A stereo microscope was used on all specimens less than 10-20 mm in length. Pictures of larger specimens were taken with a digital single-lens reflex, either Nikon D90, lens 105 or 60 mm, or Canon EOS 60D. All pictures were edited with Adobe Photoshop Lightroom Classic CC 8.0, and collages made via the website BeFunky: Create Photo Collages. All pictures of larger specimens were in addition edited with ImageJ 1.52a, and some also with Microsoft Paint 3D. All morphological analyses of Pectinidae were used to make species descriptions of the 12 species found in Norway. A single-access bracketed dichotomous key to all 12 species was made without the use of any programs.

All species descriptions are based on my own observations in the lab at NTNU University Museum and at the University Museum of Bergen, and therefore they apply especially to Norwegian species. All shell sizes in the species descriptions are also based on my own observations, meaning that these numbers are unlikely to be the highest recorded for the species in question. Material examined for all descriptions are limited due to the loss of access to most of the data from the University Museum of Bergen.

3. RESULTS

3.1 DNA BARCODING

Sequences of coxI was successfully obtained for only 82 of the 190 specimens sent to CCDB, resulting in a lower success rate than expected. Due to the low success rate it was decided to try a second and third round of PCR and sequencing at CCDB, using different primers. The success went up to 110/190, suggesting primers may have been at least part of the issue during the first trial. Only 68 of the sequences were barcode compliant, but due to the use of the default choice of including “Nucleotide Sequence Length ≥ 200 bp” in Taxon ID Tree (Ratnasingham and Hebert, 2007), the total number of sequences used in the analysis is 96, comprising a total of 45 species and 21 families.

The NJ tree generated in this study using the successful sequences (Figure 9) indicated that barcoding using coxI are a good tool for bivalve identification. When it comes to phylogenetic relationships and ancestry this tree tells us little as the main purpose was barcoding for identification, and it was only used one marker (coxI). Still, the same species are expected to end up close to each other in the tree with a short genetic distance. This expectation reveals some peculiarities in the tree, marked with red circles in the figure (Figure 9).

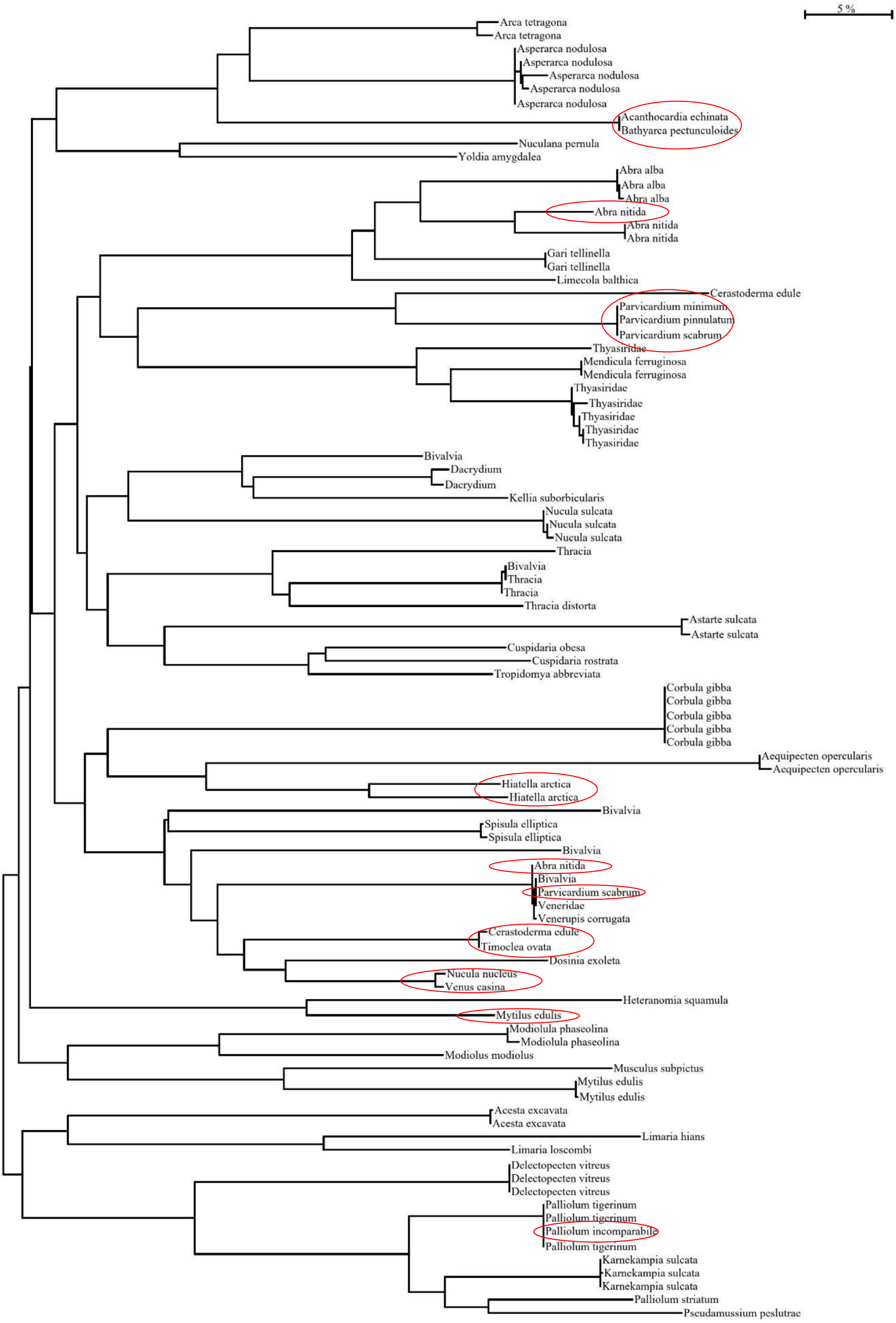

Figure 9. Neighbor joining tree of Bivalvia (n=96) in Norwegian waters, generated in BOLD. Red circles mark peculiar positions of certain sequences.

3.2 SPECIES DELIMITATION ANALYSES

Both ABGD and MPTP yielded the same result as the morphological analysis: 9 species were delimited (Figure 10). The barcode gap in the ABGD analysis was well defined, with interspecific (17-71%) and intraspecific (>4%) distances clearly distinct.

The ML-tree (Figure 9) was only generated to be able to perform a mPTP analysis. Due to the low number of sequences and the use of only one marker (coxI), this cannot be considered a phylogeny and it may or may not show common ancestry. The tree is still useful as it shows how well the molecular analyses fits with the morphological.

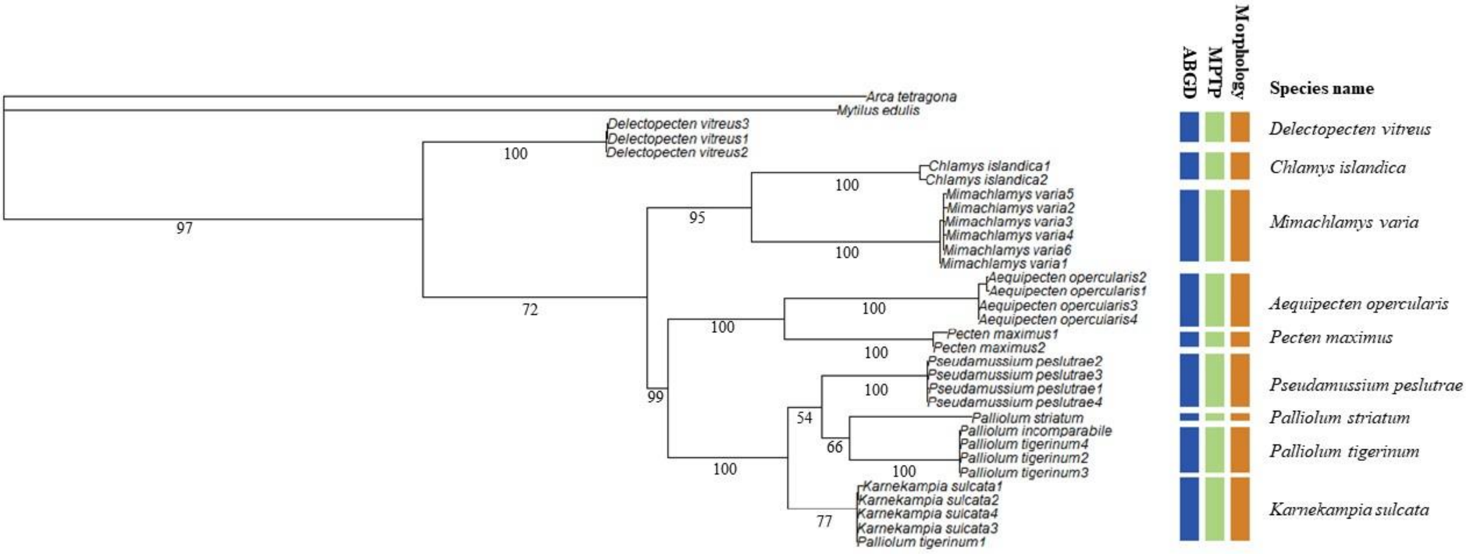

Figure 10. Species delimitation analyses of nine morphologically identified pectinid species found in Norwegian waters using species delimitation methods Multi Poisson Tree Processes (MPTP) and Automatic Barcode Gap Discovery (ABGD). Tree inferred with maximum likelihood (n=33 sequences). Bootstrap values calculated with 100 pseudo replicates. Outgroups *Arca tetragona* and *Mytilus edulis*.

3.3 MORPHOLOGICAL ANALYSES

When making the species list over registered marine bivalves in Norwegian waters (Appendix IV), it was noticed that the list made by the Norwegian Biodiversity Centre (NBICa) needs an upgrade as it contains a lot of synonyms not registered as such, as well as misspelled names and some outdated names. One species, *Chamelea gallina* is registered both in Artsdatabanken and at NTNU University Museum. This species closely resembles *Chamelea striatula*, a common species along the Norwegian coast (NBICb). The distribution of *C. gallina* however, is from south Portugal to the Mediterranean and the Black Sea, and the two species are only known to coexist along the coast of Algarve, the Gulf of Cadiz, the Strait of Gibraltar and the Alboran Sea. (Backeljau et al., 1994, Rufino et al., 2006).

When studying the museum collection in Trondheim more time were spent on common taxa I considered to be difficult to identify, i.e. Thyasiridae, *Parvicardium*, *Abra*, *Astarte*, *Macoma calcarea* vs. *Limecola balthica*, and a small group of similar looking venerids. I would consider all white bivalves approximately less than 10 mm in length to be very difficult to identify based on their size and lack of external characteristics. To learn how to properly identify these bivalves the shell requires to be opened so that internal shell characteristics, and in some cases the anatomy of the soft parts, can be studied. This would have been too time consuming in this study, especially since the opening of small bivalves without destroying them requires a lot of training.

There is little knowledge about the family Thyasiridae in Norway (Keuning and Schander, 2010). Within the family 17 species from 8 genera have been found in Norwegian waters (see Appendix IV), but after this study I would say that only one of the species are easy to distinguish from the others using morphology. *Mendicula ferruginosa* are almost completely covered by rust, making it stand out among other bivalves including its relatives within Thyasiridae. The rest of the species are with a first glance all white with both valves containing one orange-rusty spot on the anterodorsal side of the shell and one on the posterodorsal. There are small differences in shape between the species, but personally I think this is a bad character to use for identification as shapes can be subjective. With a closer look two of the species, in addition to *M. ferruginosa* were found to have some differences from the rest that may be useful in identification. *Genaxinus eumyarius* has white and clearly thickened adductor scars that are visible through the shell, and *Thyasira granulosa* has a granulated microsculpture all over the surface of the disc.

The genus *Parvicardium* (Fam. Cardiidae) are registered in Norway with 4 species. All species are white with radiating ribs partly or fully covered in spines, and they all have an entire pallial line although this may be weak and therefore difficult to observe. Differences between the species that can be used in identification are summarized in Table 3.

Table 3. Characters that can be used to separate the four species of *Parvicardium* (Fam. Cardiidae) found in Norwegian waters.

Species	**Character**
P. exiguum	Spines only posterior and anterior. Shell expanded posteriorly. Interspace equal to rib.
P. minimum	Spines on all ribs, faced ventrally.
P. pinnulatum	Spines only posterior and anterior; middle ribs smooth. Ribs densely spaced; interspace ca. 1/3 of rib.
P. scabrum	Spines on all ribs, clearly sharp and pointed posteriorly.

A character table was also made to show the difference between the 5 species in the genus *Abra* (Fam. Semelidae) found in Norwegian waters (Table 4).

Table 4. Characters that can be used to separate the four species of *Abra* (Fam. Semelidae) found in Norwegian waters.

Species	**Character**
A. alba	Posterior margin = anterior. Smooth with commarginal ridges.
A. nitida	Posterior margin acute compared to anterior. Depression posterior to umbo.
A. longicallus	Posterior margin = anterior. Commarginal ridges and weak radiating grooves.
A. prismatica	Posterior margin acute compared to anterior. Beak placed posterior of midline.
A. tenuis	Beaks at midpoint.

Nine species in the family Astartidae, in the genera *Astarte* and *Goodallia*, are registered from Norway. Six of these species were studied in the lab, with a close look at periostracum microsculpture (requires high magnification). Together with identification literature (Hayward and Ryland, 2017, Oliver, 2016) a preliminary key (Key 1) was made to all nine species. All species have an entire pallial line, are brown or almost black in color due to the long lasting periostracum, have a thick and robust hinge plate and all have commarginal ridges although they can be weak. Many of the species in the key are separated by the use of periostracum microsculpture, for pictures and more details see Skazina et al. (2013).

Key 1. A key to the nine species of Astartidae found in Norwegian waters.

1a. Commarginal ridges weak; surface appears almost completely smooth
………………………………………..… ***Goodallia triangularis***
1b. Commarginal ridges prominent; if weak, then periostracum very thick making the surface rough instead of smooth
…………………………………………….… 2 (Gen. *Astarte*)

2a. Commarginal ridges weak and/or flattened
……………………………………………………………..… 3
2b. Commarginal ridges clearly protruding out of disc
……………………………………………………………..… 4

3a. Periostracum black and very thick, covering the commarginal ridges
…………………………………………….… ***Astarte borealis***
3b. Periostracum golden brown; commarginal ridges clearly visible, but flattened
…………………………………………………… ***Astarte arctica***

4a. Periostracum microsculpture a fine wavy pattern
…………………………………………...… ***Astarte sulcata***
4b. Periostracum microsculpture not as described above
……………………………………………………………..… 5

5a. Periostracum microsculpture consist of deep pits
……………………………………………………………..… 6
5b. Periostracum microsculpture not as described above, but may be punctate
……………………………………………………………..… 7

6a. Periostracum microsculpture a mesh of oval pits; shell higher than long
…………………………………………….… ***Astarte elliptica***
6b. Periostracum microsculpture of randomly placed circular pits; shell height equal to length
…………………………………………...… ***Astarte montagui***

7a. Periostracum microsculpture punctate, may also consist of wrinkles
……………………………………………………………..… 8

7b. Periostracum microsculpture with wrinkles, but not punctate ……………………………………………….….… ***Astarte crenata***

8a. Periostracum microsculpture with wrinkles; ventral margin often crenulated
……………………………………………..… ***Astarte crebricostata***
8b. Periostracum microsculpture not with wrinkles; ventral margin smooth
……………………………………………...… ***Astarte acuticostata***

Based on earlier experiences with problems of distinguish *Macoma calcarea* and *Limecola balthica*, I decided to study these two species closer. Both species are common around the Norwegian coast (NBICb), and they are both tellinids (Fam. Tellinidae) (Horton et al., 2019). They have an external ligament, and fine commarginal ridges making the surface of the discs appear almost completely smooth. *Limecola balthica* are often bright pink and are then very unlikely to be mistaken for any other species. The problem arises in white specimens of this species, due to their similarity in other characters with *M. calcarea* who are always white. Literature search as well as the studying of specimens from the collection at NTNU University Museum, led to the realization that if you look closely at the right character, in this case the pallial sinus, they are not so hard to distinguish after all (Figure 11).

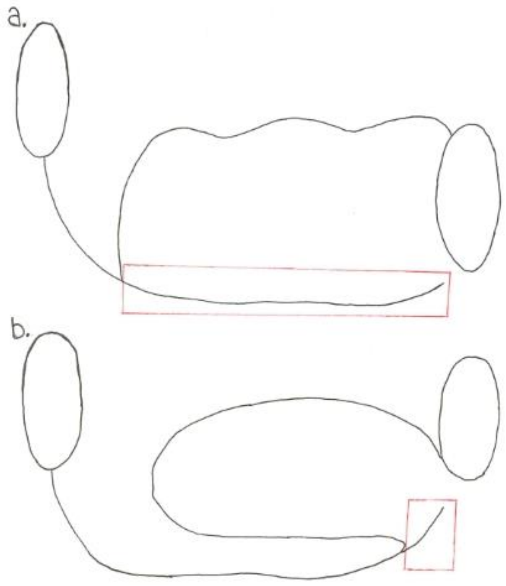

Figure 11. The pallial sinus of the right valve of two species of tellinids (Fam. Tellinidae), (a) *Limecola balthica* and (b) *Macoma calcarea*. Drawing: Nathalie Skahjem.

The family Veneridae are found in Norway with 18 species, 4 of whom are very similarly looking even though they belong to 3 different genera, *Polititapes*, *Ruditapes* and *Venerupis*. A specimen can be recognized as belonging to one of these 5 species, by three cardinal teeth in both valves (Figure 12). The species were studied in the lab, and together with identification literature (see material and methods) a preliminary identification key was made to these 4 species (Key 2).

Figure 12. The cardinal teeth of *Polititapes, Ruditapes* and *Venerupis*. Right valve of *Venerupis corrugata* shown. NB. The anterior tooth (the one farthest to the left) on this specimen is partly broken. Photo: Andreas Zsoldos, Nathalie Skahjem.

Key 2. A key to 4 species of venerids (Fam. Veneridae) found in Norwegian waters, belonging to *Polititapes, Ruditapes* and *Venerupis*.

1a. Commarginal ridges only ……………………………………..… ***Polititapes rhomboides***
1b. Commarginal ridges and at least some radiating sculpture ……………………………………………………………..… 2

2a. Commarginal ridges well developed; weak radiating ribs randomly placed over the disc; pallial sinus not confluent ……………………………………………..… ***Polititapes aureus***
2b. Commarginal ridges and radiating ribs equally developed; if radiating ribs weak, then pallial sinus confluent ……………………………………………………………..… 3

3a. Pallial sinus confluent; radiating ribs may be weak ……………………………………………..… ***Venerupis corrugata***
3b. Pallial sinus not confluent …………………………………………..… ***Ruditapes decussatus***

The identification key to Pectinidae (Key 3) includes all 12 species found in Norwegian waters and can be used on both juveniles and adults. It should be noted that some species appear more than once in the key, due to the existence of subspecies (*Mimachlamys varia nivea*) or mainly, due to a large difference between adults and juveniles. The key is only complete for Norway, but may be used as an aid in pectinid identification in the other Nordic countries as well. For the best result, the key should be used together with the descriptions and pictures below.

Key 3. A key to the 12 species of Pectinidae found in Norwegian waters.

1a. Right valve convex, with 15-18 radiating ribs; left valve flat or concave
………………………………………….… ***Pecten maximus***
1b. Both valves equally convex
……………………………………………………………… 2

2a. Shell shape distorted (Figure 13)
…………………………………..… **adult *Talochlamys pusio***
2b. Shell shape regular; not distorted
……………………………………………….…………..… 3


Figure 13

3a. Macrosculpture of radiating ribs or commarginal ridges
…………………………………………………………..… 4
3b. Macrosculpture smooth; may have vesicles
……………………………………………..………..….. 12

4a. Commarginal ridges
………………………………………… ***Hyalopecten frigidus***
4b. Radiating ribs
……………………………………………...………….… 5

5a. Both primary and secondary ribs, clearly distinguished
…………………………………………………...…….… 6
5b. Primary ribs only, or secondary ribs subequal to primary
…………………………………………………...……. 7

6a. Primary ribs clearly larger and more protruding than secondary; interspace diagonal lines (Figure 14) or rarely smooth
……………………………….……….… ***Karnekampia sulcata***
6b. Small difference between primary and secondary ribs; interspace overlapping downward pointing triangles (Figure 15) or rarely circles
……………………………….……..… ***Chlamys islandica***


Figure 14


Figure 15

7a. No more than 11 ribs
…………………………………...… ***Pseudamussium peslutrae***
7b. Number of ribs 19 or higher
……………………………………………………………… 8

8a. Umbo smooth
……………………………………….… ***Palliolum tigerinum***
8b. Umbo with ribs
……………………………………………………………… 9

9a. Ribs smooth or with densely spaced commarginal lines
…………………………………………………………..… 10
9b. At least some ribs with scales
…………………………………………………………..… 11

10a. Interspace same size as ribs; approximately 25-30 ribs

………………………………...… **juvenile *Mimachlamys varia***
10b. Interspace at least twice the size as ribs; approximately 19-25 ribs
……………………………………..… ***Aequipecten opercularis***

11a. Ribs with sharp, erect scales; primary ribs only
…………………………………… **adult *Mimachlamys varia***
11b. Ribs with downward facing scales, either flat or pointed; primary and secondary ribs
………………………………… **juvenile *Talochlamys pusio***

12a. Shell with vesicles, either both valves or left valve only (Figure 16 and 17)
……………………………………………………………. 13
12b. Shell without vesicles
…………………………………………………………..… 14

Figure 16

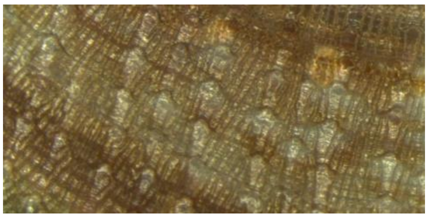

Figure 17

13a. Both left and right valve with vesicles; hyaline or white with brown periostracum
……………………………………...… ***Delectopecten vitreus***

13b. Left valve with vesicles; right valve normally smooth; multicolored (background may be hyaline)

…………………………………….… ***Palliolum striatum***

14a. Microsculpture straight radiating grooves with densely spaced nodules (Figure 18)
…………………………………… ***Palliolum incomparabile***
14b. Microsculpture not as above
…………………………………………………………..… 15

Figure 18

15a. Hyaline or white with brown periostracum; auricles on left valve without radiating ribs
……………………………………...… ***Delectopecten vitreus***

15b. Multicolored; auricles on left valve with 2-3 radiating ribs
…………………………………………. ***Palliolum tigerinum***

Phylum Mollusca
Class Bivalvia Linnaeus, 1758
Subclass Pteriomorphia Beurlen, 1944
Order Pectinida Gray, 1854
Superfamily Pectinoidea Rafinesque, 1815
Family Pectinidae Rafinesque, 1815
Subfamily Pectininae Rafinesque, 1815
Tribe Pectinini Rafinesque, 1815
Genus *Pecten* O. F. Müller, 1776

Pecten maximus (Linnaeus, 1758)

Figure 19

Ostrea maxima Linnaeus (1758:696 [original description]).
Pecten vulgaris da Costa (1778: 140-143, pl. 9 fig. 3).

Description. Shell solid, up to 130 mm long and 113 mm high, subcircular. Inequivalve, upper left valve (LV) compressed into lower right valve (RV) in juveniles, LV flat and RV convex in adults. LV pink or red, often with white or red spots; umbo white or reddish-pink. RV white or yellowish; umbo white, yellowish-white or pink. Equilateral, ears equal in size. All ears with densely spaced commarginal lines. Right anterior auricle also with radiating ribs; small byssal notch; ctenolium not visible. Right posterior auricle with weak radiating ribs; smooth with radiating grooves in juveniles. Left anterior auricle may have radiating ribs. Umbo smooth, RV might have radiating ribs; LV umbo concave, RV umbo convex; beak not protruding over dorsal margin. Ventral margin crenulated. Dorsal margin straight. Commarginal growth stages visible on both valves. Primary ribs only; (14)16-17 on LV, 15-18 on RV; ribs <4 mm LV, <6 mm RV; ribs clearly protruding, more so on RV where the ribs are rounded as opposed to flattened on LV. Microsculpture same on both valves; smooth ribs with radiating grooves in juveniles, ribs with smaller riblets (4-5 LV; 7-8 RV) in adults; interspace LV with many densely spaced commarginal lines, in adults these lines are also present on the ribs, RV with less visible commarginal lines and 5-7 smaller riblets like the ones on the ribs. These smaller riblets may also be present (2-4) on LV interspace. Interspace up to 6 mm both valves.

Etymology. Lat. pecten, noun = comb, gender masculine. Lat. maximus, adjective [sup of magnus] = greatest.

Ecology. Live in soft sediments like sand, mud, fine or sandy gravel, muddy sand and coarse sand (Oliver, 2016, Marshall et al., 2008). Prefer habitats with moderate currents and narrow sounds; 10-200 m deep (Oliver, 2016), normally 15-35 m (Moen and Svensen, 2004); recessing life habit (Marshall et al., 2008).

Distribution. The North East Atlantic coast, from northern Norway south to the Iberian Peninsula (Oliver, 2016, Marshall et al., 2008, Moen and Svensen, 2004). West Africa, the Azores, the Canary Islands, Madeira (Marshall et al., 2008).

Remarks. *Pecten maximus* is easily recognized by the flatness of the left valve, even juveniles are hard to mistake for other species in Norwegian waters. It is therefore still easy to identify this species when only LV is present. If only RV is present the species can be easily recognized by the number of ribs and the ribs microsculpture, as well as the very convex shape of the disc. The most similar-looking species to *P. maximus* is *Pecten jacobaeus* (Linnaeus, 1758), the only other European species of *Pecten* (Ghys-a). These two have been considered different species since Linnaeus described them, due to some small morphological differences. *Pecten jacobaeus* has somewhat sharp ribs on RV, while the ribs on *P. maximus* are rounded (Ríos et al., 2002). Even though these differences should make it possible to confuse them with each other, a misidentification is very unlikely to happen in Norway since *P. jacobaeus* is endemic to the Mediterranean (Peña et al., 1996, Shumway and Parsons, 2016, Ríos et al., 2002). In a study of 868 specimens (Ríos et al., 2002) these two species were studied from four localities in the Atlantic and Mediterranean Ocean. No intermediate morphological forms were found, and the species were in this study distinguished based on the number of ribs on RV and the microsculpture: 14-16 ribs with many riblets in *P. maximus* and 16-18 ribs with 4 distinct riblets on each rib (Ríos et al., 2002). Compared to my observations, the number of ribs does not seem like a good character to distinguish the two species. The number of smaller riblets, on the other hand, seems to be a better character with no overlap as I observed RV in *P. maximus* to have 7-8 of these riblets pr. main rib.

Material examined. 6 specimens were examined from the Trondheimsfjord, the Herøyfjord and Vatlestraumen outside Bergen. Specimens collected at depths from ~21-54 meters (Appendix III).

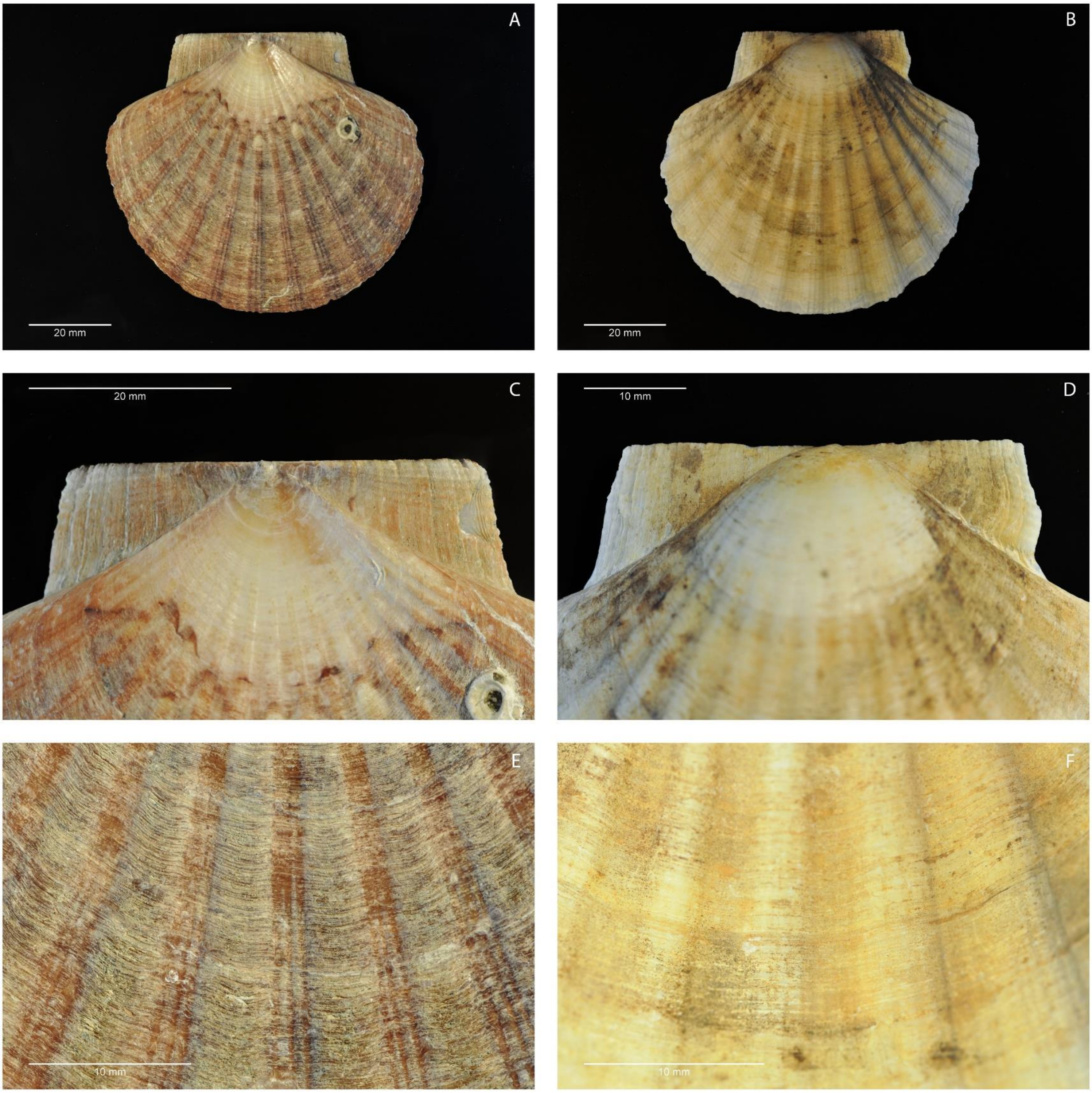

Figure 19. *Pecten maximus.* **A** left valve (LV) **B** right valve (RV) **C** auricles of LV **D** auricles of RV **E** microsculpture of LV **F** microsculpture of RV. Pictures of NTNU-VM-71789.

Subfamily Pectininae Rafinesque, 1815

Tribe Aequipectinini F. Nordsieck, 1969

Genus *Aequipecten* P. Fischer, 1886

Aequipecten opercularis (Linnaeus, 1758)

Figure 20

Ostrea opercularis Linnaeus (1758:698 [original description]).

Chlamys opercularis Linnaeus (1758:698); Bryan (1973:145).

Pecten opercularis Linnaeus (1758:698); Amirthalingam (1928:605).

Aequipecten heliacus Dall (1925); Holmes et al. (2015:4-5, Fig. 4).

Description. Shell solid, up to 43 mm long and 45 mm high subcircular. Equivalve except anterior ear. Almost flat. LV different shades of red, often with patches. RV like LV or white. Equilateral, ears subequal in size. All ears with densely spaced commarginal lines and radiating ribs: all auricles except right anterior have an interspace like the rest of the shell and may have spines on the ribs; byssal notch up to 5 mm; ctenolium well developed, up to 6 mm. The number of radiating ribs differs somewhat between the four auricles. Right anterior auricle with 6-8 ridges, left anterior with 4-11, right posterior with 5-10 and left posterior with 6-9. The ribs on right anterior auricle are badly developed in juveniles, while the ones on left anterior auricle can be badly developed even in adults. Umbo with radiating ribs although beak may be smooth on RV; beak protruding over dorsal margin on LV, not on RV. Ribs protruding over ventral margin. Dorsal margin uneven; right anterior auricle visible from LV, commarginal ridges protruding over margin on RV. Growth stages visible on both valves. Both valves with only primary ribs, protruding and often with a keel in the middle; ribs placed evenly making the appearance well-ordered. Both vales normally with 21-24 ribs; LV may have 19-25, RV 19-24; ribs 1-3 mm in diameter. Microsculpture same on both valves; ribs smooth normally with scales on each side. Interspace same on both valves, although weaker and often confined to the posterior and anteroventral parts on RV; commarginal ridges looking like cracks in adults, radiating grooves with a slight outward curve in juveniles (Figure 20E); interspace appears spiny when the shell is beginning to develop ridges; interspace smooth in some specimens. In some specimens the cracks in the interspace extends onto the ribs. Interspace ~ 0.5 mm.

Etymology. Aequipecten meaning similar to pecten, from Lat. aequi, noun = equal footing/terms, gender neuter; Lat. pecten, noun = comb, gender masculine. Opercularis from Lat. operculum, noun = lid, gender neuter.

Ecology. Sand, fine gravelly substrate (Carter, 2008, Oliver, 2016, Moen and Svensen, 2004), shelly bottom (Oliver, 2016); often together with *Modiolus modiolus* (Carter, 2008); from between the tidemarks to

200 m (Carter, 2008, Oliver, 2016, Moen and Svensen, 2004); reclining life habit (Shumway and Parsons, 2016).

Distribution. North-eastern Atlantic, from South-Eastern Iceland to the Canary Islands and the Mediterranean Sea (Carter, 2008, Dijkstra et al., 2009, Moen and Svensen, 2004). In Norway north to Lofoten (Dijkstra et al., 2009). Faroes, Iberian Peninsula, Canaries, the Azores and the Mediterranean (Oliver, 2016).

Remarks. Some specimens were found with exceptions to the characters listed in the description. One specimen (NTNU-VM-72359) had a distorted shape on the right anterior auricle. Some juveniles were found to be distorted in disc shape, but not distorted like adult individuals of *Talochlamys pusio*. Juveniles may also have commarginal ridges all over the surface of the shell. A few adults were found with a different microsculpture on LV: both interspace and ribs with smaller spiny riblets. Juveniles may be confused with juvenile *Mimachlamys varia* and *Talochlamys pusio* from Norwegian waters, but can be distinguished based on the ribs. *T. pusio* have both primary and secondary ribs, while the other two only have primary ribs, all approximately equal in size. To separate *A. opercularis* and *M. varia* when juvenile, if *M. varia* does not yet have developed spines, look at interspace which is smooth or with commarginal ridges in *M. varia* and radiating grooves in juvenile *A. opercularis*. The number of ribs also varies, with 19-25 on *A. opercularis* and 25-30 on *M. varia*. The auricles on *A. opercularis* are equal in size, while anterior auricle on *M. varia* is about 10 mm longer than posterior. It is recommended to look at all these characters when in possession of a juvenile specimen that might be either one of these two species. A similar species, *A. commutatus commutatus* is found in Southern Europe and Africa (Ghys-c). In addition to the non-overlapping distribution with *A. opercularis*, these species are not likely to be confused with each other as *A. opercularis* is almost flat, while *A. commutatus commutatus* is clearly tumid as both valves are convex (Ghys-c).

Material examined. 21 specimens were examined from the Nunfjord, the Hemnefjord, and Storegrunnen and Bessholmen in Trøndelag. Specimens collected at depths from ~14-97 meters (Appendix III).

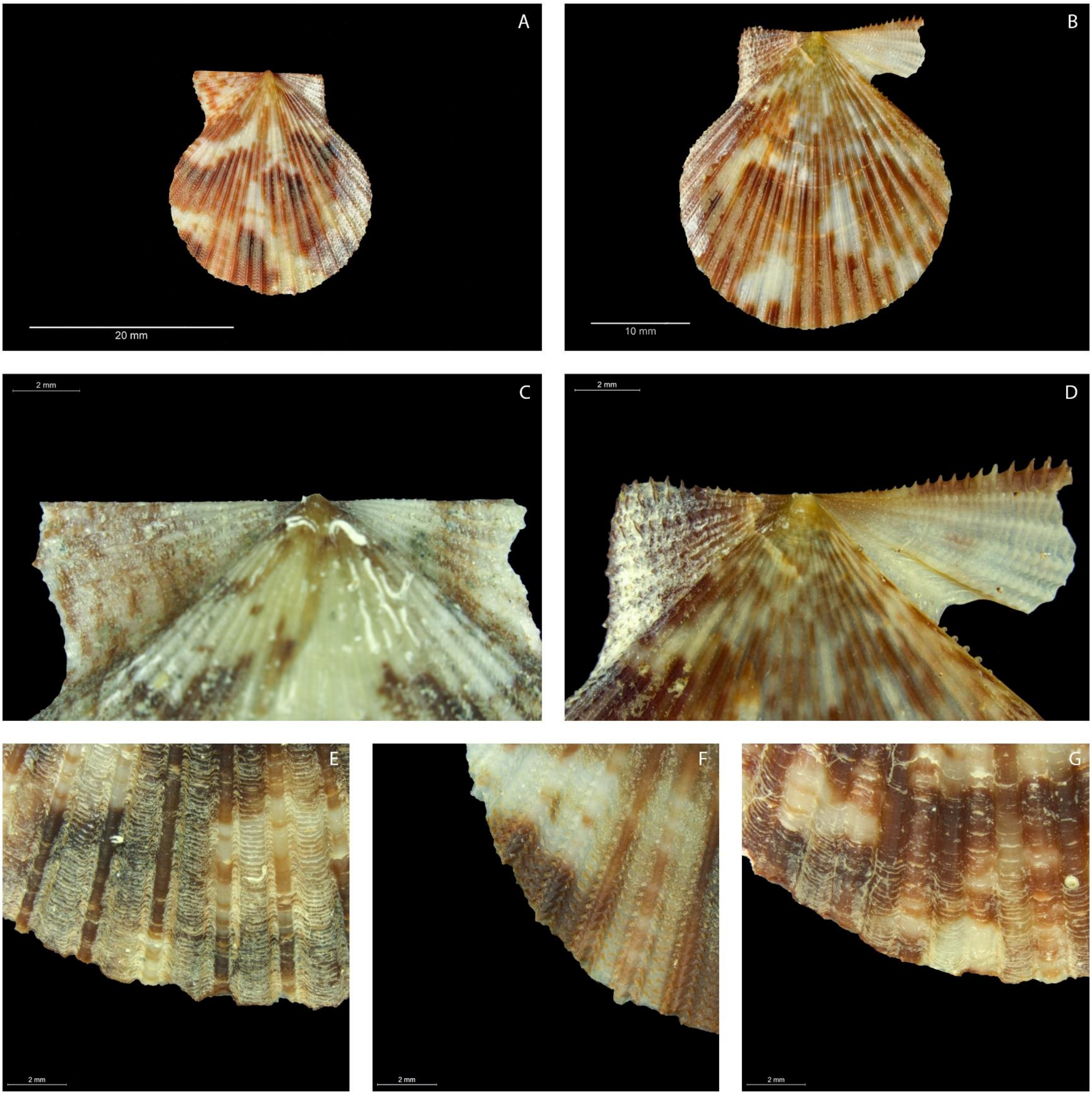

Figure 21. *Aequipecten opercularis*. **A** left valve (LV) **B** right valve (RV) **C** auricles of LV **D** auricles of RV **E** microsculpture of LV **F** alternative microsculpture of LV **G** microsculpture of RV. Pictures of NTNU-VM-71780 (A, B, D, E), NTNU-VM-64622 (F, G) and NTNU-VM-5355 (C).

Subfamily Camptonectinae Habe, 1977

Genus *Delectopecten* Stewart, 1930

Delectopecten vitreus (Gmelin, 1791)

Figure 22

Ostrea vitrea Gmelin (1791:3328 [original description]).
Chlamys papyracea Röding (1798:164, fig. 637).
Cyclopecten vitreus Gmelin (1791: 3328); Grau (1959:47, pl. 18).
Pecten vitreus Gmelin (1791: 3328); Rosenberg et al. (1996:181).

Description. Shell fragile, up to 23 mm long and 25 mm high, circular. Almost flat. Both valves hyaline, although some may be white; periostracum brown. Inequilateral, posterior auricle only slightly demarcated from disc, ears subequal in length. Right anterior auricle with commarginal ridges that become sharper and more protruding in adults and 3-5 radiating ribs with nodules that become evenly distributed when the shell is around 20 mm long; in some the lowest rib is clearly more protruding than the rest; byssal notch up to 5 mm; ctenolium well developed, up to 8 mm. All other auricles with sculpture from disc gliding into the auricles. In addition, both auricles on LV with ~4 commarginal ridges. Umbo smooth; beak not protruding over dorsal margin except LV in juveniles. Ventral margin smooth. Dorsal margin straight. Growth stages visible on both valves. Macro- and microsculpture same on both valves; disc smooth or with vesicles; vesicles placed randomly or organized in commarginal ridges; microsculpture consisting of thin radiating grooves half the size of the distance between them, the lines are evenly or unevenly ordered (Figure 22F).

Etymology. Lat. delecto, verb = charm, delight. Lat. pecten, noun = comb, gender masculine. Lat. vitreus, adjective = of glass.

Ecology. Hard substrate (Oliver, 2016); often associated with deep water corals (Oliver, 2016, Negri and Corselli, 2016); current-swept bottom (Negri and Corselli, 2016); continental shelf to over 4000 m, commonly 30-600 m (Oliver, 2016, Negri and Corselli, 2016), 50-1000 m in Scandinavia (Negri and Corselli, 2016); life habit byssal attachment (Oliver, 2016).

Distribution. Cosmopolitan (Negri and Corselli, 2016). Found all along the Western continental margin (Oliver, 2016). Atlantic Ocean, northern Norway to Antarctica (Negri and Corselli, 2016).

Remarks. Two juveniles and some adults were found to have microsculpture in the form of radiating grooves on umbo, but macrosculpture on umbo was still smooth. *Delectopecten vitreus* can at first be confused with species belonging to the family Propeamussiidae, but are easily distinguished from them by the presence of ctenolium (only present in Pectinidae). Specimens without vesicles can be confused with hyaline specimens of *Palliolum incomparabile*. These two species can then be separated by looking at the right anterior auricle: both species have radiating ribs on said auricle, but the ribs on *Delectopecten vitreus* have nodules.

Material examined. 21 specimens were examined from the Høgsfjord, Rødberg in the Trondheimsfjord, and Malangsdjupet in Troms. Specimens collected at depths from ~250-1255 meters (Appendix III).

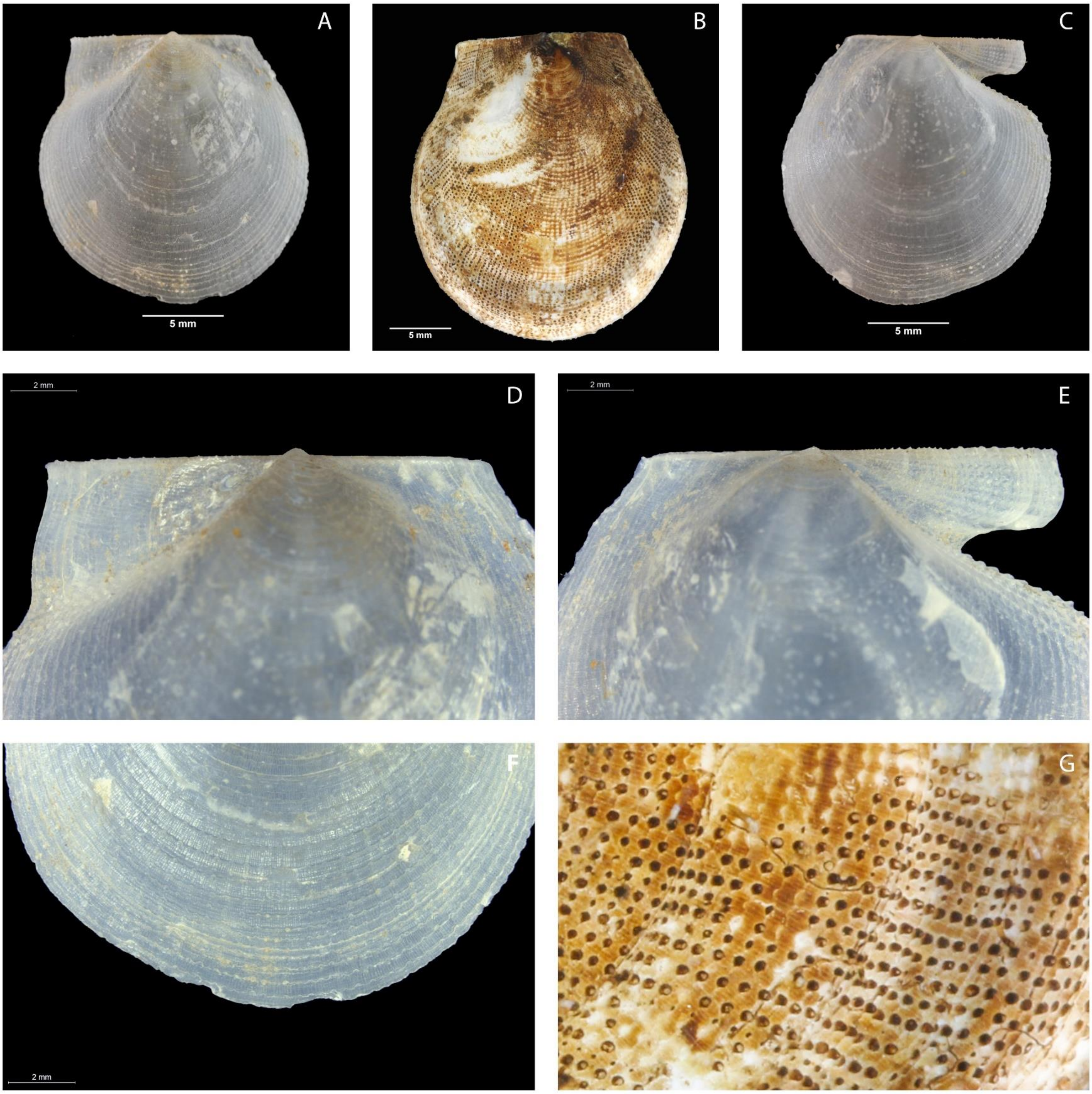

Figure 22. *Delectopecten vitreus.* **A** left valve (LV) **B** left valve (LV) with nodules **C** right valve (RV) **D** auricles of LV **E** auricles of RV **F** microsculpture of LV **F** microsculpture **G** microsculpture (close-up of B). Pictures of NTNU-VM-64628 (A, C, D, E, F) and HB2017-05-32 AG (B, G).

Subfamily Camptonectinae Habe, 1977

Genus *Hyalopecten* Verrill, 1897

Hyalopecten frigidus (Jensen, 1904)

Figure 23

Pecten frigidus Jensen (1904:305, fig. 306 [original description]).

Description. Shell thin, fragile, up to 18 mm long and 22 mm high, subcircular/oval. Almost flat. Both valves hyaline. Equilateral, ears equal in size. Right anterior auricle with ~8 commarginal ridges, with nodules placed randomly or in rows; some also with ~3 radiating ribs; byssal notch up to 2 mm; ctenolium visible, but not well developed. Right posterior auricle smooth or with commarginal ridges. LV with auricles equal in both size and sculpture: either smooth or with weak commarginal ridges; anterior auricle may also have radiating grooves. Umbo same sculpture as rest of disc; beak smooth both valves, protruding over dorsal margin on LV. Ventral margin smooth. Dorsal margin straight, but LV beak is visible over margin on RV. Macrosculpture of commarginal undulations; normally 14 or 16 on LV and 11 on RV; LV may have 11-17, RV 9-14. Microsculpture of fine radiating grooves, more developed on LV as some RV appear completely smooth: each line separated by up to 0.5 mm punctate interspace (Figure x); lines half the size of interspace.

Etymology. Hyalopecten meaning glass pecten, from Lat. hyalus, noun = glass, gender masculine; Lat. pecten, noun = comb, gender masculine. Lat. frigidus, adjective = cold, indifferent.

Ecology. Hard substrate, stones, dead shells (Oliver, 2016, Dijkstra et al., 2009); 500-4000 m (Oliver, 2016, Dijkstra et al., 2009)

Distribution. Arctic, Subarctic, north of the Scotland - Greenland Ridge (Oliver, 2016, Dijkstra et al., 2009). Norwegian basin (Boughet and Warén, 1979).

Remarks. As *Delectopecten vitreus*, *Hyalopecten frigidus* may be mistaken as belonging to Propeamussiidae. Again, the ctenolium is the best character to tell if a specimen belongs to Propeamussiidae or Pectinidae. Some of the dead fragments studied from material collected at Jan Mayen were around 2 mm in length. These specimens had not yet developed the typical commarginal undulations seen in *H. frigidus*, but had commarginal ridges looking like they were about to develop into undulations. There is one similar looking species, *Hyalopecten pudicus*, living in the North-East Atlantic south of the Scotland – Greenland Ridge (Oliver, 2016). They can be distinguished by *H. pudicus* having thin radiating ribs that are clearly developed as macrosculpture (Oliver, 2016) compared to the weak radiating grooves as microsculpture in *H. frigidus*.

Material examined. 3 specimens were studied at the University Museum of Bergen, but unfortunately I do not have access to the details about the collection of these individuals. 9 specimens were examined at NTNU University Museum, collected in Iceland at ~3006 meters (Appendix III). In addition, dead fragments collected at Jan Mayen in 2016 was studied.

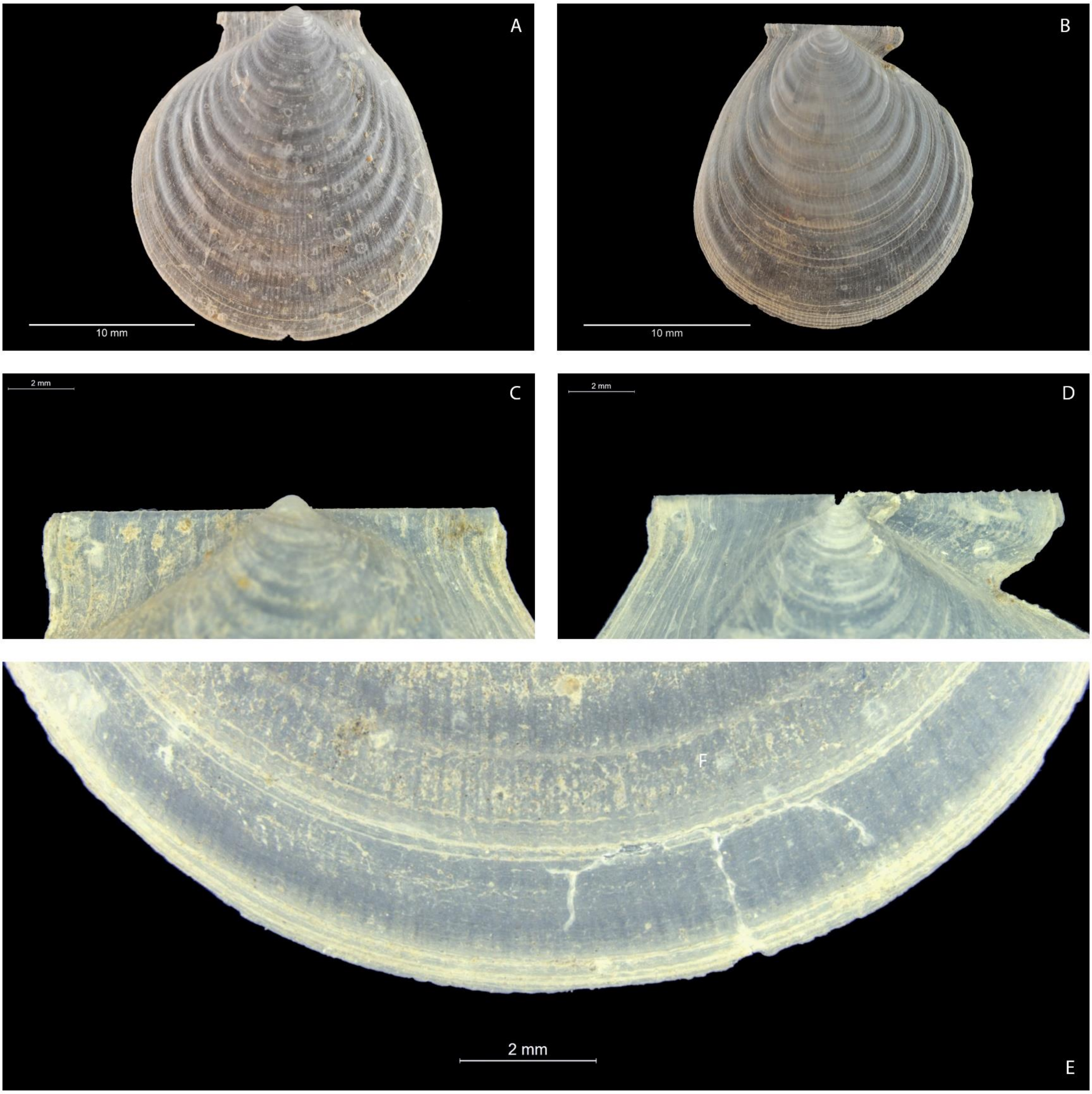

Figure 23. *Hyalopecten frigidus.* **A** left valve (LV) **B** right valve (RV) **C** auricles of LV **D** auricles of RV **E** microsculpture. Pictures of NTNU-VM-67988.

Subfamily Palliolinae Korobkov, 1960

Tribe Palliolini Korobkov, 1960

Genus *Pseudamussium* Mörch, 1853

***Pseudamussium peslutrae* (Linnaeus, 1771)**

Figure 24, 25

Ostrea peslutrae Linnaeus (1771:547 [original description]).
Pecten danicus Reeve (1852)
Pecten septemradiatus Müller O.F. (1776:248); Nydal (1977: 345).
Pseudamussium septemradiatum Müller O.F. (1776); Taviani et al. (1991:332).

Description. Shell solid, up to 42 mm long and 44 mm high, thickness up to 6 mm, subcircular. Inequivalve. LV often reddish-orange, but the color varies greatly between different mixes of yellow, brown, orange, red and white. RV mostly white, may have pink or red patches; may be different shades of orange and red with hints of brown and pink; if white, umbo often pink. Both valves often with brown periostracum visible between ribs. Inequilateral, anterior auricle slightly longer than posterior. Right anterior auricle with 3-6 protruding radiating ribs, and densely spaced commarginal ridges; byssal notch up to 3 mm; ctenolium not well developed, although some have a clearly visible ctenolium up to 8 mm. Left anterior auricle with 3-5 clearly protruding radiating ribs, and densely spaced commarginal ridges. Posterior auricles, both LV and RV, either (i) smooth, (ii) with densely spaced commarginal ridges, (iii) with weak protruding radiating ribs or (iv) with weak radiating ribs and commarginal ridges; (ii) is most common. Right posterior auricle also has radiating grooves as interspace. Umbo with radiating ribs; LV umbo smooth in juveniles; beak protruding over dorsal margin on LV. Ventral margin wavy due to the ribs; smooth. Dorsal margin uneven; right anterior auricle visible from LV, commarginal ridges protruding over margin on RV. Both valves with undulating radial ribs up to 3 mm in diameter, commonly 5-7 on each valve; LV may have 5-12 keeled pointed ribs, keels with or without nodules; RV may have 5-15 rounded ribs. Microsculpture similar on both valves, although weaker on RV; varies between individuals: (i) 2-7 smaller ribs on top of the main ribs, if more than 3 smaller ribs the one in the middle is clearly larger than the rest, (ii) densely spaced commarginal ridges and/or tiny radial lines, or (iii) smooth. (i) and (ii) may occur together. Interspace varies, but similar on both valves: (i) thin radial lines, (ii) densely spaced commarginal ridges, or (iii) smooth. Interspace up to 5 mm.

Etymology. Pseudamussium from Greek pseudḗs, adjective = false/fake, gender masculine; amussium from Greek amousía, noun = without harmony, unmusical, gender feminine. Peslutrae meaning otter-like foot from Lat. pes, noun = foot, gender masculine; lutrae derived from *Lutra lutra*, the Latin name for otter.

Ecology. Soft substrate like sand and gravel (Moen and Svensen, 2004), fine sediments (Dijkstra et al., 2009), muddy mixed sediment (Negri and Corselli, 2016, Oliver, 2016); continental shelf to 600 (939) m (Moen and Svensen, 2004, Oliver, 2016, Dijkstra et al., 2009), normally 50-500 m (Dijkstra et al., 2009);

Distribution. Widespread from Western Africa to Northern Norway (Moen and Svensen, 2004, Negri and Corselli, 2016). North Sea (Negri and Corselli, 2016). Alboran basin in the Mediterranean (Negri and Corselli, 2016). West coast of Scotland and coast of Northumberland and Durham (Moen and Svensen, 2004). Eastern Atlantic, the whole Norwegian coast to the western Mediterranean (Dijkstra et al., 2009).

Remarks. Some specimens were observed to have interspace and umbo consisting of a mesh of oval pits. A few specimens have nodules antero- and posterodorsally on the disc as well as on the smaller ribs on both interspace and the main ribs. Juveniles in this description is referred to as specimens less than 9 mm in length. Microsculpture on the ribs are almost always smooth in juveniles. Depending on the size of the juvenile, it might be possible to observe the beginning of the development of the smaller ribs seen in many adults. Among the species found in Norwegian waters, it is very unlikely to mistake *Pseudamussium peslutrae* for another species. There are, however, some species in other parts of Europe that may be confused with *P. peslutrae*. *Pseudamussium clavatum*, distributed in Southern Europe (Horton et al., 2019) are easiest distinguished from *P. peslutrae* by its crenulated ventral margin (Ghys-d).

Material examined. 20 specimens were examined from the Høgsfjord, Tømmerdalen, Terningen and Kovsodden in Trøndelag, and Rebbenesøy in Troms. Specimens collected at depths from ~87-419 meters (Appendix III).

Figure 24. *Pseudamussium peslutrae*. **A** left valve (LV) **B** right valve (RV) **C** left valve (LV) **D** right valve (RV). Pictures of NTNU-VM-5280 (A, B) and HåkonMosbyMøre2005 (C, D).

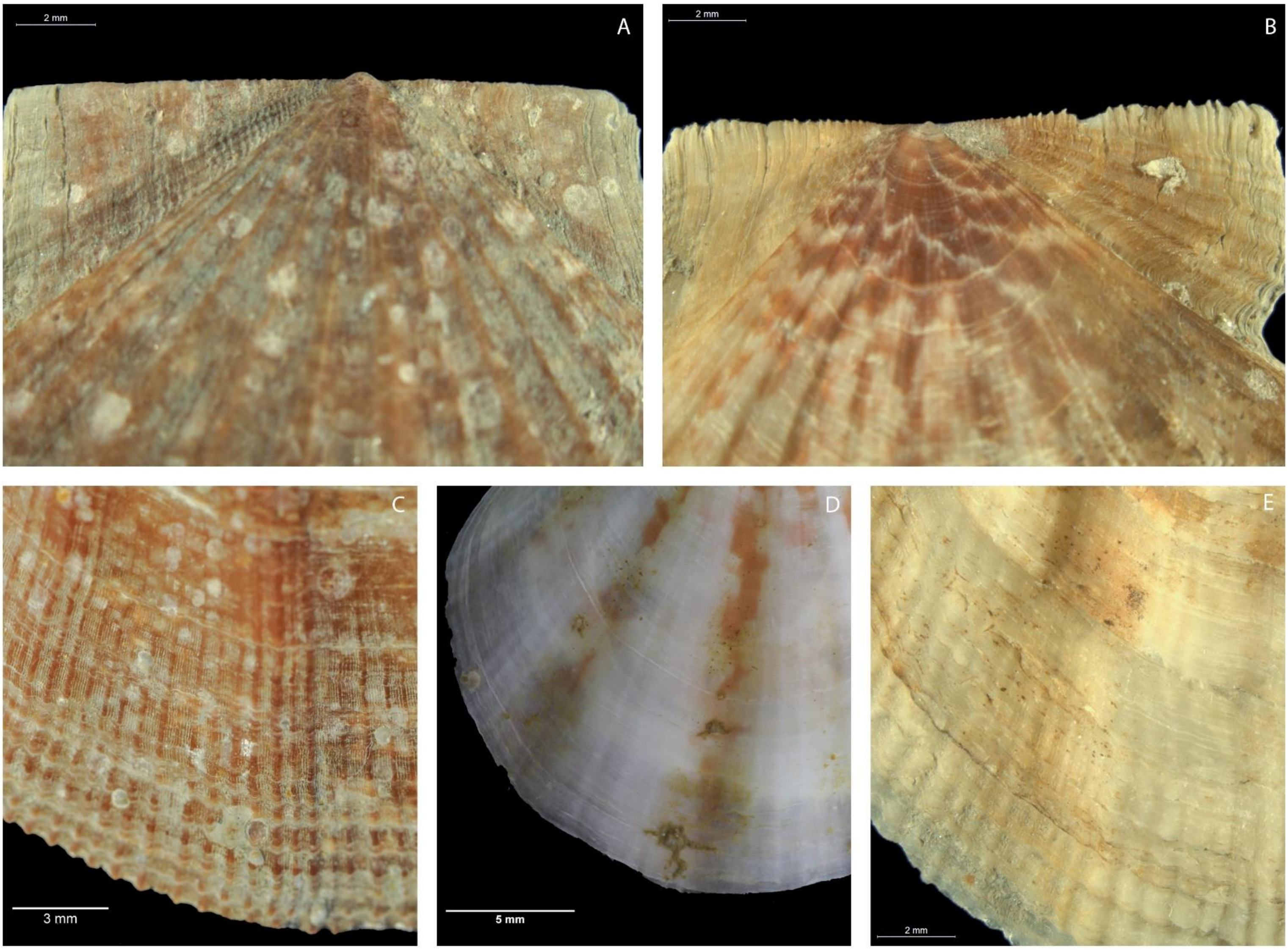

Figure 25. *Pseudamussium peslutrae.* **A** auricles of LV **B** auricles of RV **C** microsculpture of LV **D** microsculpture of RV. Pictures of NTNU-VM-5280 (A, B, C, E) and HåkonMosbyMøre2005 (D).

Subfamily Palliolinae Korobkov, 1960

Tribe Palliolini Korobkov, 1960

Genus *Karnekampia* H. P. Wagner, 1988

***Karnekampia sulcata* (Müller, 1776)**

Figure 26

Pecten sulcatus Müller O.F. (1776:248 [original description]).
Chlamys sulcata Müller O.F. (1776).
Pseudamussium sulcatum Müller O.F. (1776); Crocetta and Spanu (2008:63).

Description. Shell solid, up to 22 mm long and 24 mm high, subtrigonal/subcircular. Inequivalve. Almost flat. LV light pink with dark red commarginal bands, dark red, reddish-pink with various patterns, pale orange-pink, yellow-white or a ventrodorsally gradient from white to read. RV same colors as LV, but often brighter. Inequilateral, anterior auricle longer than posterior. Right anterior auricle with 3-5 radiating ribs with radiating grooves and/or nodules; commarginal lines densely spaced, protruding; interspace smooth or same as rest of the shell; byssal notch up to 4 mm; ctenolium well developed, up to 8 mm. Left anterior auricle with 2-7 radiating ribs; sculpture same as RV; microsculpture and interspace same as right anterior auricle; 9-18 protruding commarginal lines; either ribs or lines more developed than the other. Right posterior auricle with 2-4 protruding radiating ribs; microsculpture, interspace and commarginal lines as right anterior auricle. Left posterior auricle with 0-4 weak radiating ribs with nodules; the whole auricle might seem covered with nodules; weak commarginal lines; interspace smooth or with straight radiating grooves. Umbo with radiating ribs, smooth in juveniles and some adult RV, LV juvenile smooth with some visible growth stages; RV might have ribs only on half; beak smooth, not protruding over dorsal margin (except some RV juveniles). Ribs clearly protruding over ventral margin, especially on LV. Dorsal margin uneven; right anterior auricle visible from LV. Growth stages visible on both valves. LV with 38-59 radiating ribs; RV with 41-46, often separated in groups of 3-4. Primary ribs much larger and more protruding than secondary ribs, especially on LV; largest primary ribs ca. 1.5 mm. Anterior and posterior surface densely covered in nodules on both valves. Microsculpture same on both valves although often weaker or missing on RV; ribs with evenly spaced nodules; 4 specimens was observed to have flat scales pointing upwards, instead of nodules. Interspace LV consisting of diagonal wavy lines (Figure 26G); interspace divided into compartments separated by commarginal lines in specimens > 20 mm. Interspace RV same as LV, almost smooth or with wavy lines randomly placed (Figure 26H). Interspace difficult to measure on both valves; less than 0.5 mm.

Etymology. Genus named in honor of the dutch shell-enthusiast Mr. Cor Karnekamp. Lat. sulcatus, verb = cleave.

Ecology. Sand, mud (Negri and Corselli, 2016), rocks, gravel (Dijkstra et al., 2009) often associated with coral reefs, e.g. *Desmophyllum pertusum* (Moen and Svensen, 2004, Negri and Corselli, 2016, Oliver, 2016, Dijkstra et al., 2009); current-swept bottoms (Dijkstra et al., 2009) continental shelf to 2000 m (Oliver, 2016), normally in deep water (150 m and below) (Moen and Svensen, 2004).

Distribution. Iceland and northern Norway (Negri and Corselli, 2016, Oliver, 2016) to the Mediterranean (Moen and Svensen, 2004, Oliver, 2016, Dijkstra et al., 2009) and northwestern Africa and Cape Verde (Negri and Corselli, 2016, Oliver, 2016). Northern (Moen and Svensen, 2004) and eastern (Dijkstra et al., 2009) Atlantic. Found on *Desmophyllum* at 50 m in the Trondheimsfjord, Norway (Moen and Svensen, 2004). In Norway, north to Andfjorden (Dijkstra et al., 2009).

Remarks. May be difficult to see sculpture on left posterior auricle, and interspace on the discs. Easy to recognize due to the large difference between primary and secondary ribs, hard to mistake for anything else in Norwegian waters. Juvenile *Chlamys islandica* and juvenile *Karnekampia sulcata* can look similar to each other, but can be separated by looking at interspace sculpture: downward pointing overlapping triangles, or circles in *C. islandica* and wavy lines or smooth in *K. sulcata*. No European species found that look similar (Ghys-a).

Material examined. 30 specimens were examined from different locations in Trøndelag. Specimens collected at depths from ~104-381 meters (Appendix III).

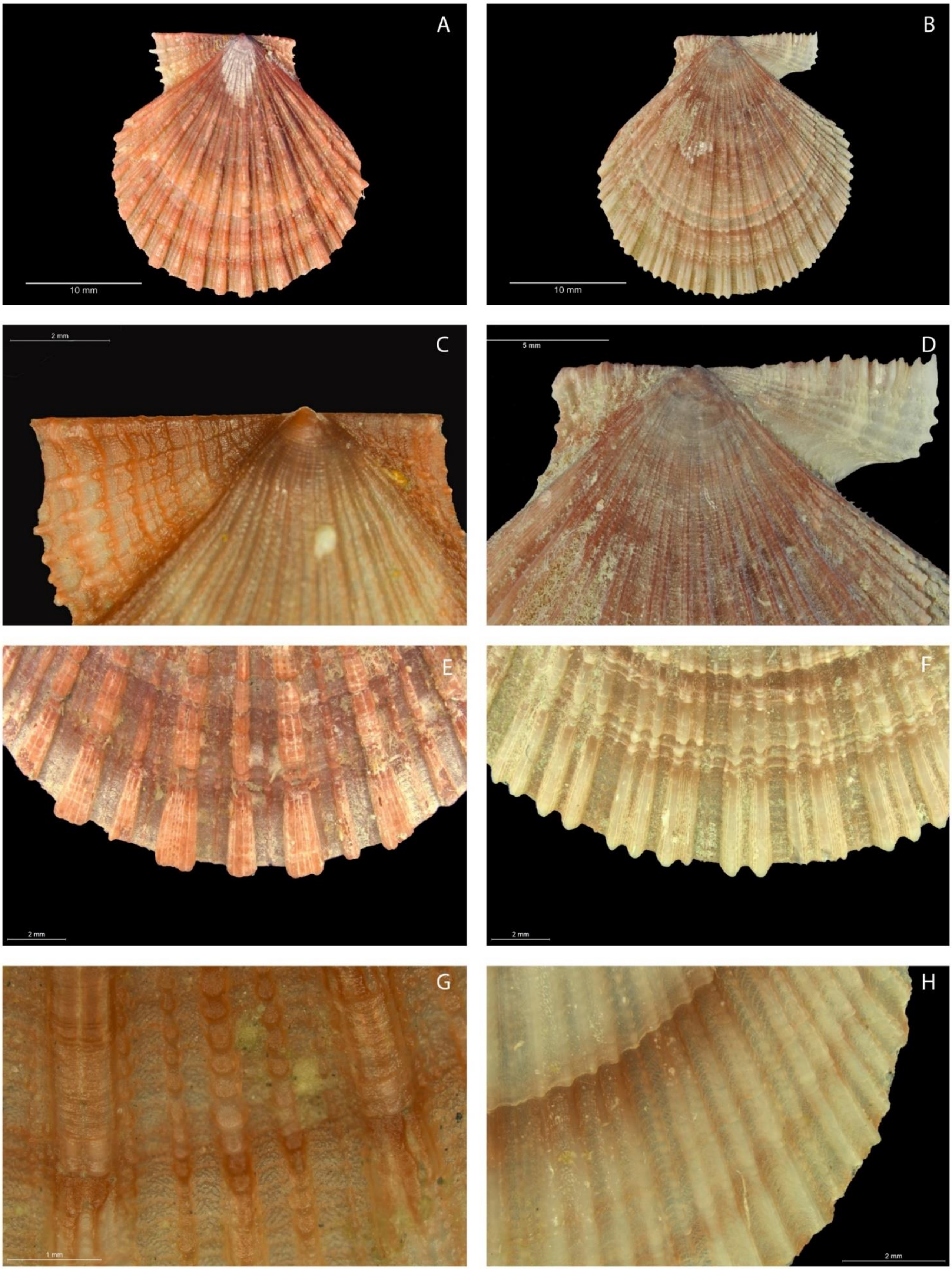

Figure 26. *Karnekampia sulcata.* **A** left valve (LV) **B** right valve (RV) **C** auricles of LV **D** auricles of RV **E** ribs LV **F** ribs RV **G** microsculpture and interspace LV **H** microsculpture and interspace RV. Pictures of NTNU-VM-5242 (A,B, D, E, F) and NTNU-VM-5353 (C, G, H).

Subfamily Palliolinae Korobkov, 1960

Tribe Palliolini Korobkov, 1960

Genus *Palliolum* Monterosato, 1884

Palliolum tigerinum (O. F. Müller, 1776)

Figure 27, 28

Pecten tigerinus Müller O.F. (1776:248 [original description]); Forbes and Godwin-Austen (1859:109). *Pecten triradiatus* Müller O.F. (1776: 248).

Description. Shell solid, up to 24 mm long, 25 mm high and 3 mm thick, subtrigonal/subcircular. LV and RV similar in color, although the number and placement of spots can vary between the two valves; very variable in color, often with spots, if not spots then commonly light purple or light yellow. Inequilateral, anterior auricle at least three times longer than posterior. All auricles with densely spaced commarginal ridges, although they can be poorly developed and thus difficult to see. Right anterior auricle with 3-6 radiating ribs; may be smooth if disc is smooth; byssal notch up to X mm; ctenolium XXX, up to X mm. Left anterior auricle with 3-5 radiating ribs and densely spaced radiating grooves; ribs may have spines if disc is smooth. Right posterior auricle with ~3 radiating ribs and densely spaced radiating grooves; may be smooth if disc is smooth. Left posterior auricle with 2-4 radiating ribs; interspace checkerboard pattern; some appears to have a rough surface and no clear sculpture is visible. Umbo same sculpture as rest of disc or smooth; if same as rest of disc, interspace is straight lines instead of diagonal; beak protruding over dorsal margin on LV. If disc has ribs, the ribs are protruding over ventral margin making it uneven; if disc is smooth ventral margin is smooth. Dorsal margin uneven; right anterior auricle visible from LV, commarginal ridges protruding over margin on RV. Growth stages visible on both valves. Sculpture same on both valves, two different variants: (i) disc smooth or (ii) disc with radiating ribs; LV with 38-52, RV with 38-54; ribs usually smooth, but may have thin radiating grooves or interspace pattern. Interspace LV (i) checkerboard pattern, (ii) different shades of lines (Figure x), (iii) diagonal grooves with nodules, or (iv) smooth. Interspace RV (i) same as LV, but weaker, (ii) diagonal grooves without nodules or (iii) smooth. If ribs, then interspace same size or half the size of ribs.

Etymology. Named after it’s tiger-like appearance.

Ecology. Coarse sediment (Oliver, 2016), rock, mud, sand (Dijkstra et al., 2009); intertidal to 400 m (Dijkstra et al., 2009, Oliver, 2016);

Distribution. Scarce or absent from the southern North Sea (Oliver, 2016). Mediterranean, Cape Verde, eastern Atlantic and all Norwegian coasts, absent from the White Sea (Dijkstra et al., 2009).

Remarks. Shiny periostracum observed in one specimen. One specimen observed with very different colors on the two valves: LV light pink with reddish-brown spots, RV yellow. One specimen observed to have broad almost wavy ribs around umbo. The three species of *Palliolum* in Norwegian waters, *Palliolum tigerinum*, *Palliolum striatum* and *Palliolum incomparabile*, can look very similar, especially when juvenile. There are however some exceptions to the difficulty of species identification. If *P. tigerinum* have radiating ribs, it can’t be mistaken for any of the other two as they never have ribs for macrosculpture. If LV of *P. striatum* is present, then the presence of vesicles will separate it from *P. incomparabile* and *P. tigerinum*. The problem arise if only RV is present or when confronted with a smooth specimen of *P. tigerinum*. Microsculpture seems then to be the best way to distinguish between them, although the microsculpture often are more visible on LV. *P. tigerinum* is smooth or with various forms of radiating grooves, but never vertical grooves with nodules as seen in *P. incomparabile*. The microsculpture of *P. striatum* is very similar to that of *P. tigerinum*. Dijkstra et al. (2009) also discuss the difference in microsculpture between these species, and says that the microsculpture of *P. tigerinum* is stronger compared to *P. striatum*. They also state that the height/length-ratio is greater in *P. tigerinum* than in the other two, as well as a more cancellate structure on the anterior auricles, meaning that it has both strong ribs and commarginal ridges. The latter fits with my observations, while the former wasn’t investigated in this study.

Material examined. 24 specimens were examined from different locations in Trøndelag, Hordaland, Troms, the Norwegian Sea and Svalbard. Specimens collected at depths from ~22-243 meters (Appendix III).

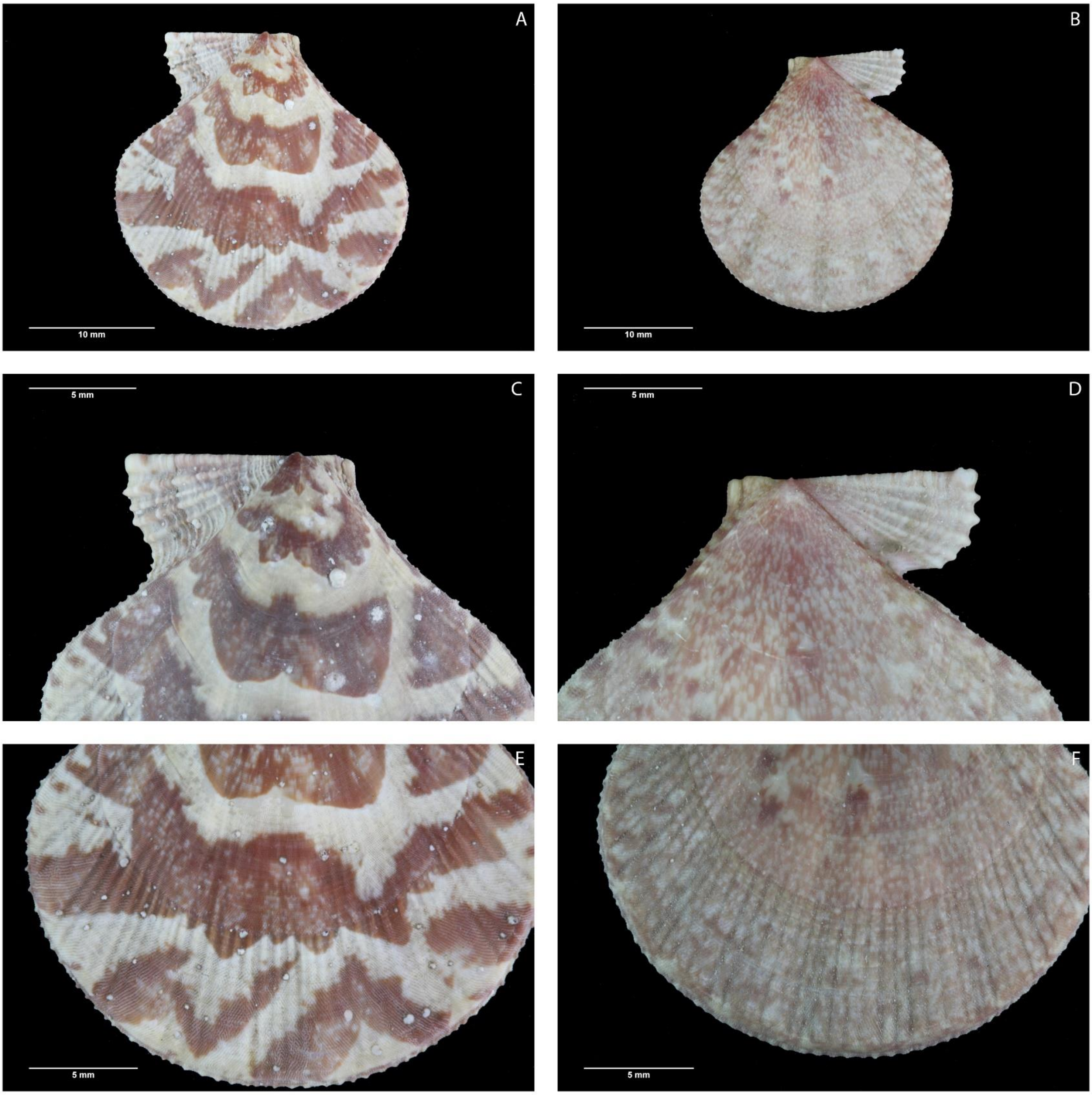

Figure 27. *Palliolum tigerinum.* **A** left valve (LV) **B** right valve (RV) **C** auricles of LV **D** auricles of RV **E** microsculpture of LV **F** microsculpture of RV. Pictures of NTNU-VM-46144.

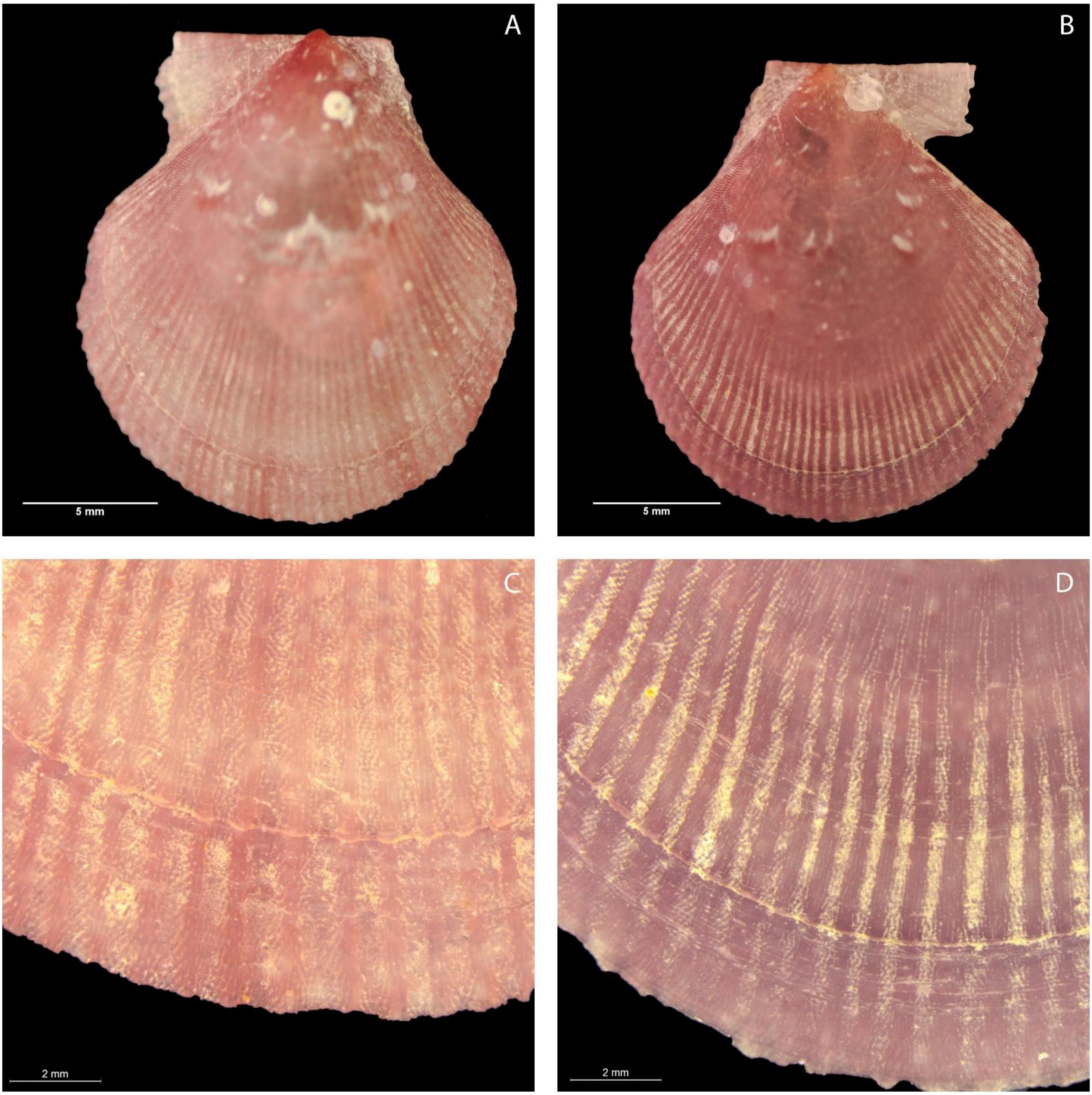

Figure 28. *Palliolum tigerinum.* **A** left valve (LV) **B** right valve (RV) **C** microsculpture of LV **D** microsculpture of RV. Pictures of NTNU-VM-5239.

Palliolum striatum **(O. F. Müller, 1776)**

Figure 29

Pecten striatus Müller O.F. (1776: 248 [original description]).
Camptonectes striatus Müller O.F. (1776:248); Panetta et al. (2006:204).
Chlamys striata Müller O.F. (1776:248); Shumway et al. (2016:42).

Description. Shell solid, up to 24 mm long and 25 mm high, subcircular. Almost flat. LV and RV similar in color: hyaline or white with stripes or spots in different shades of orange, red and white; disc may be reddish-brown. Inequilateral, anterior auricle approximately three times longer than posterior. Right anterior auricle 5-8 radiating ribs and commarginal ridges, both ribs and ridges either weak or strong; byssal notch up to 3 mm; ctenolium well developed, up to 5 mm. Left anterior auricle 5-6 weak radiating ribs, weak commarginal ridges and nodules; some have thin radiating grooves. Right posterior auricle thin radiating grooves; some with commarginal ridges. Left posterior auricle same as left anterior, except for the number of ribs (difficult to count posterior). Umbo smooth, RV with thin radiating grooves; beak weakly protruding over dorsal margin LV. Dorsal margin uneven; right anterior auricle visible from LV, commarginal ridges weakly protruding over margin RV, LV beak visible from RV. Ventral margin weakly uneven. LV with nodules making the surface rough; nodules covering all of disc, or only certain areas. RV normally smooth; three specimens observed with nodules. Microsculpture LV thin radiating grooves randomly placed, RV thin radiating grooves regularly placed (Figure x).

Etymology. Lat. striatus, verb = groove, striated.

Ecology. Coarse sediment (Oliver, 2016, Dijkstra et al., 2009), gravel, shells (Dijkstra et al., 2009); continental shelf to 500 m, most common 30-80 m (Oliver, 2016, Moen and Svensen, 2004); life habit byssally attached (Dijkstra et al., 2009).

Distribution. Widespread from the Mediterranean to northern Norway (Hammerfest) (Dijkstra et al., 2009, Moen and Svensen, 2004). North-west and north-east Atlantic (Dijkstra et al., 2009).

Remarks. One specimen right posterior auricle with ~3 radiating ribs, another specimen with a few nodules. The structures on the auricle are variable, not all individuals have all characters listed for each auricle in description. See remarks of *Palliolum tigerinum* for how to distinguish from other *Palliolum*.

Material examined. 9 specimens were examined from different locations in Trøndelag and Nordland. Specimens collected at depths from ~15-165 meters (Appendix III).

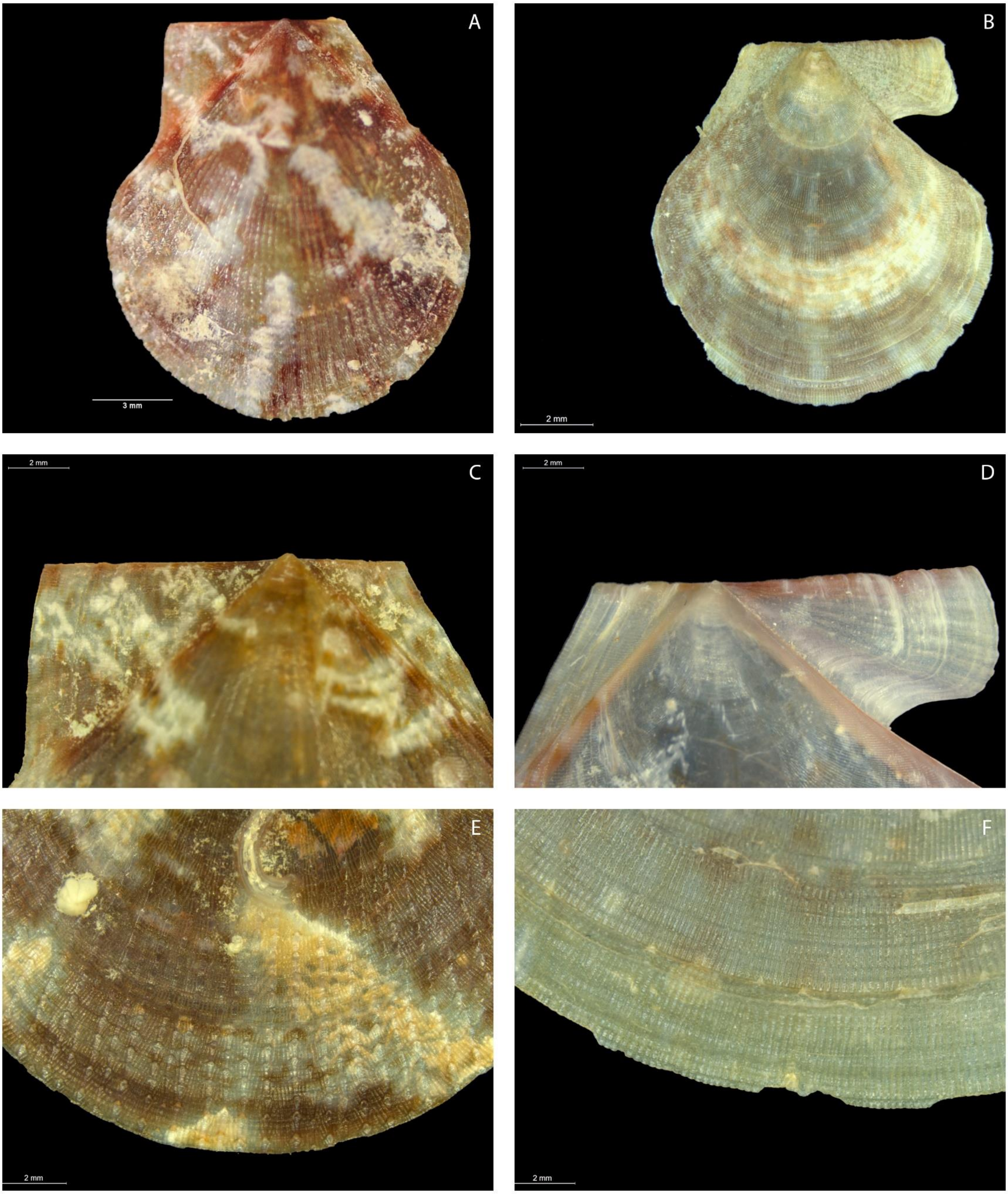

Figure 29. *Palliolum striatum.* **A** left valve (LV) **B** right valve (RV) **C** auricles of LV **D** auricles of RV **E** microsculpture of LV **F** microsculpture of RV. Pictures of NTNU-VM-64698 (A, B, F) and NTNU-VM-64682 (C, D, E).

Palliolum incomparabile (Risso, 1826)

Figure 30

Pecten incomparabilis Risso (1826 [original description]).

Chlamys furtiva Lovén (1846:31); Marčeta et al. (2016:81).

Palliolum furtivum Lovén (1846:31).

Pecten furtivus Lovén (1846:31); Møhlenberg and Riisgård (1979); Hily (1991).

Description. Shell thin, fragile, up to 20 mm long and 20 mm high, subcircular. Almost flat. LV and RV similar in color, reddish-orange, reddish-brown and white, lilac, pink, reddish-purple, white, reddish-brown; often with spots, patches or radiating rays. Inequilateral, anterior auricle approximately two times longer than posterior. Right anterior auricle with commarginal ridges weak or strong, 3-6 radiating ribs weak or strong; byssal notch up to 2 mm; ctenolium up to 4 mm. All other auricles with radiating grooves the disc and weak commarginal ridges. Umbo same microsculpture as rest of disc LV; umbo completely smooth RV; beak protruding over dorsal margin LV. Dorsal margin uneven; right anterior auricle visible from LV, commarginal ridges weakly protruding over margin RV, LV beak visible from RV. Ventral margin smooth. Growth stages visible on both valves. Macrosculpture smooth. Microsculpture same on both valves: radiating grooves with flat nodules (Figure x); more developed in juveniles; often less developed (both nodules and lines) in adult RV; both valves with some bifurcating lines ventrally; space between lines about twice as big as the lines themselves.

Etymology. Lat. incomparabile, adjective = incomparable.

Ecology. Mud, sand, among algae, attached to rocks (Dijkstra and Goud, 2002); Continental shelf to 300 m (Oliver, 2016, Dijkstra and Goud, 2002).

Distribution. West coasts of Britain and Ireland from the Channel Islands to Shetland (Oliver, 2016). Svalbard (Rózycki, 1987). North Sea, Norwegian shelf (Malkowsky et al., 2014). Western Mediterranean (Pena et al., 1996, Dijkstra and Goud, 2002). Absent from Iceland and Faroe Islands (Dijkstra et al., 2009). North-east Atlantic to the tropical east Atlantic (Dijkstra and Goud, 2002).

Remarks. Similar to *Palliolum tigerinum* and *P. striatum*, especially smooth tigerinum. See remarks of *P. tigerinum* for how to distinguish these three species. Commarginal ridges on left anterior auricle might be protruding and sharp by the disc (one specimen) or well developed. Eight specimens were found with 2-6 radiating ribs on left anterior auricle, some with scales or nodules, some even consisting only of scales (no ribs). The identification of these eight specimens are somewhat uncertain as the auricle structure fits better with *P. tigerinum*. Seven specimens were found with 2-3 radiating ribs on left posterior auricle, some with nodules.

Material examined. 14 specimens were examined from different locations in Trøndelag, Møre and Romsdal, and Nordland. Specimens collected at depths from ~20-97 meters (Appendix III). The identification of some of the specimens is a bit uncertain.

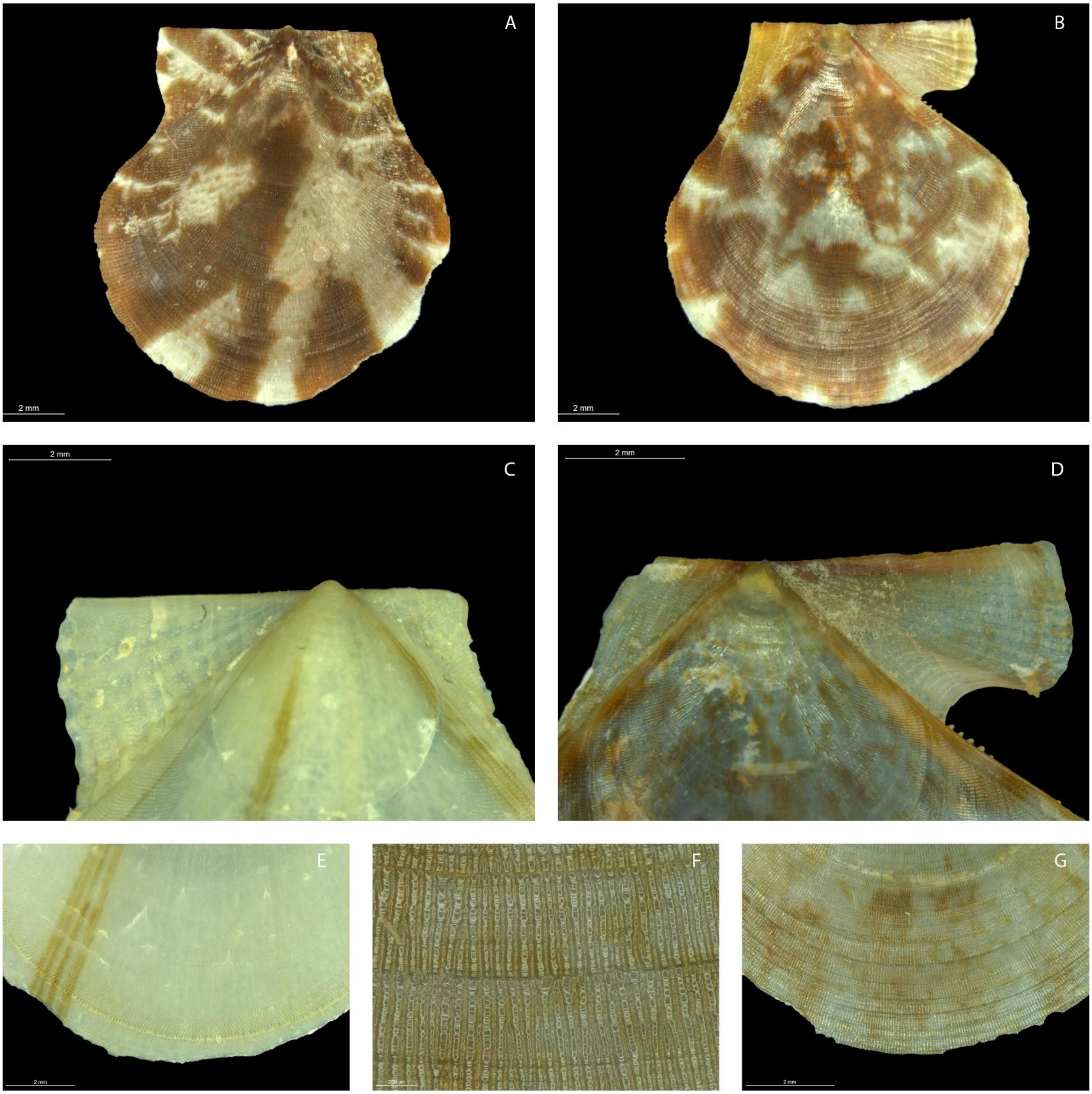

Figure 30. *Palliolum incomparabile.* **A** left valve (LV) **B** right valve (RV) **C** auricles of LV **D** auricles of RV **E** microsculpture of LV **F** microsculpture and interspace **G** microsculpture of RV. Pictures of NTNU-VM-65325 (A, B), NTNU-VM-69725 (C, E) and NTNU-VM-72911 (D, F, G).

Subfamily Pedinae Bronn, 1862

Tribe Chlamydini Teppner, 1922

Genus *Chlamys* Röding, 1798

Chlamys islandica (O. F. Müller, 1776)

Figure 31

Pecten islandicus Müller O.F. (1776:248 [original description]).
Ostrea cinnabarina Born (1778).

Description. Shell solid, up to 60 mm long and 65 mm high, subtrigonal. Almost flat. LV different combinations and patterns of red, orange and pink. RV like LV or white. Inequilateral, anterior auricle longer than posterior. Right anterior auricle densely spaced commarginal ridges and 3-5 radiating ribs; byssal notch up to 8 mm; ctenolium well developed up to 12 mm. Left anterior auricle 5-11 radiating ribs same sculpture as disc and densely spaced commarginal ridges either sharp or weak; interspace like disc. Right posterior auricle 4-8 radiating ribs and (i) nodules everywhere, (ii) smooth or (iii) densely spaced commarginal ridges. Left posterior auricle 3-11 radiating ribs same sculpture as disc and densely spaced commarginal ridges; interspace like disc. Umbo smooth and hyaline in juveniles, smooth radiating ribs in adults (RV may be smoother than LV); beak not protruding over dorsal margin RV, may protrude weakly LV. Dorsal margin smooth, but right anterior auricle visible from LV. Ribs on disc protruding over ventral margin. Both primary and secondary radiating ribs, densely spaced, on some so dense that interspace doesn't exist; LV up to 117 ribs, RV up to 124; the number of ribs may vary with more than 10 ribs between the valves on the same individual. Ribs LV with flat downward pointing scales, either all ribs or only secondary, number of scales varies. All ribs RV with scales like LV or smooth. Interspace same on both valves; normally downward pointing overlapping triangles in radiating rows; some have circles in commarginal rows. Interspace pattern may be present also on ribs.

Etymology. Lat. chlamys, noun = cloak, mantle, gender feminine. Species epithet named after the type locality, Iceland.

Ecology. Gravel, stones, rock (Dijkstra et al., 2009); intertidal to 200 m (Oliver, 2016, Dijkstra et al., 2009); often in current-rich areas along the coast (Moen and Svensen, 2004); life habit byssally attached (Oliver, 2016, Dijkstra et al., 2009).

Distribution. Southern Arctic (Moen and Svensen, 2004), Faroes (Oliver, 2016, Dijkstra et al., 2009), Iceland (Oliver, 2016, Dijkstra et al., 2009), Greenland (Dijkstra et al., 2009), Barents Sea (Moen and Svensen, 2004) and western Atlantic (Dijkstra et al., 2009). Norway south to Bergen (Oliver, 2016, Dijkstra et al., 2009), some post-glaciation relics south of Bergen (Dijkstra et al., 2009).

Remarks. One juvenile specimen was found with ~12 commarginal ridges and no radiating ribs on left anterior auricle. Interspace microsculpture and the high number of densely spaced ribs makes the species easy to distinguish from others in Norwegian waters. For separating juveniles from juveniles of *Karnekampia sulcata*, the only species in Norway it is likely to be confused with, see remarks of *K. sulcata*.

Material examined. 7 specimens were examined from different locations in Trøndelag, Jan Mayen, Møre and Romsdal, Troms and Hordaland. Specimens collected at depths from ~15-372 meters (Appendix III).

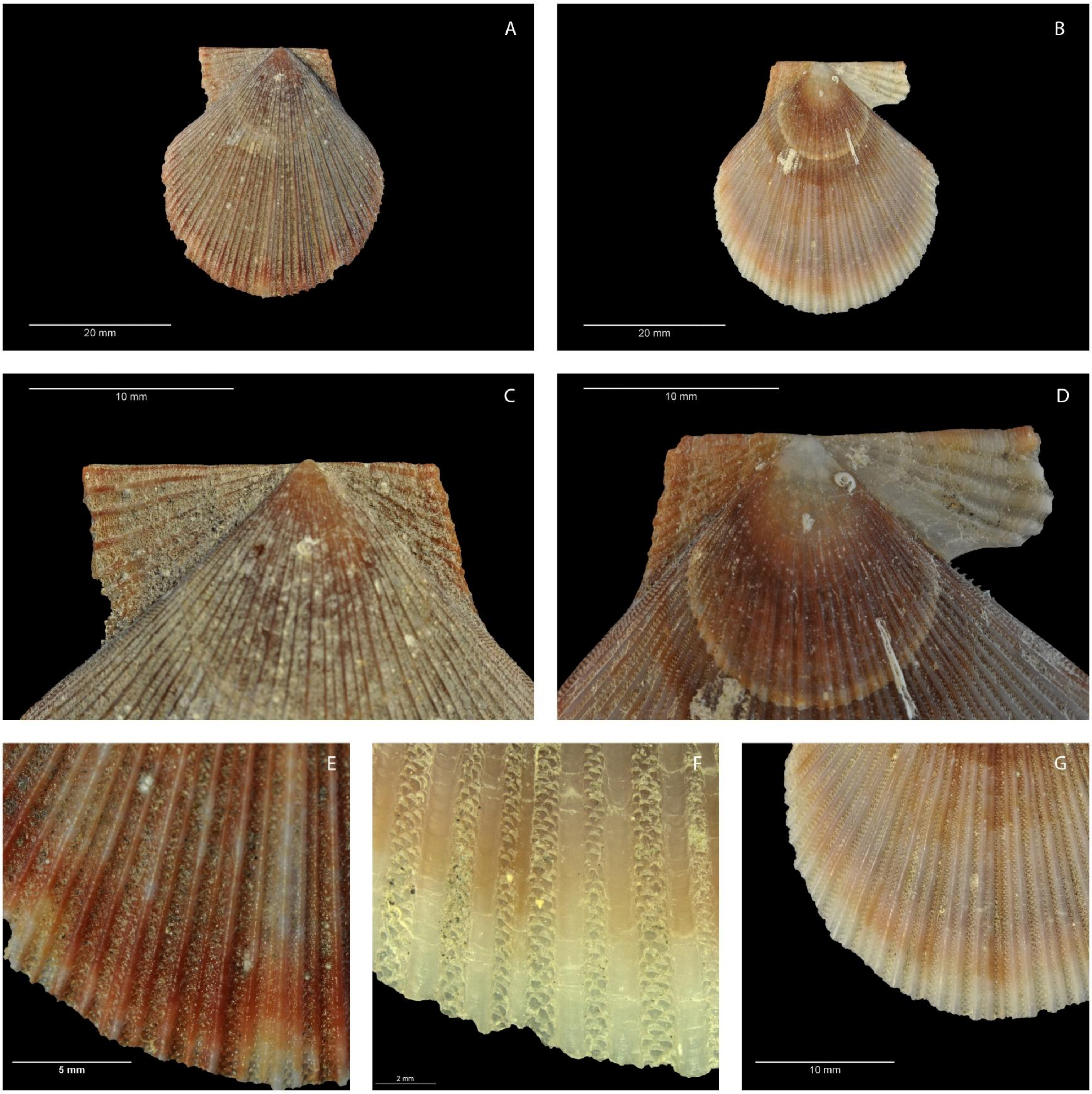

Figure 31. *Chlamys islandica.* **A** left valve (LV) **B** right valve (RV) **C** auricles of LV **D** auricles of RV **E** microsculpture of LV **F** interspace **G** microsculpture of RV. Pictures of NTNU-VM-5084.

Subfamily Pedinae Bronn, 1862
Tribe Chlamydini Teppner, 1922
Genus *Talochlamys* Iredale, 1929

Talochlamys pusio (Linnaeus, 1758)

Figure 32, 33, 34

Ostrea pusio Linnaeus (1758:698 [original description]).
Chlamys distorta da Costa (1778); Beaumont and Gruffydd (1974).
Crassadoma pusio Linnaeus (1758:698); Ávila et al. (2007:46).
Ostrea sinuosa Gmelin (1791); Reagin (1992:155).
Hinnites distorta da Costa (1778).

Description. Shell solid, irregular shape, up to 20 mm length subcircular. Shell up to 32 mm long, 36 mm high and 4 mm thick. Inequivalve. LV yellowish-white, reddish-brown, light pink, white with pinkish-brown spots or white with hints of pink. RV white; may have small reddish-brown spots or yellow patches; umbo mostly white, some light brown. Inequilateral, ears unequal in size; may seem equilateral due to the distorted shape. All ears may or may not be distorted; never distorted in juveniles. Right anterior auricle with 3-6 radiating ribs with or without spines, or with commarginal lines protruding over dorsal margin; byssal notch <3mm; ctenolium <9mm; byssal notch and ctenolium difficult to see if distorted. Left anterior auricle with 6-11 radiating ribs with scales places either randomly or in rows. Right posterior auricle smooth, or with radiating ribs; may have densely spaced commarginal ridges by beak. Left posterior auricle with 5-8 radiating ribs with scales, or commarginal lines. Umbo with densely spaced radiating ribs; never distorted; beak not protruding over dorsal margin. Ventral margin completely distorted or crenulated either randomly or in a pattern. Dorsal margin uneven; RV auricle visible from LV, commarginal ridges protruding over dorsal margin on RV. Macrosculpture same on both valves; difficult to distinguish any sculpture if distorted, otherwise both primary and secondary ribs present; ribs with downward-pointing scales of different size, random placement; 36-49 on LV, 35-45 on RV; ribs <4mm LV, <6mm RV. Microsculpture same on both valves; smooth ribs or ribs with radiating grooves curving up (Fig. x) ; interspace same as rib-microsculpture. Interspace <6mm both valves.

Etymology. Named after its easily recognized distorted shape, from Lat. tālis, adjective = so distinguished; Lat. chlamys, noun = cloak, gender feminine. Lat. pūsiō, noun = little boy, gender masculine.

Ecology. Hard substrate (Neal, 2004, Dijkstra et al., 2009), often in empty *Arctica islandica* in Scandinavia (Dijkstra et al., 2009); littoral zone to 200 (900) m (Oliver, 2016, Neal, 2004, Dijkstra and Goud, 2002), commonly 0-45 m (Dijkstra and Goud, 2002); byssally attached when juvenile, cementing life habit as adult (Shumway and Parsons, 2016, Oliver, 2016, Dijkstra et al., 2009).

Distribution. Northern to eastern Atlantic (Dijkstra et al., 2009). Northern Norway to the Ivory Coast (Dijkstra et al., 2009). Western Mediterranean (rare) and the Azores (Dijkstra and Goud, 2002, Dijkstra et al., 2009). Very rare in Skagerak (Dijkstra et al., 2009). Common in the British Isles (Dijkstra and Goud, 2002, Dijkstra et al., 2009). Southern Macaronesia (Dijkstra and Goud, 2002). Rare in the Canary Islands (Dijkstra et al., 2009).

Remarks. It may be distorted in both shape and sculpture, although some forms might be regularly shaped even as adults. If an individual is distorted it is hard to mistake for something else. To differentiate from juvenile *Mimachlamys varia*: only primary ribs, finer sculpture. See remarks for *Aequipecten opercularis* on comparison between juveniles (e.g. non-distorted) of *T. pusio* and juveniles of *A. opercularis* and *Mimachlamys varia*. *Talochlamys multistriata* (Poli, 1791) are difficult to distinguish from juveniles of *T. pusio (Ghys-e)*. They can be separated by studying the auricles: *T. multistriata* has very unequal auricles, while *T. pusio* has equal (Ghys-e). *Talochlamys multistriata* is also less distorted than *T. pusio* (Ghys-e)

Material examined. 9 specimens were examined from different locations in Trøndelag. Specimens collected at depths from ~11-67 meters (Appendix III).

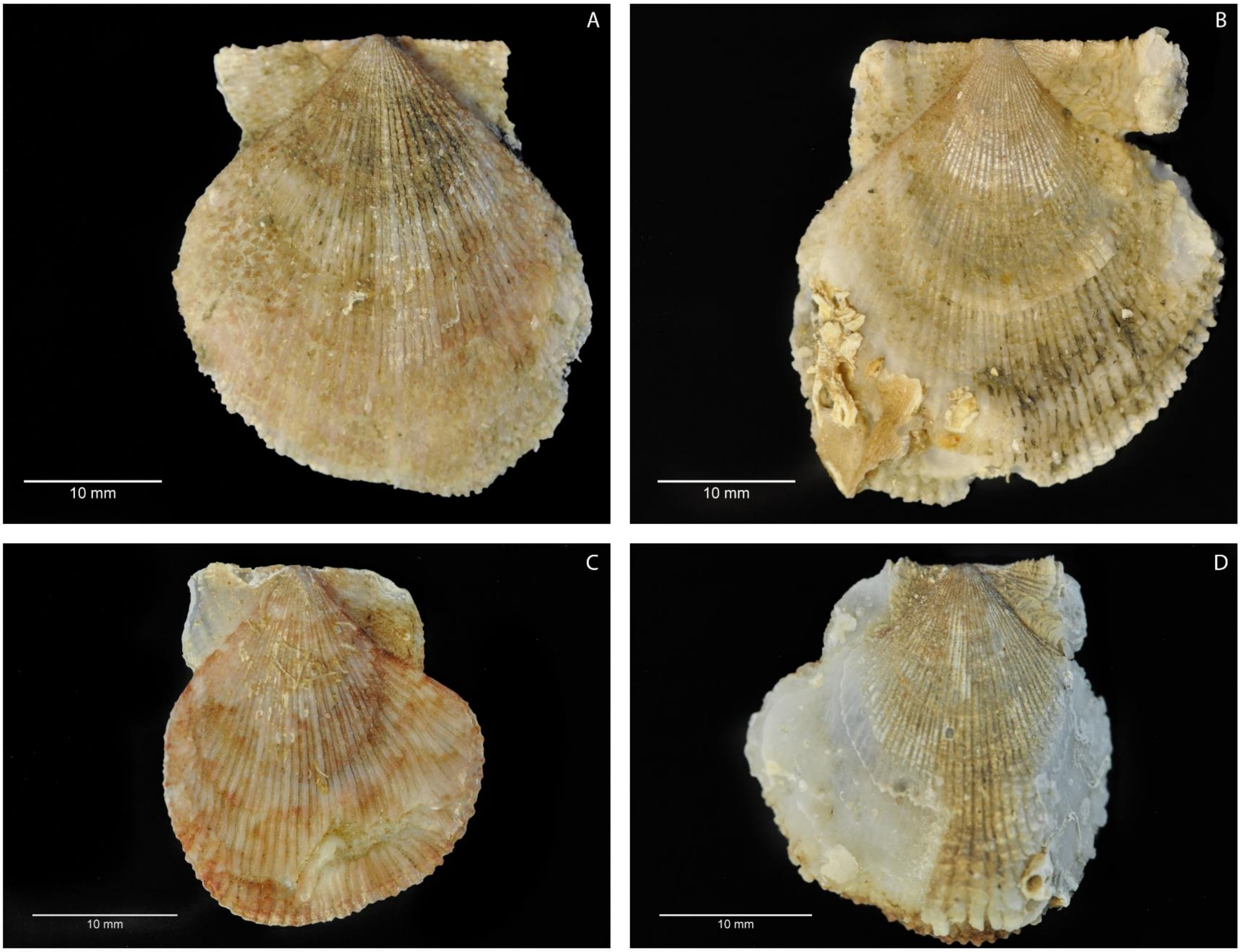

Figure 32. *Talochlamys pusio.* **A** left valve (LV) **B** right valve (RV) **C** left valve (LV) **D** right valve (RV)**.** Pictures of NTNU-VM-66163 (A, B) and NTNU-VM-65988 (C, D).

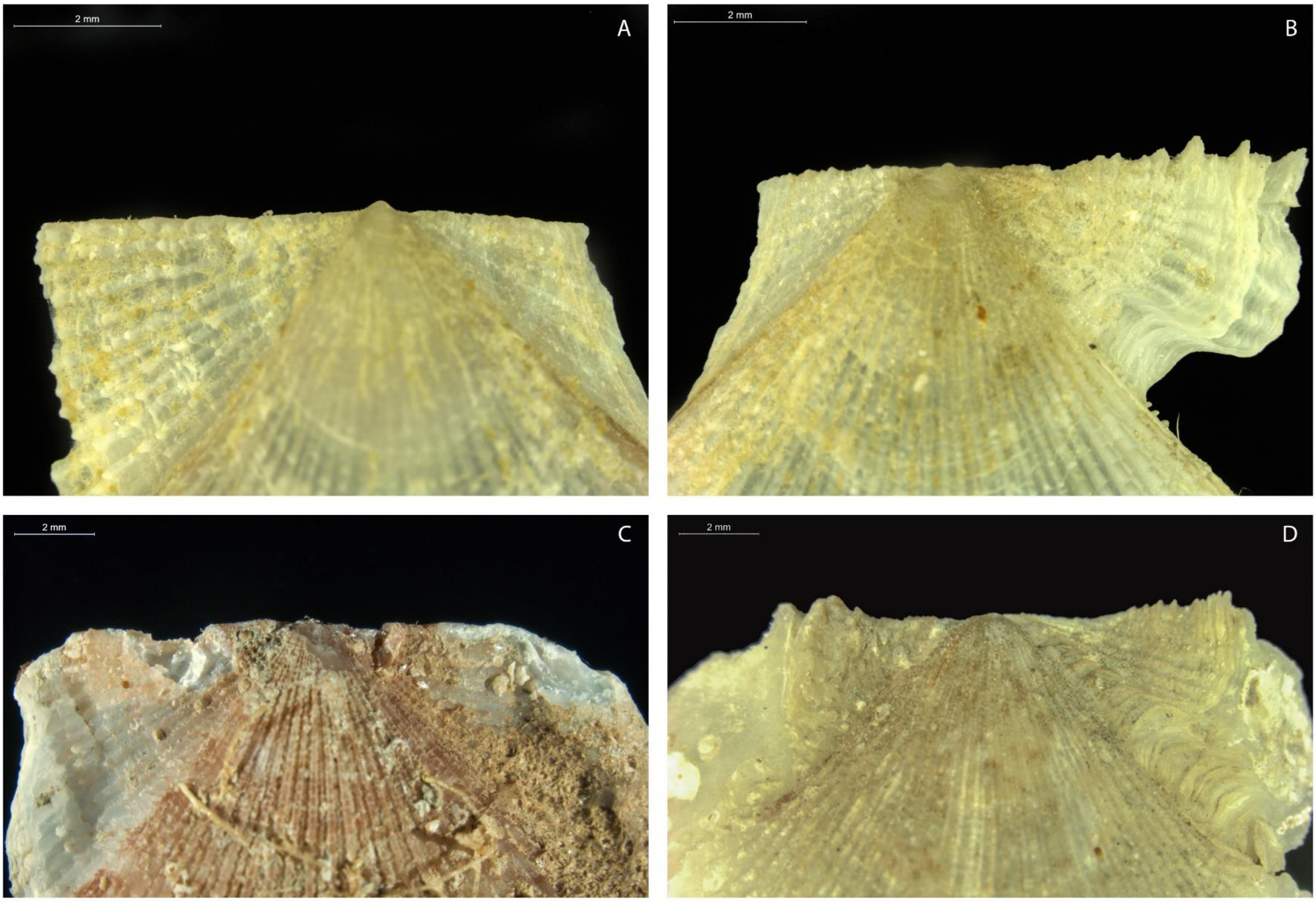

Figure 33. *Talochlamys pusio.* **A** auricles of LV **B** auricles of RV **C** auricles of LV **D** auricles of RV**.** Pictures of NTNU-VM-5157 (A, B) and NTNU-VM-65988 (C, D).

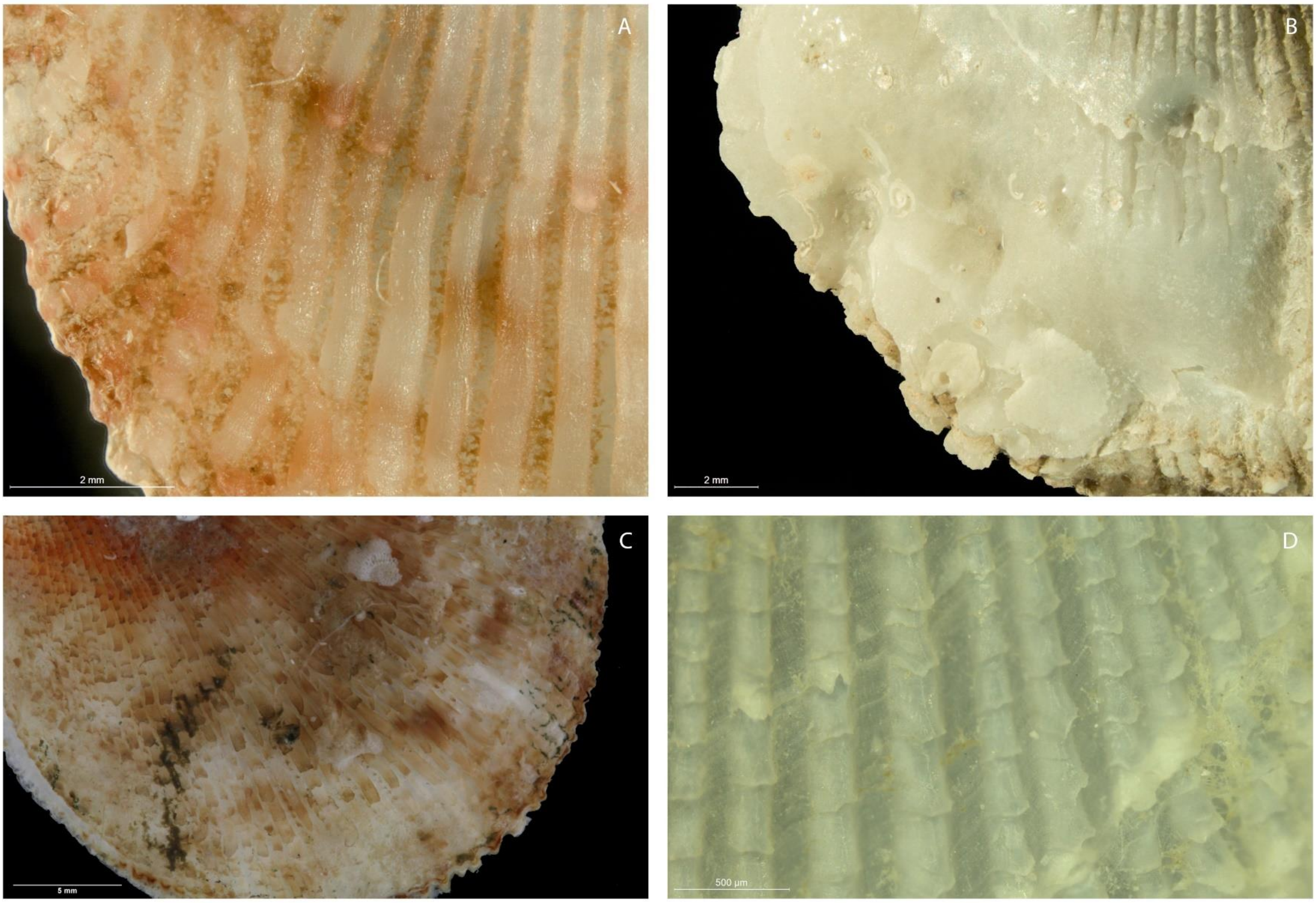

Figure 34. *Talochlamys pusio.* **A** microsculpture of LV **B** microsculpture of RV **C** microsculpture of LV **D** microsculpture of RV**.** Pictures of NTNU-VM-65988 (A, B), Vatlestraumen2005 (C) and NTNU-VM-5157 (D).

Subfamily Pedinae Bronn, 1862

Tribe Mimachlamydini Waller, 1993

Genus *Mimachlamys* Iredale, 1929

Mimachlamys varia (Linnaeus, 1758)

Figure 35

Ostrea varia Linnaeus (1758:698 [original description]).
Chlamys varia Linnaeus (1758: 698); Forester (1979:1).
Chlamys varius Linnaeus (1758:698); Giresse et al. (1984:182).
Pecten varius Linnaeus (1758:698); Horváth and Varjú (1993:154); Davenport and Hubbard (1904:607).

Description. Shell solid, up to 60 mm long, 65 mm high and 60 mm thick, subcircular. LV brown or brownish-purple. RV brown, brownish-purple or white with a hint of pink. One specimen found with yellow ribs and reddish-brown interspace. Inside of both valves normally strong purple. Slightly Inequilateral, anterior auricle ~10 mm longer than posterior. Right anterior auricle commarginal ridges and 2-5 radiating ribs with scales; byssal notch up to 7 mm; ctenolium normally well developed, up to 19 mm. Left anterior auricle densely spaced commarginal ridges and 4-8 radiating ribs with torn scales. Right posterior auricle either (i) densely spaced commarginal ridges and 2-5 radiating ribs with scales, or (ii) scales randomly placed all over auricle. Left posterior auricle like right posterior. Umbo with radiating ribs; beak normally protruding over dorsal margin LV. Dorsal margin uneven; right anterior auricle visible from LV, left beak visible from RV and some commarginal ridges protruding over margin RV. Ribs protruding over ventral margin. Growth stages weakly visible on both valves in some specimens. Both valves with protruding ribs with scales that are reddish-brown, salmon-pink or brown in color; scales variable, (i) sharp (varies even within the same valve on one specimen) or (ii) flat; scales may be randomly placed on ribs, and the number varies between valves and individuals; LV 26-30 ribs, RV 27-29. Commarginal ridges all over discs, normally densely spaced or interspace and microsculpture between scales smooth.

Etymology. Lat. mima, noun = mime actress, gender feminine. Lat. chlamys, noun = cloak, gender feminine. Lat. varia, adjective = variegated.

Ecology. Rocky substrate or rough ground (Oliver, 2016, Oakley, 2007), often in algal holdfasts (Oakley, 2007, Moen and Svensen, 2004). Some amongst rubble on mud or sand

(Dijkstra and Goud, 2002). Low intertidal to 200 m (Oliver, 2016, Oakley, 2007, Moen and Svensen, 2004); life habit byssally attached (Oliver, 2016, Shumway and Parsons, 2016).

Distribution. Denmark (Oakley, 2007), Northern Norway (Dijkstra and Goud, 2002, Moen and Svensen, 2004) and off all British Isles (Oakley, 2007, Moen and Svensen, 2004). The Iberian Peninsula (Oakley, 2007), Mediterranean (Oakley, 2007, Dijkstra and Goud, 2002, Moen and Svensen, 2004), off the coast of west Africa to Senegal (Oakley, 2007, Moen and Svensen, 2004) and the Cape Verde Islands (Dijkstra and Goud, 2002).

Remarks. One specimen was found to be distorted on the left posterior auricle. Some specimens were observed to have 1-2 ribs that may look like secondary ribs because they are smaller than the rest. See remarks in *Aequipecten opercularis* for details on how to distinguish juveniles with juveniles of *Talochlamys pusio* and *A. opercularis*. A subspecies of *M. varia*, *Mimachlamys varia nivea*, can be separated from the common subspecies *Mimachlamys varia varia* in distribution, number of ribs and shell shape. *Mimachlamys varia nivea* is circular with 41-48 ribs and very often white, whereas *M. varia varia* is generally more elongate in shape with 27-35, and rarely white in color (Ghys-f, Oliver, 2016). *Mimachlamys varia varia* is however unlikely to be misidentified as *M. varia nivea* in Norway as the latter subspecies only lives in West Scotland and the Hebrides Islands (Ghys-f, Oliver, 2016).

Material examined. 11 specimens were examined from Trøndelag and the Norwegian Sea. Specimens collected at depths from the littoral zone to ~190 meters (Appendix III).

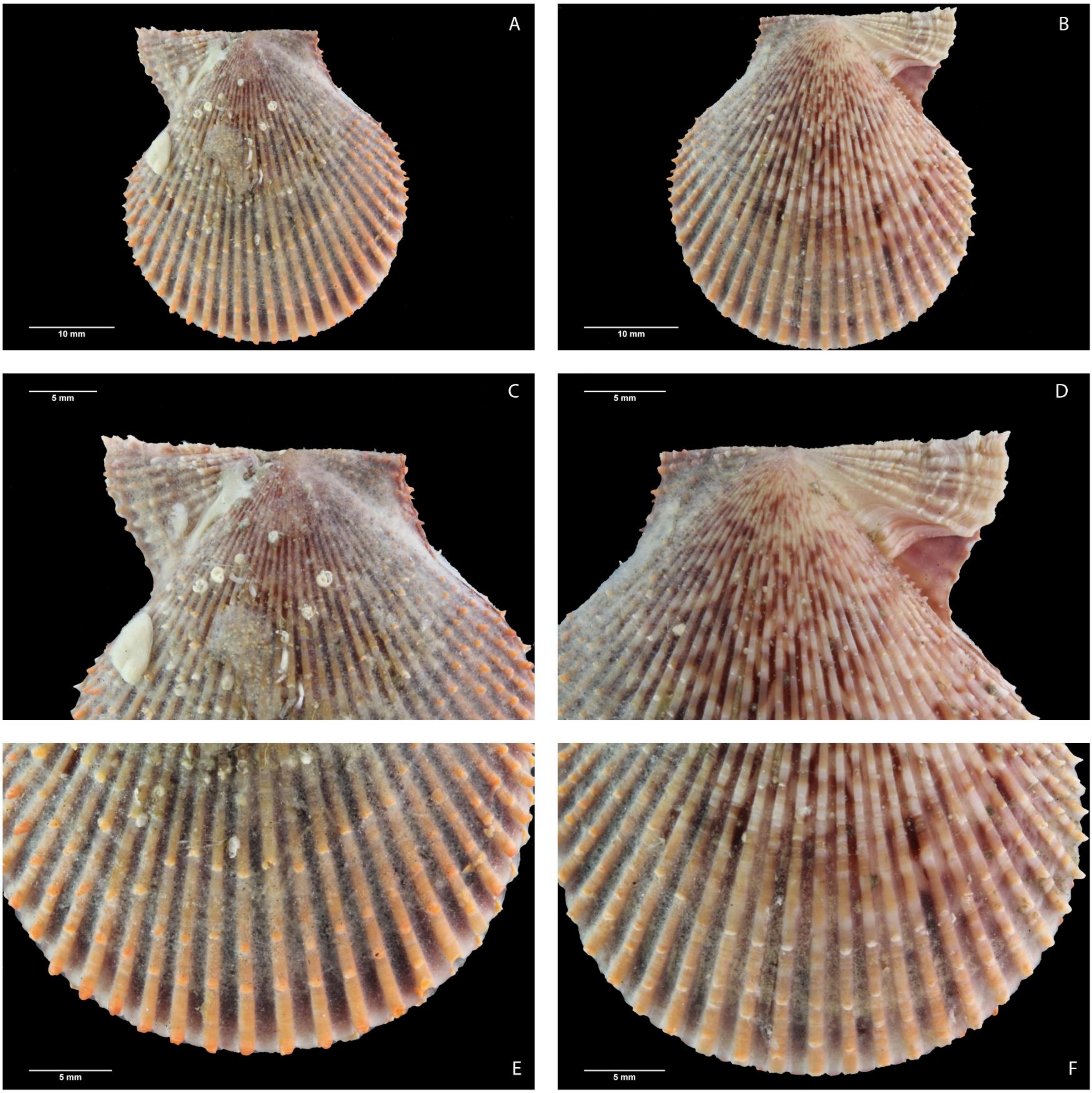

Figure 35. *Mimachlamys varia*. **A** left valve (LV) **B** right valve (RV) **C** auricles of LV **D** auricles of RV **E** microsculpture of LV **F** microsculpture of RV. Pictures of ZMUB-55783.

4. DISCUSSION

4.1 DNA BARCODING

The low success rate in this study can be explained by the fixation of the specimens not being sufficiently enough due to the bivalves' ability to close the two valves tightly together preventing ethanol from entering the shell. Other explanations might be the amount of time the specimens have been preserved, although no specimens with a collection date older than 2006 was used, or issues concerning primers.

Other studies concerning sequencing of coxI in various bivalve taxa, have in several cases yielded a success rate of over 80 % (Prié and Puillandre, 2014, Feng et al., 2011b, Ni et al., 2012). Prié and Puillandre (2014) got success by using the universal Folmer primers (Folmer et al., 1994) as well as a primer pair developed by Prié et al. (2012). In the study by Feng et al. (2011b) the Folmer primers didn't work at all, but the success rate was close to 100 % when using primers designed by Matsumoto (2003). Ni et al. (2012) also got a success rate of 100 %, even though the Folmer primers failed on some specimens for them as well. On the specimens that failed using Folmer primers from Chen et al. (2011) were used with success. One study on marine molluscs in Canada however, only got a success rate of approximately 33 % in bivalves (Layton et al., 2014). This study used a total set of four primers, including the Folmer primers and BivF4_t1/BivR1_t1 (Prosser), divided over two rounds of PCR. Approximately 56 % success rate was achieved among bivalves in a study of molluscs in the North Sea, also using Folmer primers (Barco et al., 2016).

Feng et al. (2011a) sequenced both mitochondrial coxI and 16S genes from 8 species of pectinids. They showed that both genes work well for DNA-barcoding of this group, although the universal coxI primers did not amplify coxI for all species. All the species in this study made monophyletic clades when using DNA for species identification. (Layton et al., 2014) used coxI to barcode 53 bivalve species, mostly from the family Mytilidae. The success rate in this study was relatively low, only 33.1 %. Marín et al. (2015) found that the 5´ end of 16S is the best to use for barcoding of Pectinidae.

There are likely to be several different reasons for the placement of some taxa within a seemingly far-related group (see red circles in Figure 9), but the main explanation seems to be possible misidentification as the contaminants were removed before the analysis. This makes sense because many of the specimens used in the study were juveniles, and thus harder to identify.

Studying the clade with *Asperarca nodulosa* (Figure 9), one branch is noted to be longer than the rest. Performing a search in BLAST, revealed an identity match with the similar looking species *A. secreta* of almost 90% with a 100 % query coverage. *A. secreta* is found in the Mediterranean (La Perna, 1997), so the long branch sequence belonging to this species is unlikely. The sequence with the longer branch is not barcode compliant as it is about 200 bp shorter than the rest of the sequences in the clade, making this the most likely explanation for the branch being longer than the rest and for the high match with *A. secreta*.

The genetic distance between the two sequences identified as *Hiatella arctica* (Figure 9) exceeds the expected genetic distance. This may be explained by the fact there are two very morphologically similar species of *Hiatella* that both live in Norwegian waters, *H. arctica* and *H. rugosa* (NBICb, Oliver, 2016). A search in BLAST revealed that one of the sequences matched with *Hiatella* sp. while the other yielded no trustable results at all. The distance within the *Abra nitida* clade is also greater than anticipated. All these three sequences come out as *Abra nitida* when searching in BLAST, but since the species in this genus is known to be hard to identify (Oliver, 2016) there may be misidentifications in the sequences from GenBank as well as the ones barcoded in this study.

The placement of *Mytilus edulis* (Figure 9) close to a saddle oyster (Fam. Anomiidae) could have been explained by an anomiid growing on the blue mussel so that DNA was taken from this species instead of the blue mussel itself. However, no anomiid was found on the specimen so this seems unlikely.

The *Parvicardium* clade (Figure 9) is comprised of three sequence with almost no genetic distance. Still, these sequences are morphologically identified to belong to three different species. The species in this genus may be difficult to distinguish, but when taking a closer look at the specimens I would consider misidentification and contamination to share the reason for the small genetic distance between the three seemingly different species. All three sequences matched with *P. minimum* in the BLAST-search, and the one identified as *P. scabrum* may be a misidentification in the favor of *P. minimum*. *P. pinnulatum* on the other hand, is often easier to recognize due to its completely smooth middle ribs, so misidentification is probably unlikely.

This specimen was placed close to the one identified as *P. scabrum* on the plate, so there may have been some contamination.

The identification of the specimen identified as *Nucula nucleus* may be wrong as nuculids (Fam. Nuculidae) are difficult to identify with traditional taxonomy (La Perna, 2007), but it is not at all likely that it was misidentified with a venerid (Fam. Veneridae) such as *Venus casina*. I haven't been able to find any reasonable explanation for the short genetic distance between these two sequences (Figure 9). In one of the other clades containing venerids, two sequences seemingly belonging to *Abra nitida* and *Parvicardium scabrum* are placed. None of these two species are likely to have been misidentified with venerids, but they both retrieve high matches with venerids in BLAST. This can be explained by these two peculiar sequences both being shorter than 350 bp and thus are more likely to fit with not-closely related sequences.

4.2 SPECIES DELIMITATION ANALYSES

Both distance based and tree based species delimitation methods seems to work well on pectinids, as they both delimit the same number of species as found when using morphology. These results reflect the robustness of the dataset, even though it was a small one comprised of only 33 sequences including the outgroups. Both ABGD and PTP can be considered simple methods for species delimitation (Puillandre et al., 2012, Zhang et al., 2013), which means that even the easiest methods are sufficient to discriminate between different species in this group, possibly within Bivalvia in general. A study by Huang et al. (2019) showed that both ABGD and mPTP tended to delimit species the same way in freshwater mussels in the order Unionida.

This well-defined barcode gap suggests that coxI is a good marker for bivalve identification, at least among pectinids. This can be helpful when confronted with morphologically similar species, e.g. species in the family Thyasiridae (see results about morphological analyses). Barcoding and species delimitation may also aid in the identification of juvenile species that lack many of the characteristics used for recognition in adults.

In the *Palliolum tigerinum*-clade one sequence is labelled *P. incomparabile* (Figure 10). Based on the results from the species delimitation analyses, together with a closer look on the morphology this is most likely the result of a misidentification as these two *Palliolum* species can be very difficult to distinguish morphologically (see remarks in the species descriptions below). The sequence *Palliolum tigerinum 1* placed within the clade consisting of *Karnekampia* *sulcata* is also likely to be the result of a misidentification. The *Palliolum tigerinum 1* sequence was downloaded from GenBank, and it has a specimen page in BOLD (SWEMA331-15). By looking at the picture submitted on this page, I would identify this specimen as *K. sulcata* and not as *P. tigerinum* due to the presence of secondary ribs. The microsculpture on the ribs are also fitting better with *K. sulcata* as the ribs on the specimen in the picture are comprised of nodules compared to the smooth surface mainly seen in *P. tigerinum* with ribs. There may be some weaker microsculpture on the ribs of *P. tigerinum*, but never nodules.

4.3 MORPHOLOGICAL ANALYSES

Rufino et al. (2006) studied the difference *C. gallina* and *C. striatula*, two morphologically very similar species. The latter is widely distributed all over Norway (NBICb). Two wet specimens at NTNU University Museum are identified as *C. gallina*, but I consider one of them to be misidentified. Due to the large distance between each commarginal ridge on NTNU-VM-9362, I identify this specimen as *Clausinella fasciata*. The other specimen was together with specimens identified as *C. striatula* studied using the pallial index (PI) created by Rufino et al. (2006). This index measures the length of the pallial sinus and divides it with the total shell length. All specimens studied had a PI greater than 0.119, which according to Rufino et al. (2006) says that the species belongs to *C. striatula*. Even though I only have studied one of the 13 registered specimens of *C. gallina* from Norway (NBICb), I would based on own findings and the known distribution of *C. gallina* from the literature, question the presence of this species in Norwegian waters.

All specimens sent to sequencing identified as Thyasiridae indet looked very similar morphologically, but the genetic distance between them (see Figure 9) were greater than what would have been expected if it was only one species. There are classification issues within this families, and the species are known to be difficult to distinguish (Keuning and Schander, 2010, Oliver and Drewery, 2014, Taylor et al., 2007, Payne and Allen, 1991). A species delimitation study of Thyasiridae would be interesting as well as studies using barcoding so that a decent library for species in this family can be established.

All identification literature used in this study (see material and methods) can be recommended to people who are interested in identifying bivalves. They should, however, be used together as they vary in which species they contain and also in which characters that are used in the keys. It should be noted that all keys (except for Pectinidae) and character tables in this thesis are preliminary due the low number of specimens studied. They should therefore be used with care, and preferably together with other literature such as those mentioned in material and methods.

Mature scallops in Norway are easily distinguishable when looking at the right characters. Microsculpture both on ribs and interspace have proven extra useful when confronted with difficult specimens, such as juveniles and species within the genus *Palliolum*.

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APPENDIX I

Table A. Specimens sent to the Canadian Centre for DNA Barcoding (CCDB). All specimens belong to the collection at Department of Natural History, NTNU University Museum. The Barcode-column tells whether or not the sequencing worked and gave a successful barcode.

Sample ID	Species	Identifier	Collection Date	Collection Site	Lat (ºN)	Lon (ºE)	Depth (m)	Habitat	Barcode
KeSu04	*Kellia suborbicularis*	Nathalie Skahjem	13-Jun-2018	Mølnbukta	63.6289	9.64262		Mixed bottom, *Modiolus modiolus*	Yes
NTNU-VM-71141	*Kellia suborbicularis*	Øystein Stokland	28-Aug-2011	Tautrasvaet	63.555	10.6217	6	Rocks, clay	No
KeSu03	*Kellia suborbicularis*	Jon-Arne Sneli	08-Nov-2007	Brandsfjorden	64.2234	10.2853	173 ± 6	Soft bottom	No
KeSu02	*Kellia suborbicularis*	Jon-Arne Sneli	08-Nov-2007	Brandsfjorden	64.2234	10.2853	173 ± 6	Soft bottom	No
KeSu01	*Kellia suborbicularis*	Jon-Arne Sneli	08-Nov-2007	Brandsfjorden	64.2234	10.2853	173 ± 6	Soft bottom	No
CoGi04	*Corbula gibba*	Anita Kaltenborn	06-Nov-2007	Valsfjorden	63.8133	9.64947	67 ± 1	Soft bottom, mud with shell fragments	No
CoGi03	*Corbula gibba*	Jon-Arne Sneli	06-Nov-2007	Lysøysund	63.9109	9.87693	43 ± 15		No
CoGi02	*Corbula gibba*	Jon-Arne Sneli	06-Nov-2007	Lysøysund	63.9109	9.87693	43 ± 15		No
NTNU-VM-67329	*Corbula gibba*	Anita Kaltenborn	08-Nov-2007	Brandsfjorden	64.2083	10.3584	135 ± 6	Soft bottom	No
CoGi01	*Corbula gibba*	Nathalie Skahjem	07-Feb-2018		63.4437	10.6519	24 ± 6		Yes
KuBi05	*Kurtiella bidentata*		28-Aug-2011	Tautrasvaet	63.5633	10.6033	4	Rocks, gravel	No
KuBi04	*Kurtiella bidentata*		28-Aug-2011	Tautrasvaet	63.553	10.6318	4	Sand, clay	No
KuBi03	*Kurtiella bidentata*		28-Aug-2011	Tautrasvaet	63.555	10.6217	6	Rocks, mud	No
KuBi02	*Kurtiella bidentata*		28-Aug-2011	Tautrasvaet	63.5652	10.6313	5 ± 1	Rocks	No
KuBi01	*Kurtiella bidentata*		28-Aug-2011	Tautrasvaet	63.5633	10.6517	9		No
MeFe04	*Mendicula ferruginosa*	Jon-Arne Sneli	08-Nov-2007	Brandsfjorden	64.2234	10.2853	173 ± 6	Soft bottom	No
MeFe03	*Mendicula ferruginosa*	Jon-Arne Sneli	08-Nov-2007	Brandsfjorden	64.2234	10.2853	173 ± 6	Soft bottom	No
NTNU-VM-67310	*Mendicula ferruginosa*	Jon-Arne Sneli	06-Nov-2007	Lysøysund	63.9109	9.87693	43 ± 15	Hard bottom, rocks	No
MeFe02	*Mendicula ferruginosa*	Nathalie Skahjem	07-Feb-2018		63.4441	10.5065	29 ± 1		Yes
MeFe01	*Mendicula ferruginosa*	Nathalie Skahjem	07-Feb-2018		63.4475	10.6273	75 ± 2		Yes
NuSu02	*Nucula sulcata*	Jon-Arne Sneli	05-Nov-2007	Tarvefjorden	63.763	9.38397	269 ± 15	Soft bottom, mud and sand	No
NuSu01	*Nucula sulcata*	Jon-Arne Sneli	10-Feb-2014	Prestbukta	63.4833	9.99957	26 ± 14	Rocks with a little sand	Yes

NTNU-VM-70522	*Nucula sulcata*	Jon-Arne Sneli	12-Feb-2014	Valset	63.65	9.70948	153 ± 49	Sand	Yes
NTNU-VM-70521	*Nucula sulcata*	Jon-Arne Sneli	10-Feb-2014	Prestbukta	63.4882	10.0292	40 ± 10	Rocks with a little sand	No
NuNu01	*Nucula nucleus*	Nathalie Skahjem	13-Jun-2018	Mølnbukta	63.6289	9.64262		Mixed bottom, *Modiolus modiolus*	Yes
NuNi01	*Nucula nitidosa*	Nathalie Skahjem	12-Jun-2018	Agdenesflua	63.6529	9.76623	183 ± 116	Hard bottom	Yes
AzCh01	*Azorinus chamasolen*	Jon-Arne Sneli	29-Jun-2017	Brødreskift	63.496	9.93963	40 ± 19	Hard bottom	No
Tsp02	*Thracia*	Nathalie Skahjem	07-Feb-2018		63.4441	10.5065	29 ± 1		Yes
Tsp01	*Thracia*	Nathalie Skahjem	07-Feb-2018		63.4441	10.5065	29 ± 1		Yes
PaSc04	*Parvicardium scabrum*	Øystein Stokland	28-Aug-2011	Tautrasvaet	63.5652	10.6313	5 ± 1	Rocks	No
PaSc03	*Parvicardium scabrum*	Nathalie Skahjem	07-Feb-2018		63.4475	10.6273	75 ± 2		No
PaSc02	*Parvicardium scabrum*	Nathalie Skahjem	06-Nov-2007	Valsfjorden	63.8133	9.64947	67 ± 1	Soft bottom, mud with shell fragments	No
PaSc01	*Parvicardium scabrum*	Nathalie Skahjem	06-Nov-2007	Valsfjorden	63.8133	9.64947	67 ± 1	Soft bottom, mud with shell fragments	No
Thy09	*Thyasiridae*	Nathalie Skahjem	07-Feb-2018		63.4475	10.6273	75 ± 2		No
NuPe01	*Nuculana pernula*	Anita Kaltenborn	07-Nov-2007	Pølen	63.9901	10.0444	106 ± 4	Soft bottom, mud	Yes
Nath08	Bivalvia	Nathalie Skahjem	29-Jun-2018	Mølnbukta	63.6289	9.64262		Mixed bottom, with *Modiolus modiolus*	No
AeOp06	*Aequipecten opercularis*	Nathalie Skahjem	29-Jun-2018	Mølnbukta	63.6289	9.64262		Mixed bottom, with *Modiolus modiolus*	No
Tsp03	*Thracia*	Nathalie Skahjem	29-Jun-2018	Mølnbukta	63.6289	9.64262		Mixed bottom, with *Modiolus modiolus*	Yes
SpEl02	*Spisula elliptica*	Nathalie Skahjem	29-Jun-2018	Mølnbukta	63.6289	9.64262		Mixed bottom, with *Modiolus modiolus*	Yes
VeCa02	*Venus casina*	Nathalie Skahjem	29-Jun-2018	Mølnbukta	63.6289	9.64262		Mixed bottom, with *Modiolus modiolus*	Yes
MyUn01	*Mysia undata*	Nathalie Skahjem	29-Jun-2018	Mølnbukta	63.6289	9.64262		Mixed bottom, with *Modiolus modiolus*	No
AsAr02	*Astarte arctica*	Nathalie Skahjem	29-Jun-2018	Mølnbukta	63.6289	9.64262		Mixed bottom, with *Modiolus modiolus*	No
AsAr01	*Astarte arctica*	Nathalie Skahjem	29-Jun-2018	Mølnbukta	63.6289	9.64262		Mixed bottom, with *Modiolus modiolus*	No

MiVa01	*Mimachlamys varia*	Nathalie Skahjem	11-Jun-2018	Sletvik	63.5945	9.5255			No
PeMa02	*Pecten maximus*	Nathalie Skahjem	30-Jun-2018	Vernes ferry docks	63.5809	9.50954			No
NTNU-VM-71789	*Pecten maximus*	Jon-Arne Sneli	10-Feb-2014	Prestbukta	63.4833	9.99957	26 ± 14	Rocks, a little bit of sand	No
OsEd01	*Ostrea edulis*	Anita Kaltenborn	30-Jul-2006	Øyrasanden	62.4028	5.36018			No
LiHi01	*Limaria hians*	Nathalie Skahjem	29-Jun-2018	Mølnbukta	63.6289	9.64262		Mixed bottom, *Modiolus modiolus*	No
LuBo01	*Lucinoma borealis*	Øystein Stokland	28-Aug-2011	Tautrasvaet	63.5683	10.66	12		Yes
PsPe05	*Pseudamussium peslutrae*	Nathalie Skahjem	12-Jun-2018	Brødreskift	63.6831	10.0825	36 ± 12		No
MoMo01	*Modiolus modiolus*	Jon-Arne Sneli	10-Feb-2014	Håøy	63.7389	9.94543	22 ± 1	Gravel, sand	Yes
Yol01	*Yoldia amygdalea*	Jon-Arne Sneli	09-Oct-2011	Østerbotn	70.12	25.1863	109	Soft bottom	Yes
TaPu03	*Talochlamys pusio*	Guro Sylling	02-Jul-2008	Stavøy	63.5917	9.49903	68 ± 36	Shell fragments, dead *Modiolus modiolus*	No
PeMa01	*Pecten maximus*	Nathalie Skahjem	12-Jun-2018	Agdenesflua	63.6529	9.76623	183 ± 116	Hard bottom	No
NTNU-VM-64677	*Talochlamys pusio*	Guro Sylling	12-Jun-2006	Stavøy	63.5947	9.50333	126 ± 74		No
MyTr01	*Mya truncata*	Nathalie Skahjem	11-Jun-2018	Sletvik	63.5945	9.5255			Yes
TaPu02	*Talochlamys pusio*	Guro Sylling	02-Jul-2008	Stavøy	63.5917	9.49903	68 ± 36	Shell fragments, dead *Modiolus modiolus*	No
PsPe04	*Pseudamussium peslutrae*	Anita Kaltenborn	08-Nov-2007	Brandsfjorden	64.2083	10.3584	135 ± 6	Soft bottom	No
AsSu02	*Astarte sulcata*	Nathalie Skahjem	07-Feb-2018		63.4437	10.6519	24 ± 6		No
AcEc03	*Acanthocardia echinata*	Øystein Stokland	28-Aug-2011	Tautrasvaet	63.5717	10.4467	12		No
CeEd02	*Cerastoderma edule*	Nathalie Skahjem	11-Jun-2018	Sletvik	63.5945	9.5255			Yes
TaPu01	*Talochlamys pusio*	Guro Sylling	02-Jul-2008	Stavøy	63.5917	9.49903	68 ± 36	Shell fragments, dead *Modiolus modiolus*	No
AeOp05	*Aequipecten opercularis*	Guro Sylling	12-Jun-2006	Rødberg	63.4778	10.0103	30 ± 10		No
Myt03	*Mytilus edulis*	Øystein Stokland	28-Aug-2011	Tautrasvaet	63.553	10.6318	4	Sand, clay	Yes
AeOp04	*Aequipecten opercularis*	Nathalie Skahjem	13-Jun-2018	Mølnbukta	63.6289	9.64262		Mixed bottom, with *Modiolus modiolus*	No

VeCo01	*Venerupis corrugata*	Nathalie Skahjem	11-Jun-2018	Sletvik	63.5945	9.5255			Yes
NTNU-VM-71759	*Arctica islandica*	Øystein Stokland	28-Aug-2011	Tautrasvaet	63.57	10.6433	8		Yes
KaSu04	*Karnekampia sulcata*	Guro Sylling	28-Jun-2007	Agdenesflua	63.6474	9.75616	96 ± 19	Corals, hard bottom	No
HeSq02	*Heteranomia squamula*	Nathalie Skahjem	13-Jun-2018	Mølnbukta	63.6289	9.64262		Mixed bottom, with *Modiolus modiolus*	No
PsPe03	*Pseudamussium peslutrae*	Guro Sylling	12-Jun-2006	Stavøy	63.5947	9.50333	126 ± 74		No
DoEx01	*Dosinia exoleta*	Nathalie Skahjem	11-Jun-2018	Sletvik	63.5945	9.5255			No
DeVi03	*Delectopecten vitreus*	Nathalie Skahjem	12-Jun-2018	Agdenesflua	63.6529	9.76623	183 ± 116	Hard bottom	No
AeOp03	*Aequipecten opercularis*	Nathalie Skahjem	12-Jun-2018	Agdenesflua	63.6529	9.76623	183 ± 116	Hard bottom	No
AsSu01	*Astarte sulcata*	Nathalie Skahjem	12-Jun-2018	Agdenesflua	63.6529	9.76623	183 ± 116	Hard bottom	No
PoPa01	*Pododesmus patelliformis*	Nathalie Skahjem	11-Jun-2018	Sletvik	63.5945	9.5255			Yes
PaTi02	*Palliolum tigerinum*	Nathalie Skahjem	13-Jun-2018	Trondheimsleia	63.6193	9.53498	416 ± 6	Mixed bottom	Yes
HiAr02	*Hiatella arctica*	Nathalie Skahjem	12-Jun-2018	Agdenesflua	63.6529	9.76623	183 ± 116	Hard bottom	No
ArTe01	*Arca tetragona*		26-Oct-2017	Stavøya	63.5947	9.50252	45 ± 6	Dead *Modiolus modiolus*	Yes
Myt02	*Mytilus edulis*	Jon-Arne Sneli	25-Nov-2014	Hemnefjorden	63.3307	9.11648			Yes
ThDi01	*Thracia distorta*	Nathalie Skahjem	13-Jun-2018	Mølnbukta	63.6289	9.64262		Mixed bottom, with *Modiolus modiolus*	No
KaSu03	*Karnekampia sulcata*	Nathalie Skahjem	12-Jun-2018	Agdenesflua	63.6529	9.76623	183 ± 116	Hard bottom	No
GaTe01	*Gari tellinella*	Nathalie Skahjem	13-Jun-2018	Mølnbukta	63.6289	9.64262		Mixed bottom, with *Modiolus modiolus*	Yes
NTNU-VM-68350	*Astarte elliptica*	Jon-Arne Sneli	07-Dec-2006	Svartdalsbukta	63.4582	10.2577	25 ± 5	Rocks, coarse gravel	No
SpEl01	*Spisula elliptica*	Nathalie Skahjem	13-Jun-2018	Mølnbukta	63.6289	9.64262		Mixed bottom, with *Modiolus modiolus*	Yes
PaSt05	*Palliolum striatum*	Nathalie Skahjem	12-Jun-2018	Brødreskift	63.6831	10.0825	36 ± 12		No
DeVi02	*Delectopecten vitreus*	Guro Sylling	05-Dec-2006	Rødberg	63.4778	10.0103	250 ± 50	Corals	Yes
Ace01	*Acesta excavata*	Nathalie Skahjem	12-Jun-2018	Agdenesflua	63.6529	9.76623	183 ± 116	Hard bottom	Yes

MuSu01	*Musculus subpictus*	Nathalie Skahjem	07-Feb-2018		63.4437	10.6519	24 ± 6		Yes
NTNU-VM-70534	*Cuspidaria rostrata*	Jon-Arne Sneli	11-Feb-2014	Karlsøya	63.7828	9.33658	253 ± 107	Mud, *Acesta*, *Primnoa*, Brachiopoda	Yes
NTNU-VM-71958	*Pododesmus patelliformis*	Jon-Arne Sneli	10-Feb-2014	Prestbukta	63.4882	10.0292	40 ± 10	Rocks, a little bit of sand	No
NTNU-VM-70541	*Lyonsia norwegica*	Jon-Arne Sneli	10-Feb-2014	Prestbukta	63.4833	9.99957	26 ± 14	Rocks, a little bit of sand	No
PaSt04	*Palliolum striatum*	Nathalie Skahjem	13-Jun-2018	Mølnbukta	63.6289	9.64262		Mixed bottom, with *Modiolus modiolus*	No
NTNU-VM-64705	*Palliolum tigerinum*	Guro Sylling	12-Jun-2006	Stavøy	63.5947	9.50333	125 ± 75		No
LiLo01	*Limaria loscombi*	Nathalie Skahjem	13-Jun-2018	Mølnbukta	63.6289	9.64262		Mixed bottom, with *Modiolus modiolus*	Yes
PsPe02	*Pseudamussium peslutrae*	Jon-Arne Sneli	10-Feb-2014	Grønningsbukta	63.4937	9.96747	37 ± 11	Rocks, coarse sand	No
TiOv01	*Timoclea ovata*	Nathalie Skahjem	10-Feb-2014	Håøy	63.7389	9.94543	22 ± 1	Gravel, sand	Yes
DeVi01	*Delectopecten vitreus*	Guro Sylling	01-Jul-2008	Agdenesflua	63.6511	9.76263	116 ± 31	Hard bottom	Yes
PaSt03	*Palliolum striatum*	Guro Sylling	12-Jun-2006	Rødberg	63.4778	10.0103	30 ± 10		No
PoAu01	*Polititapes aureus*	Nathalie Skahjem	13-Jun-2018	Mølnbukta	63.6289	9.64262		Mixed bottom, with *Modiolus modiolus*	No
KaSu02	*Karnekampia sulcata*		26-Oct-2017	Stavøya	63.5947	9.50252	45 ± 6	Dead *Modiolus modiolus*	Yes
LiBa01	*Limecola balthica*	Nathalie Skahjem	29-Aug-2014	Grandefjaera	63.7033	9.57267		Soft bottom	Yes
PsPe01	*Pseudamussium peslutrae*		26-Oct-2017	Stavøya	63.5947	9.50252	45 ± 6	Dead *Modiolus modiolus*	No
NTNU-VM-68326	*Astarte elliptica*	Jon-Arne Sneli	06-Nov-2007	Fjordskjaeret	64.0177	9.98697	63 ± 22	Hard bottom, rocks with clay	No
AeOp01	*Aequipecten opercularis*	Jon-Arne Sneli	25-Nov-2014	Hemnefjorden	63.3228	9.14118			No
Myt01	*Mytilus edulis*	Nathalie Skahjem	11-Jun-2018	Sletvik	63.5945	9.5255			Yes
AeOp02	*Aequipecten opercularis*	Jon-Arne Sneli	25-Nov-2014	Snillfjord (ytre)	63.3641	9.30358			No
NTNU-VM-71969	*Acesta excavata*	Jon-Arne Sneli	10-Feb-2014	Agdenesflua	63.6531	9.76397	225 ± 75	Corals	Yes
NTNU-VM-70530	*Delectopecten vitreus*	Jon-Arne Sneli	12-Feb-2014	Valset	63.65	9.70948	153 ± 49	Sand	No
PaSt02	*Palliolum striatum*	Nathalie Skahjem	07-Feb-2018		63.4437	10.6519	24 ± 6		No

HeSq01	*Heteranomia squamula*	Nathalie Skahjem	12-Jun-2018	Agdenesflua	63.6529	9.76623	183 ± 116	Hard bottom	No
AsMo01	*Astarte montagui*	Øystein Stokland	28-Aug-2011	Tautrasvaet	63.555	10.6217	6	Rock, clay	No
KaSu01	*Karnekampia sulcata*	Nathalie Skahjem	13-Jun-2018	Trondheimsleia	63.6193	9.53498	416 ± 6	Mixed bottom	Yes
PaIn03	*Palliolum incomparabile*	Nathalie Skahjem	12-Jun-2006	Stavøy	63.5947	9.50333	125 ± 75		No
NTNU-VM-67397	*Palliolum incomparabile*	Nathalie Skahjem	05-Nov-2007	Tørrisholmflua	63.7912	9.48633	44 ± 6	Rocks	No
ChSt01	*Chamelea striatula*	Øystein Stokland	28-Aug-2011	Tautrasvaet	63.562	10.621	3	Gravel, rock	No
NTNU-VM-64685	*Palliolum incomparabile*	Guro Sylling	02-Jul-2008	Stavøy	63.5917	9.49903	68 ± 36	Gravel, rock	No
Dac02	*Dacrydium*	Nathalie Skahjem	07-Feb-2018		63.4475	10.6273	75 ± 2		Yes
Dac01	*Dacrydium*	Nathalie Skahjem	07-Feb-2018		63.4475	10.6273	75 ± 2		Yes
PaSt01	*Palliolum striatum*	Nathalie Skahjem	13-Jun-2018	Trondheimsleia	63.6193	9.53498	416 ± 6	Mixed bottom	No
NTNU-VM-71824	*Karnekampia sulcata*	Jon-Arne Sneli	08-Nov-2007	Terningen	64.2298	10.2519	88 ± 42	Hard bottom, big rock	No
PaPi01	*Parvicardium pinnulatum*	Nathalie Skahjem	29-Jun-2018	Mølnbukta	63.6289	9.64262		Mixed bottom, *Modiolus modiolus*	No
NTNU-VM-71163	*Dosinia lupinus*	Øystein Stokland	28-Aug-2011	Tautrasvaet	63.5652	10.6313	5 ± 1	Rocks	No
NTNU-VM-70484	*Modiolula phaseolina*	Jon-Arne Sneli	10-Feb-2014	Prestbukta	63.4833	9.99957	26 ± 14	Rocks, a little bit of sand	Yes
PaIn02	*Palliolum incomparabile*	Nathalie Skahjem	07-Feb-2018		63.4475	10.6273	75 ± 2		No
PaTi03	*Palliolum tigerinum*	Nathalie Skahjem	13-Jun-2018	Mølnbukta	63.6289	9.64262		Mixed bottom, *Modiolus modiolus*	Yes
PaTi04	*Palliolum tigerinum*		06-Nov-2007	Lysøysund	63.9144	9.88858	60 ± 10	Hard bottom, rocks	No
PaTi01	*Palliolum tigerinum*	Nathalie Skahjem	12-Jun-2018	Brødreskift	63.6831	10.0825	36 ± 12		Yes
MoPh01	*Modiolula phaseolina*		26-Oct-2017	Stavøya	63.5947	9.50252	45 ± 6	Dead *Modiolus modiolus*	No
Nath07	*Kellia suborbicularis*	Nathalie Skahjem	29-Jun-2018	Mølnbukta	63.6289	9.64262		Mixed bottom, *Modiolus modiolus*	No
NTNU-VM-71970	*Delectopecten vitreus*	Jon-Arne Sneli	11-Feb-2014	Karlsøya	63.7972	9.34293	208 ± 62	Dead *Lophelia*, clay	No
HiAr01	*Hiatella arctica*	Nathalie Skahjem	12-Jun-2018	Agdenesflua	63.6529	9.76623	183 ± 116	Hard bottom	No

NTNU-VM-70480	*Hiatella arctica*	Jon-Arne Sneli	12-Feb-2014	Valset	63.65	9.70948	153 ± 49	Sand	No
AcEc02	*Acanthocardia echinata*	Jon-Arne Sneli	06-Nov-2007	Valsfjorden	63.8133	9.64947	67 ± 1	Soft bottom, mud with shell fragments	No
AcEc01	*Acanthocardia echinata*	Jon-Arne Sneli	06-Nov-2007	Valsfjorden	63.8133	9.64947	67 ± 1	Soft bottom, mud with shell fragments	No
NTNU-VM-71255	*Parvicardium pinnulatum*	Øystein Stokland	28-Aug-2011	Tautrasvaet	63.563	10.6345	5	Clay, sand	No
NTNU-VM-67330	*Parvicardium pinnulatum*	Nathalie Skahjem	08-Nov-2007	Brandsfjorden	64.2083	10.3584	135 ± 6	Soft bottom	No
CeEd01	*Cerastoderma edule*	Jon-Arne Sneli	10-Feb-2014	Prestbukta	63.4833	9.99957	26 ± 15	Rocks, a little bit of sand	Yes
PaMi05	*Parvicardium minimum*	Jon-Arne Sneli	17-Jan-2013	Flakk	63.4447	10.1771	41 ± 10	Sand, clay	No
CuOb01	*Cuspidaria obesa*	Jon-Arne Sneli	17-Jan-2013	Flakk	63.4447	10.1771	41 ± 10	Sand, clay	Yes
MyAr02	*Mya arenaria*	Grethe S Haugen	31-Oct-2014	Øyamelen	63.3358	10.2157		Sand, clay, bits of old *Lophelia*	No
PaMi02	*Parvicardium minimum*	Nathalie Skahjem	07-Feb-2018		63.4475	10.6273	75 ± 2		No
MyAr01	*Mya arenaria*	Øystein Stokland	28-Aug-2011	Tautrasvaet	63.5783	10.6372	12		No
ArTe03	*Arca tetragona*	Nathalie Skahjem	2018-06-13	Mølnbukta	63.6289	9.64262		Mixed bottom, *Modiolus modiolus*	Yes
LyNo01	*Lyonsia norwegica*	Jon-Arne Sneli	06-Nov-2007	Valsfjorden	63.8133	9.64947	67 ± 1	Soft bottom, mud with shell fragments	No
GaTe02	*Gari tellinella*	Nathalie Skahjem	13-Jun-2018	Mølnbukta	63.6289	9.64262		Mixed bottom, *Modiolus modiolus*	Yes
NTNU-VM-203556	Thyasiridae	Nathalie Skahjem	07-Feb-2018		63.4475	10.6273	75 ± 2		Yes
NTNU-VM-203555	Thyasiridae	Nathalie Skahjem	07-Feb-2018		63.4441	10.5065	29 ± 1		No
Thy03	Thyasiridae	Nathalie Skahjem	07-Feb-2018		63.4441	10.5065	29 ± 1		Yes
Thy02	Thyasiridae	Nathalie Skahjem	07-Feb-2018		63.4441	10.5065	29 ± 1		No
Thy01	Thyasiridae	Nathalie Skahjem	07-Feb-2018		63.4551	10.5319	127 ± 3		Yes
ThSa01	*Thyasira sarsii*	Øystein Stokland	28-Aug-2011	Tautrasvaet	63.5633	10.6517	9		No
KeMi05	*Kelliella miliaris*			Ytterøy	63.7881	11.1617	20		No
KeMi04	*Kelliella miliaris*			Ytterøy	63.7881	11.1617	20		No
KeMi03	*Kelliella miliaris*	Jon-Arne Sneli	08-Nov-2007	Brandsfjorden	64.2234	10.2853	173 ± 6	Soft bottom	No

KeMi02	*Kelliella miliaris*	Jon-Arne Sneli	08-Nov-2007	Brandsfjorden	64.2234	10.2853	173 ± 6	Soft bottom	No
KeMi01	*Kelliella miliaris*	Jon-Arne Sneli	08-Nov-2007	Brandsfjorden	64.2234	10.2853	173 ± 6	Soft bottom	No
LiGw02	*Limatula gwyni*	Nathalie Skahjem	07-Feb-2018		63.4475	10.6273	75 ± 2		No
LiGw01	*Limatula gwyni*	Nathalie Skahjem	07-Feb-2018		63.4475	10.6273	75 ± 2		No
NTNU-VM-71826	*Bathyarca pectunculoides*	Jon-Arne Sneli	06-Nov-2007	Lauvøyfjorden	63.9094	9.88658	126 ± 6	Soft bottom, mud	No
AsNo04	*Asperarca nodulosa*	Nathalie Skahjem	12-Jun-2018	Agdenesflua	63.6529	9.76623	183 ± 116	Hard bottom	Yes
AsNo03	*Asperarca nodulosa*	Nathalie Skahjem	12-Jun-2018	Agdenesflua	63.6529	9.76623	183 ± 116	Hard bottom	Yes
AsNo02	*Asperarca nodulosa*		24-Oct-2016	Galgeneset	63.5861	9.84555	191 ± 89	Hard bottom	No
AsNo01	*Asperarca nodulosa*		24-Oct-2016	Galgeneset	63.5861	9.84555	191 ± 89	Hard bottom	Yes
NTNU-VM-70520	*Asperarca nodulosa*	Jon-Arne Sneli	12-Feb-2014	Røysaneset	63.6282	9.6055	184 ± 145	Dead *Modiolus modiolus*, Alcyonacea, Porifera	Yes
TrAb02	*Tropidomya abbreviata*	Jon-Arne Sneli	10-Feb-2014	Håøy	63.735	9.92843	128 ± 34	Clay	No
NTNU-VM-70539	*Tropidomya abbreviata*		11-Feb-2014	Karlsøya	63.7828	9.33658	253 ± 107	Mud, *Acesta*, *Primnoa*, Brachiopoda	Yes
TrAb01	*Tropidomya abbreviata*	Nathalie Skahjem	07-Feb-2018		63.4475	10.6273	75 ± 2		No
SaJe02	*Saxicavella jeffreysi*	Øystein Stokland	28-Aug-2011	Tautrasvaet	63.555	10.6217	6	Rocks, clay	No
SaJe01	*Saxicavella jeffreysi*	Øystein Stokland	28-Aug-2011	Tautrasvaet	63.555	10.6217	6	Rocks, clay	No
Thy08	Thyasiridae	Nathalie Skahjem	07-Feb-2018		63.4475	10.6273	75 ± 2		Yes
Thy07	Thyasiridae	Nathalie Skahjem	07-Feb-2018		63.4475	10.6273	75 ± 2		Yes
Thy06	Thyasiridae	Nathalie Skahjem	07-Feb-2018		63.4475	10.6273	75 ± 2		Yes
EnTe01	*Ennucula tenuis*	Nathalie Skahjem	07-Feb-2018		63.4475	10.6273	75 ± 2		No
NTNU-VM-67367	*Abra nitida*	Jon-Arne Sneli	06-Nov-2007	Lysøysund	63.9109	9.87693	43 ± 15	Hard bottom	No
AbNi04	*Abra nitida*	Nathalie Skahjem	07-Feb-2018		63.4475	10.6273	75 ± 2		No
AbNi03	*Abra nitida*		07-Nov-2007	Pølen	63.9901	10.0444	106 ± 4	Soft bottom	Yes
AbNi02	*Abra nitida*		06-Nov-2007	Valsfjorden	63.8133	9.64947	67 ± 1	Soft bottom	Yes
AbNi01	*Abra nitida*		08-Nov-2007	Brandsfjorden	64.2234	10.2853	173 ± 6	Soft bottom	No

AbLo01	*Abra longicallus*	Nathalie Skahjem	08-Nov-2007	Brandsfjorden	64.2083	10.3584	135 ± 6	Soft bottom	No
NTNU-VM-71270	*Abra alba*	Øystein Stokland	28-Aug-2011	Tautrasvaet	63.5583	10.6133	7	Clay, sand	No
AbAl04	*Abra alba*		06-Nov-2007	Valsfjorden	63.8133	9.64947	67 ± 1	Soft bottom	No
AbAl03	*Abra alba*		06-Nov-2007	Valsfjorden	63.8133	9.64947	67 ± 1	Soft bottom	Yes
AbAl02	*Abra alba*	Jon-Arne Sneli	07-Nov-2007	Pølen	63.9969	10.0225	100 ± 4	Soft bottom	Yes
AbAl01	*Abra alba*	Jon-Arne Sneli	07-Nov-2007	Pølen	63.9969	10.0225	100 ± 4	Soft bottom	Yes
Nath06	Bivalvia	Nathalie Skahjem	07-Feb-2018		63.4475	10.6273	75 ± 2		No
Nath05	Bivalvia	Nathalie Skahjem	07-Feb-2018		63.4475	10.6273	75 ± 2		Yes
Nath04	Bivalvia	Nathalie Skahjem	07-Feb-2018		63.4475	10.6273	75 ± 2		No
Nath03	Bivalvia	Nathalie Skahjem	07-Feb-2018		63.4441	10.5065	29 ± 1		No
Nath02	Bivalvia	Nathalie Skahjem	07-Feb-2018		63.4441	10.5065	29 ± 1		Yes
Nath01	Veneridae	Nathalie Skahjem	11-Jun-2018	Sletvik	63.5945	9.5255			Yes

APPENDIX II

```
library(ape)
library(phangorn)

file <- read.nexus.data("pect_align.nexus")
ml_dna <- as.DNAbin(file)
ml_phylo <- as.phyDat(ml_dna)

tr <- nj(dist.ml(ml_phylo))
ml <- pml(tr, ml_phylo,k=4)

test <- modelTest(ml_phylo,model="all")
bestmodel <- test$Model[which.min(test$AIC)]
bestmodel

ML <- optim.pml(ml, model="HKY",
rearrangement="stochastic",optGamma=TRUE, optInv=TRUE)

par(xpd=TRUE,mar=rep(2,4))
plot(ML,cex=.4)

tr$tip.label
outgr <- tr$tip.label[1:2]
outgr
plot(root(tr,outgr,resolve.root = TRUE),cex=.5,use.edge.length=TRUE)

bs <- bootstrap.pml(ML, bs=100, optNni=TRUE)
BP <- prop.clades(ML$tree,bs)

tree <- ML$tree
tree$node.label <- BP
drawSupportOnEdges(tree$node.label,cex=.5, frame="n", pos=1)

write.tree(tree, "pectinidae_ml.nwk")
```

APPENDIX III

Table B. A list of all studied material belonging to Pectinidae.

*Not all material was registered with a museum ID. When museum ID is absent, the station nr. or equivalent information is written instead, shaded in grey. Two of the shaded specimens are marked with **, these are vouchers used for the DNA Barcoding in this study. Specimens marked red are registered with museum ID, but I didn't get access to the information stored in the museum database.

Museum ID*	Institute storing	Species	No. of specimens studied	Identifier	Collection Date	Collection Site	Lat (°N)	Lon (°E)	Depth (m)	Depth precision (±m)	Habitat
5095	NTNU-VM	*Aequipecten opercularis*	3	Stokland, Øystein	12-Jun-1970	Bessholmen	63,7301	9,9563	97	89	Stone/gravel
5146	NTNU-VM	*Aequipecten opercularis*	1	Soot-Ryen, Tron		Stillevika	60,5788	4,7910			
64622	NTNU-VM	*Aequipecten opercularis*	2	Kaltenborn, Anita	21-Oct-1970	Nunfjorden	64,0216	10,0609	24	15	
65996	NTNU-VM	*Aequipecten opercularis*	3	Sneli, Jon-Arne	29-May-1970	Storegrunnen	63,5059	10,4295	14	5	
71779	NTNU-VM	*Aequipecten opercularis*	3	Jon-Arne Sneli	2014-Oct-25	Hemnefjorden	63,37095	9,30073			Coral/gravel
71780	NTNU-VM	*Aequipecten opercularis*	1	Sneli, Jon-Arne	26-Nov-2014	Hemnefjorden	63,2946	9,1097			
72359	NTNU-VM	*Aequipecten opercularis*	2	Nathalie Skahjem	2017-10-27	Tosenfjord	65.08144	012.45573			Top of a rope
72376	NTNU-VM	*Aequipecten opercularis*	3	Nathalie Skahjem	2017-10-27	Tosenfjord	65.11338	012.45394			Top of a rope
72380	NTNU-VM	*Aequipecten opercularis*	2	Nathalie Skahjem	2017-10-27	Tosenfjord	65.13478	012.56701			Top of a rope
HB 2016.9.7.2	ZMUB	*Aequipecten opercularis*	1		28-Jun-2006	Spærrumpen	58,3876	8,7490	66		Shell sand
5084	NTNU-VM	*Chlamys islandica*	1	Steinnes, Audun	11-Aug-1972	Jan Mayen	71,0000	-8,5000	75	15	
5108	NTNU-VM	*Chlamys islandica*	2			Tautra	63,5785	10,6125			
6908	NTNU-VM	*Chlamys islandica*	1	Stokland, Øystein	17-Aug-1979	Sunndalsfjorden	62,7871	8,3150	110		
60969	NTNU-VM	*Chlamys islandica*	1	Leiknes, Øystein	25-Jun-1973	Fiborgtangen	63,7442	11,1781	50	50	

69608	NTNU-VM	*Chlamys islandica*	1	Sneli, Jon-Arne	12-Jun-1993	Brøstadbotn	69,0892	17,6050	15	15	
69609	NTNU-VM	*Chlamys islandica*	1	Sneli, Jon-Arne	8-Jun-1993	Rebbenesøy	70,1075	18,1500	372	3	Coarse sand, rock
UNIS 2015, Stn: 825 RP Vest	ZMUB	*Chlamys islandica*	1		7-Sep-2016	Sotra, Glesvær	60,2007	5,0384	45	15	
64628	NTNU-VM	*Delectopecten vitreus*	3	Sylling, Guro	5-Dec-2006	Rødberg	63,4778	10,0103	250	50	Corals
69652	NTNU-VM	*Delectopecten vitreus*	1	Sneli, Jon-Arne	9-Jun-1993	Malangsdjupet	69,7950	17,0447	279	1	Mud, sand, rock
69653	NTNU-VM	*Delectopecten vitreus*	1	Sneli, Jon-Arne	6-Jun-1993	Sørøysundet	70,4302	22,7752	519	1	Mud, sand
HB2017-05-32AG	ZMUB	*Delectopecten vitreus*	8		6-May-2017	Sognefjorden	61,1268	5,7509	1255		
HM2014/06-43, RP	ZMUB	*Delectopecten vitreus*	4		10-Jun-2014	Høgsfjorden, right outside Lysefjorden	58,94855	5,98631	250	1	
R1512-158, RP	ZMUB	*Delectopecten vitreus*	1		21-Aug-2015	Norwegian Sea	64,9935	5,8958	490		
R1574-554, BSL: 260	ZMUB	*Delectopecten vitreus*	2		4-Sep-2015	Norwegian Sea	66,8491	8,4398	259		
R838-16, RP	ZMUB	*Delectopecten vitreus*	1		10-May-2012	Norwegian Sea	67,1322	9,9350	382	2	
8628	ZMUB	*Hyalopecten frigidus*	3								
67988	NTNU-VM	*Hyalopecten frigidus*	6	Kaltenborn, Anita	10-Jul-2001	Iceland	67,0227	-6,1937	3006	1	
5242	NTNU-VM	*Karnekampia sulcata*	3			Rødberg	63,4778	10,0103			
63450	NTNU-VM	*Karnekampia sulcata*	3	Kaltenborn, Anita	26-May-1994						
64617	NTNU-VM	*Karnekampia sulcata*	3	Sylling, Guro	13-Jun-2006	Agdeneståa	63,6457	9,7521	200	100	
64618	NTNU-VM	*Karnekampia sulcata*	4	Sylling, Guro	1-Jul-2008	Agdenesflua	63,6511	9,7626	115	31	Hard substrate
64621	NTNU-VM	*Karnekampia sulcata*	3	Sylling, Guro	13-Jun-2008	Stavøy	63,5910	9,4971	104	70	Shell fragments, dead *Modiolus modiolus*
72881	NTNU-VM	*Karnekampia sulcata*	8	Jon Arne Sneli	2016-10-24	Trondheimsfjorden, Galgenes	63 35.167	9 50.733	191	89	Hard substrate

R1096-62, RP	ZMUB	*Karnekampia sulcata*	2		17-Jun-2013	Norwegian Sea	65,92940	6,52997	332	1	
R1320-116, RP	ZMUB	*Karnekampia sulcata*	1		21-Apr-2014	Barents Sea	71,03267	29,65200	333		
R1330-500, BT	ZMUB	*Karnekampia sulcata*	1		24-Apr-2014	Barents Sea	71,18667	28,97083	381		
R1574-554, BSL: 259	ZMUB	*Karnekampia sulcata*	2		4-Sep-2015	Norwegian Sea	66,8491	8,4398	259		
46284	ZMUB	*Mimachlamys varia*	1								
49687	ZMUB	*Mimachlamys varia*	5								
51092	ZMUB	*Mimachlamys varia*	1								
55783	ZMUB	*Mimachlamys varia*	1								
59626	ZMUB	*Mimachlamys varia*	1								
68846	NTNU-VM	*Mimachlamys varia*	1	Sneli, Jon-Arne	20-Mar-1985	Norwegian Sea	61,2483	2,8050	190	190	
MiVa01**	NTNU-VM	*Mimachlamys varia*	1	Skahjem, Nathalie	11-Jun-2018	Sletvik	63,5945	9,5255	Littoral		
Polyskag 2014/10-8	ZMUB	*Mimachlamys varia*	1		8-Oct-2014				15		
5249	NTNU-VM	*Palliolum incomparabile*	1	Stokland, Øystein	19-Jul-1928	Grip	63,2307	7,6079	25		Coarse shell-sand
5250	NTNU-VM	*Palliolum incomparabile*	1	Stokland, Øystein	4-Jul-1935	Aursundet	63,2000	8,5803			
5251	NTNU-VM	*Palliolum incomparabile*	2	Stokland, Øystein	23-Aug-1951	Terningen fyr	63,4967	9,0244	20	10	
5252	NTNU-VM	*Palliolum incomparabile*	2	Stokland, Øystein	12-Jun-1970	Fevåg	63,6956	9,8700	22	7	Shell fragments, a lot of dead material
5253	NTNU-VM	*Palliolum incomparabile*	1	Stokland, Øystein	12-Jun-1970	Bessholmen	63,7301	9,9563	97	89	Stone/gravel
64675	NTNU-VM	*Palliolum incomparabile*	2	Sylling, Guro	10-Jun-1969	Vingvågen	63,5222	9,3056	32	17	
65325	NTNU-VM	*Palliolum incomparabile*	1	Sylling, Guro	3-Jul-1969	Risværfjorden	64,9819	11,5583	26	2	Gravel, slad, red algae, rock
72919	NTNU-VM	*Palliolum incomparabile*	1	Jon Arne Sneli	2016-10-26	Agdenes, Stavøya	63 35.650	9 30.487	50	6	Shell/gravel

72922	NTNU-VM	*Palliolum incomparabile*	3	Jon Arne Sneli	2016-10-26	Norskehavet	61.2416667	2.0266667	138		Shell/gravel
10164	ZMUB	*Palliolum striatum*	5								
55701	ZMUB	*Palliolum striatum*	1								
64682	NTNU-VM	*Palliolum striatum*	1	Sylling, Guro	7-Jul-1969	Øksningen	65,1500	12,3417	165	115	Stone/gravel
64693	NTNU-VM	*Palliolum striatum*	1	Sylling, Guro	28-Sep-1967	Rolsøydypet	63,8683	11,3283	15	15	
64698	NTNU-VM	*Palliolum striatum*	1	Sylling, Guro	13-Jun-2008	Stavøy	63,5910	9,4971	104	70	Shell fragments, dead *Modiolus modiolus*
5239	NTNU-VM	*Palliolum tigerinum*	1	Stokland, Øystein	12-Jun-1970	Fevåg	63,6956	9,8700	22	7	Shell fragments, a lot of dead material
5246	NTNU-VM	*Palliolum tigerinum*	1	Stokland, Øystein	12-Jun-1970	Bessholmen	63,7301	9,9563	97	89	Stone/gravel
10271	ZMUB	*Palliolum tigerinum*	3								
11134	ZMUB	*Palliolum tigerinum*	2								
11137	ZMUB	*Palliolum tigerinum*	2								
11138	ZMUB	*Palliolum tigerinum*	1								
42825	ZMUB	*Palliolum tigerinum*	2								
46132	ZMUB	*Palliolum tigerinum*	1								
46137	ZMUB	*Palliolum tigerinum*	2								
46144	ZMUB	*Palliolum tigerinum*	1								
47867	ZMUB	*Palliolum tigerinum*	1								
48248	ZMUB	*Palliolum tigerinum*	1								
55713	ZMUB	*Palliolum tigerinum*	2								

63453	NTNU-VM	*Palliolum tigerinum*	1	Olssøn, Ragni	10-Jun-1986	Norwegian Sea	62,5050	-5,2083	115	115	
69727	NTNU-VM	*Palliolum tigerinum*	1	Sneli, Jon-Arne	10-Jun-1993	Bjarkøy	68,9835	16,5418	39	3	
HB2017.06.06-2	ZMUB	*Palliolum tigerinum*	1		20-Jan-2016	Vatlestraumen, Nilsvika	60,3347	5,1741	50		
Vatlestraumen 20/1-2016	ZMUB	*Palliolum tigerinum*	2		13-May-2015	Svalbard	78,14872	13,12559	243		
5243	NTNU-VM	*Pecten maximus*	1		3-Jul-1970	Leinøya by Røyrasund	62,3208	5,7278	21	9	*Laminaria* and rocks
71789	NTNU-VM	*Pecten maximus*	1	Sneli, Jon-Arne	10-Feb-2014	Prestbukta	63,4833	9,9996	26	14	Coarse rock with a small amount of sand
106065	ZMUB	*Pecten maximus*	1								
106066	ZMUB	*Pecten maximus*	1								
G.M.Dannevig 2006, Stn: 21	ZMUB	*Pecten maximus*	1		6-Jun-2017	Vatlestraumen	60,3272	5,1446	54	1	Gravel
PeMa02**	NTNU-VM	*Pecten maximus*	1	Skahjem, Nathalie	30-Jun-2018	Vernes ferry docks	63,5808	9,5095			
5280	NTNU-VM	*Pseudamussium peslutrae*	1		24-Jul-1923	Tømmerdalen	63,6131	10,5897	225	25	Soft substrate, clay
63301	NTNU-VM	*Pseudamussium peslutrae*	1	Kaltenborn, Anita	26-May-1994						
67392	NTNU-VM	*Pseudamussium peslutrae*	1	Kaltenborn, Anita	8-Nov-2007	Terningen	64,2298	10,2519	87	42	Hard substrate, big rock
67394	NTNU-VM	*Pseudamussium peslutrae*	1	Kaltenborn, Anita	7-Nov-2007	Kovsodden	64,0844	9,9731	150	50	Hard substrate, rock with clay
69610	NTNU-VM	*Pseudamussium peslutrae*	1		9-Jun-1993	Rebbenesøy	70,1593	17,8840	328	4	Mud, sand
72909	NTNU-VM	*Pseudamussium peslutrae*	1	Jon Arne Sneli	2016-10-26	Agdenes, Stavøya	63 35.650	9 30.487	50	6	Shell/gravel
HM2014/06-42	ZMUB	*Pseudamussium peslutrae*	2		10-Jun-2014	Høgsfjorden, right outside Lysefjorden	58,94339	5,99305	248	2	
HM2014/06-43	ZMUB	*Pseudamussium peslutrae*	1		10-Jun-2014	Høgsfjorden, right outside Lysefjorden	58,94855	5,98631	250	1	Mud

Håkon Mosby - Møre 2005, stn. 49	ZMUB	*Pseudamussium peslutrae*	9		13-Oct-2005	Kornstadfjorden	62,93767	7,55767	108	1	Many sponges and small pectinids
KB2017-05-34RT	ZMUB	*Pseudamussium peslutrae*	1		6-May-2017	North Sea	60,9343	4,2703	419		
R1096-62, RP	ZMUB	*Pseudamussium peslutrae*	1								
5105	NTNU-VM	*Talochlamys pusio*	1	Stokland, Øystein	23-Aug-1951	Ramsøysund	63,4298	8,3357	11	3	
5157	NTNU-VM	*Talochlamys pusio*	1	Sylling, Guro	10-Jun-1969	Vingvågen	63,5244	9,3066	60		
57266	NTNU-VM	*Talochlamys pusio*	1	Kaltenborn, Anita	25-Jun-1936	Terningen	63,4951	9,0392			
64623	NTNU-VM	*Talochlamys pusio*	1	Sylling, Guro	2-Jul-2008	Stavøy	63,5917	9,4990	67	36	Shell fragments, dead *Modiolus modiolus*
64940	NTNU-VM	*Talochlamys pusio*	1	Sneli, Jon-Arne	29-Jun-1970	Dromnessundet	63,4000	8,6111	15	5	Kelp, some small rocks
65988	NTNU-VM	*Talochlamys pusio*	1		14-Aug-1974	Inntian	63,6892	8,9214	17	17	
66163	NTNU-VM	*Talochlamys pusio*	1		29-May-1970	Storegrunnen	63,5059	10,4295	14	5	
Vatlestraumen 4th May 2005	ZMUB	*Talochlamys pusio*	1		4-May-2005				25		Gravel

Museum ID*	Institute storing	Species	No. of specimens studied	Identifier	Collection Date	Collection Site	Lat (°N)	Lon (°E)	Depth (m)	Depth precision (m)	Habitat
5095	NTNU-VM	*Aequipecten opercularis*	3	Stokland, Øystein	12-Jun-1970	Bessholmen	63,7301	9,9563	97	89	Stone/gravel
5146	NTNU-VM	*Aequipecten opercularis*	1	Soot-Ryen, Tron		Stillevika	60,5788	4,7910			
64622	NTNU-VM	*Aequipecten opercularis*	2	Kaltenborn, Anita	21-Oct-1970	Nunfjorden	64,0216	10,0609	24	15	
65996	NTNU-VM	*Aequipecten opercularis*	3	Sneli, Jon-Arne	29-May-1970	Storegrunnen	63,5059	10,4295	14	5	
71779	NTNU-VM	*Aequipecten opercularis*	3	Jon-Arne Sneli	25-Oct-2016	Hemnefjorden	63,37095	9,30073			Coral/gravel
71780	NTNU-VM	*Aequipecten opercularis*	1	Sneli, Jon-Arne	26-Nov-2014	Hemnefjorden	63,2946	9,1097			

72359	NTNU-VM	*Aequipecten opercularis*	2	Nathalie Skahjem	27-Oct-2017	Tosenfjord	65,0814	12,4557			Top of a rope
72376	NTNU-VM	*Aequipecten opercularis*	3	Nathalie Skahjem	27-Oct-2017	Tosenfjord	65,1133	12,4539			Top of a rope
72380	NTNU-VM	*Aequipecten opercularis*	2	Nathalie Skahjem	27-Oct-2017	Tosenfjord	65,1347	12,5670			Top of a rope
HB 2016.9.7.2	ZMUB	*Aequipecten opercularis*	1		28-Jun-2006	Spærrumpen	58,3876	8,7490	66		Shell sand
5084	NTNU-VM	*Chlamys islandica*	1	Steinnes, Audun	11-Aug-1972	Jan Mayen	71,0000	-8,5000	75	15	
5108	NTNU-VM	*Chlamys islandica*	2			Tautra	63,5785	10,6125			
6908	NTNU-VM	*Chlamys islandica*	1	Stokland, Øystein	17-Aug-1979	Sunndalsfjorden	62,7871	8,3150	110		
60969	NTNU-VM	*Chlamys islandica*	1	Leiknes, Øystein	25-Jun-1973	Fiborgtangen	63,7442	11,1781	50	50	
69608	NTNU-VM	*Chlamys islandica*	1	Sneli, Jon-Arne	12-Jun-1993	Brøstadbotn	69,0892	17,6050	15	15	
69609	NTNU-VM	*Chlamys islandica*	1	Sneli, Jon-Arne	8-Jun-1993	Rebbenesøy	70,1075	18,1500	372	3	Coarse sand, rock
UNIS 2015, Stn: 825 RP Vest	ZMUB	*Chlamys islandica*	1		7-Sep-2016	Sotra, Glesvær	60,2007	5,0384	45	15	
64628	NTNU-VM	*Delectopecten vitreus*	3	Sylling, Guro	5-Dec-2006	Rødberg	63,4778	10,0103	250	50	Corals
69652	NTNU-VM	*Delectopecten vitreus*	1	Sneli, Jon-Arne	9-Jun-1993	Malangsdjupet	69,7950	17,0447	279	1	Mud, sand, rock
69653	NTNU-VM	*Delectopecten vitreus*	1	Sneli, Jon-Arne	6-Jun-1993	Sørøysundet	70,4302	22,7752	519	1	Mud, sand
HB2017-05-32AG	ZMUB	*Delectopecten vitreus*	8		6-May-2017	Sognefjorden	61,1268	5,7509	1255		
HM2014/06-43, RP	ZMUB	*Delectopecten vitreus*	4		10-Jun-2014	Høgsfjorden, right outside Lysefjorden	58,94855	5,98631	250	1	
R1512-158, RP	ZMUB	*Delectopecten vitreus*	1		21-Aug-2015	Norwegian Sea	64,9935	5,8958	490		
R1574-554, BSL: 260	ZMUB	*Delectopecten vitreus*	2		4-Sep-2015	Norwegian Sea	66,8491	8,4398	259		
R838-16, RP	ZMUB	*Delectopecten vitreus*	1		10-May-2012	Norwegian Sea	67,1322	9,9350	382	2	
8628	ZMUB	*Hyalopecten frigidus*	3								

67988	NTNU-VM	*Hyalopecten frigidus*	6	Kaltenborn, Anita	10-Jul-2001	Iceland	67,0227	-6,1937	3006	1	
5242	NTNU-VM	*Karnekampia sulcata*	3			Rødberg	63,4778	10,0103			
63450	NTNU-VM	*Karnekampia sulcata*	3	Kaltenborn, Anita	26-May-1994						
64617	NTNU-VM	*Karnekampia sulcata*	3	Sylling, Guro	13-Jun-2006	Agdeneståa	63,6457	9,7521	200	100	
64618	NTNU-VM	*Karnekampia sulcata*	4	Sylling, Guro	1-Jul-2008	Agdenesflua	63,6511	9,7626	115	31	Hard substrate
64621	NTNU-VM	*Karnekampia sulcata*	3	Sylling, Guro	13-Jun-2008	Stavøy	63,5910	9,4971	104	70	Shell fragments, dead *Modiolus modiolus*
72881	NTNU-VM	*Karnekampia sulcata*	8	Sneli, Jon-Arne	24-Oct-2016	Galgenes	63,5861	9,8455	191	89	Hard substrate
R1096-62, RP	ZMUB	*Karnekampia sulcata*	2		17-Jun-2013	Norwegian Sea	65,92940	6,52997	332	1	
R1320-116, RP	ZMUB	*Karnekampia sulcata*	1		21-Apr-2014	Barents Sea	71,03267	29,65200	333		
R1330-500, BT	ZMUB	*Karnekampia sulcata*	1		24-Apr-2014	Barents Sea	71,18667	28,97083	381		
R1574-554, BSL: 259	ZMUB	*Karnekampia sulcata*	2		4-Sep-2015	Norwegian Sea	66,8491	8,4398	259		
46284	ZMUB	*Mimachlamys varia*	1								
49687	ZMUB	*Mimachlamys varia*	5								
51092	ZMUB	*Mimachlamys varia*	1								
55783	ZMUB	*Mimachlamys varia*	1								
59626	ZMUB	*Mimachlamys varia*	1								
68846	NTNU-VM	*Mimachlamys varia*	1	Sneli, Jon-Arne	20-Mar-1985	Norwegian Sea	61,2483	2,8050	190	190	
MiVa01**	NTNU-VM	*Mimachlamys varia*	1	Skahjem, Nathalie	11-Jun-2018	Sletvik	63,5945	9,5255	Littoral		
Polyskag 2014/10-8	ZMUB	*Mimachlamys varia*	1		8-Oct-2014				15		
5249	NTNU-VM	*Palliolum incomparabile*	1	Stokland, Øystein	19-Jul-1928	Grip	63,2307	7,6079	25		Coarse shell-sand

5250	NTNU-VM	*Palliolum incomparabile*	1	Stokland, Øystein	4-Jul-1935	Aursundet	63,2000	8,5803			
5251	NTNU-VM	*Palliolum incomparabile*	2	Stokland, Øystein	23-Aug-1951	Terningen fyr	63,4967	9,0244	20	10	
5252	NTNU-VM	*Palliolum incomparabile*	2	Stokland, Øystein	12-Jun-1970	Fevåg	63,6956	9,8700	22	7	Shell fragments, a lot of dead material
5253	NTNU-VM	*Palliolum incomparabile*	1	Stokland, Øystein	12-Jun-1970	Bessholmen	63,7301	9,9563	97	89	Stone/gravel
64675	NTNU-VM	*Palliolum incomparabile*	2	Sylling, Guro	10-Jun-1969	Vingvågen	63,5222	9,3056	32	17	
65325	NTNU-VM	*Palliolum incomparabile*	1	Sylling, Guro	3-Jul-1969	Risværfjorden	64,9819	11,5583	26	2	Gravel, slad, red algae, rock
72919	NTNU-VM	*Palliolum incomparabile*	1	Sneli, Jon-Arne	26-May-2016	Stavøya	63,5941	9,5081	50	6	Shell/gravel
72922	NTNU-VM	*Palliolum incomparabile*	3	Sneli, Jon-Arne	26-May-2016	Norwegian Sea	61,2416	2,0266	138		Shell/gravel
10164	ZMUB	*Palliolum striatum*	5								
55701	ZMUB	*Palliolum striatum*	1								
64682	NTNU-VM	*Palliolum striatum*	1	Sylling, Guro	7-Jul-1969	Øksningen	65,1500	12,3417	165	115	Stone/gravel
64693	NTNU-VM	*Palliolum striatum*	1	Sylling, Guro	28-Sep-1967	Rolsøydypet	63,8683	11,3283	15	15	
64698	NTNU-VM	*Palliolum striatum*	1	Sylling, Guro	13-Jun-2008	Stavøy	63,5910	9,4971	104	70	Shell fragments, dead *Modiolus modiolus*
5239	NTNU-VM	*Palliolum tigerinum*	1	Stokland, Øystein	12-Jun-1970	Fevåg	63,6956	9,8700	22	7	Shell fragments, a lot of dead material
5246	NTNU-VM	*Palliolum tigerinum*	1	Stokland, Øystein	12-Jun-1970	Bessholmen	63,7301	9,9563	97	89	Stone/gravel
10271	ZMUB	*Palliolum tigerinum*	3								
11134	ZMUB	*Palliolum tigerinum*	2								

11137	ZMUB	*Palliolum tigerinum*	2								
11138	ZMUB	*Palliolum tigerinum*	1								
42825	ZMUB	*Palliolum tigerinum*	2								
46132	ZMUB	*Palliolum tigerinum*	1								
46137	ZMUB	*Palliolum tigerinum*	2								
46144	ZMUB	*Palliolum tigerinum*	1								
47867	ZMUB	*Palliolum tigerinum*	1								
48248	ZMUB	*Palliolum tigerinum*	1								
55713	ZMUB	*Palliolum tigerinum*	2								
63453	NTNU-VM	*Palliolum tigerinum*	1	Olssøn, Ragni	10-Jun-1986	Norwegian Sea	62,5050	-5,2083	115	115	
69727	NTNU-VM	*Palliolum tigerinum*	1	Sneli, Jon-Arne	10-Jun-1993	Bjarkøy	68,9835	16,5418	39	3	
HB2017.06.06-2	ZMUB	*Palliolum tigerinum*	1		20-Jan-2016	Vatlestraumen, Nilsvika	60,3347	5,1741	50		
Vatlestraumen 20/1-2016	ZMUB	*Palliolum tigerinum*	2		13-May-2015	Svalbard	78,14872	13,12559	243		
5243	NTNU-VM	*Pecten maximus*	1		3-Jul-1970	Leinøya by Røyrasund	62,3208	5,7278	21	9	*Laminaria* and rocks
71789	NTNU-VM	*Pecten maximus*	1	Sneli, Jon-Arne	10-Feb-2014	Prestbukta	63,4833	9,9996	26	14	Coarse rock with a small amount of sand
106065	ZMUB	*Pecten maximus*	1								
106066	ZMUB	*Pecten maximus*	1								
G.M.Dannevig 2006, Stn: 21	ZMUB	*Pecten maximus*	1		6-Jun-2017	Vatlestraumen	60,3272	5,1446	54	1	Gravel
PeMa02**	NTNU-VM	*Pecten maximus*	1	Skahjem, Nathalie	30-Jun-2018	Vernes ferry docks	63,5808	9,5095			
5280	NTNU-VM	*Pseudamussium peslutrae*	1		24-Jul-1923	Tømmerdalen	63,6131	10,5897	225	25	Soft substrate, clay

63301	NTNU-VM	*Pseudamussium peslutrae*	1	Kaltenborn, Anita	26-May-1994						
67392	NTNU-VM	*Pseudamussium peslutrae*	1	Kaltenborn, Anita	8-Nov-2007	Terningen	64,2298	10,2519	87	42	Hard substrate, big rock
67394	NTNU-VM	*Pseudamussium peslutrae*	1	Kaltenborn, Anita	7-Nov-2007	Kovsodden	64,0844	9,9731	150	50	Hard substrate, rock with clay
69610	NTNU-VM	*Pseudamussium peslutrae*	1		9-Jun-1993	Rebbenesøy	70,1593	17,8840	328	4	Mud, sand
72909	NTNU-VM	*Pseudamussium peslutrae*	1	Sneli, Jon-Arne	26-Oct-2016	Stavøya	63,5941	9,5081	50	6	Shell/gravel
HM2014/06-42	ZMUB	*Pseudamussium peslutrae*	2		10-Jun-2014	Høgsfjorden, right outside Lysefjorden	58,94339	5,99305	248	2	
HM2014/06-43	ZMUB	*Pseudamussium peslutrae*	1		10-Jun-2014	Høgsfjorden, right outside Lysefjorden	58,94855	5,98631	250	1	Mud
Håkon Mosby - Møre 2005, stn. 49	ZMUB	*Pseudamussium peslutrae*	9		13-Oct-2005	Kornstadfjorden	62,93767	7,55767	108	1	Many sponges and small pectinids
KB2017-05-34RT	ZMUB	*Pseudamussium peslutrae*	1		6-May-2017	North Sea	60,9343	4,2703	419		
R1096-62, RP	ZMUB	*Pseudamussium peslutrae*	1								
5105	NTNU-VM	*Talochlamys pusio*	1	Stokland, Øystein	23-Aug-1951	Ramsøysund	63,4298	8,3357	11	3	
5157	NTNU-VM	*Talochlamys pusio*	1	Sylling, Guro	10-Jun-1969	Vingvågen	63,5244	9,3066	60		
57266	NTNU-VM	*Talochlamys pusio*	1	Kaltenborn, Anita	25-Jun-1936	Terningen	63,4951	9,0392			
64623	NTNU-VM	*Talochlamys pusio*	1	Sylling, Guro	2-Jul-2008	Stavøy	63,5917	9,4990	67	36	Shell fragments, dead *Modiolus modiolus*
64940	NTNU-VM	*Talochlamys pusio*	1	Sneli, Jon-Arne	29-Jun-1970	Dromnessundet	63,4000	8,6111	15	5	Kelp, some small rocks
65988	NTNU-VM	*Talochlamys pusio*	1		14-Aug-1974	Inntian	63,6892	8,9214	17	17	

66163	NTNU-VM	*Talochlamys pusio*	1		29-May-1970	Storegrunnen	63,5059	10,4295	14	5	
Vatlestraumen 4th May 2005	ZMUB	*Talochlamys pusio*	1		4-May-2005				25		Gravel

APPENDIX IV

Table C. Marine bivalve species found in Norwegian waters.

Family	Species
Anomiidae	*Anomia ephippium*
	Heteranomia squamula
	Pododesmus patelliformis
	P. squama
Arcidae	*Arca tetragona*
	Asperarca nodulosa
	Bathyarca frielei
	B. glacialis
	B. pectunculoides
	B. philippiana
Arcticidae	*Arctica islandica*
Astartidae	*Astarte arctica*
	A. acuticostata
	A. borealis
	A. crebricostata
	A. crenata
	A. elliptica
	A. montagui
	A. sulcata
	Goodallia triangularis
Basterotiidae	*Saxicavella jeffreysi*
Cardiidae	*Acanthocardia echinata*
	A. aculeata
	Cerastoderma edule
	C. glaucum
	Ciliatocardium ciliatum
	Goethemia elegantula
	Laevicardium crassum
	Parvicardium exiguum
	P. minimum
	P. pinnulatum
	P. scabrum
	Serripes groenlandicus
Corbulidae	*Corbula gibba*
Cuspidariidae	*Cardiomya cadiziana*
	C. costellata
	C. striata
	Cuspidaria arctica
	C. centobi
	C. cuspidata
	C. glacialis
	C. lamellosa
	C. obesa
	C. rostrata
	C. subtorta
	Tropidomya abbreviata
Donacidae	*Donax vittatus*
Glossidae	*Glossus humanus*

Glycymerididae	*Glycymeris glycymeris*
Hiatellidae	*Hiatella arctica*
	H. rugosa
	Panomya norvegica
Kelliellidae	*Kelliella miliaris*
Kelliidae	*Kellia suborbicularis*
Lasaeidae	*Altenaeum dawsoni*
	Boreacola maltzani
	Devonia perrieri
	Epilepton clarkiae
	Hemilepton nitidum
	Kelliola symmetros
	Kurtiella bidentata
	K. tumidula
	Lasaea rubra
	Lepton squamosum
	Montacuta substriata
	Tellimya ferruginosa
	T. tenella
	T. voeringi
Limidae	*Acesta excavata*
	Limaria hians
	L. loscombi
	Limatula gwyni
	L. subauriculata
	L. subovata
	Limea crassa
Limopsidae	*Limopsis cristata*
	L. aurita
	L. minuta
Lucinidae	*Lucinoma borealis*
	Myrtea spinifera
Lyonsiellidae	*Lyonsiella abyssicola*
	Policordia jeffreysi
Lyonsiidae	*Lyonsia arenosa*
	Lyonsia norwegica
Mactridae	*Lutraria lutraria*
	Mactra stultorum
	Rangia cuneata
	Spisula elliptica
	S. solida
	S. subtruncata
Malletiidae	*Malletia obtusa*
Myidae	*Mya arenaria*
	M. pseudoarenaria
	M. truncata
	Sphenia binghami
Mytilidae	*Crenella decussata*

	Dacrydium ockelmanni
	D. vitreum
	Gibbomodiola adriatica
	Idas simpsoni
	Modiolula phaseolina
	Modiolus modiolus
	Musculus discors
	M. niger
	M. subpictus
	Mytilus edulis
	M. trossulus
Nuculanidae	*Nuculana minuta*
	N. pernula
	Ledella messanensis
	L. pustulosa
Nuculidae	*Ennucula corticata*
	E. tenuis
	Nucula atacellana
	N. hanleyi
	N. nitidosa
	N. nucleus
	N. sulcata
	N. tumidula
Ostreidae	*Magallana gigas*
	Ostrea edulis
Pandoridae	*Pandora pinna*
Parilimyidae	*Parilimya loveni*
Pectinidae	*Aequipecten opercularis*
	Chlamys islandica
	Delectopecten vitreus
	Hyalopecten frigidus
	Karnekampia sulcata
	Mimachlamys varia
	Palliolum incomparabile
	P. striatum
	P. tigerinum
	Pecten maximus
	Pseudamussium peslutrae
	Talochlamys pusio
Periplomatidae	*Cochlodesma praetenue*
Pharidae	*Ensis ensis*
	E. leei
	E. magnus
	E. minor
	E. siliqua
	Phaxas pellucidus
Pholadidae	*Barnea candida*
	Pholas dactylus
	Zirfaea crispata
Poromyidae	*Poromya granulata*
Propeamussiidae	*Cyclopecten hoskynsi*
	Similipecten greenlandicus
	S. similis

Psammobiidae	*Gari costulata*
	G. depressa
	G. fervensis
	G. tellinella
Semelidae	*Abra alba*
	A. longicallus
	A. nitida
	A. prismatica
	A. tenuis
	Scrobicularia plana
Solecurtidae	*Azorinus chamasolen*
	Solecurtus scopula
Solenidae	*Solen marginatus*
Tellinidae	*Arcopagia crassa*
	Asbjornsenia pygmaea
	Fabulina fabula
	Limecola balthica
	Macoma calcarea
	M. moesta
	Macomangulus tenuis
Teredinidae	*Nototeredo norvagica*
	Psiloteredo megotara
	Teredo navalis
Thraciidae	*Thracia convexa*
	T. distorta
	T. gracilis
	T. myopsis
	T. phaseolina
	T. pubescens
	T. septentrionalis
	T. villosiuscula
Thyasiridae	*Adontorhina similis*
	Axinopsida orbiculata
	Axinulus croulinensis
	Genaxinus eumyarius
	Leptaxinus minutus
	Mendicula ferruginosa
	M. ockelmanni
	M. pygmaea
	Parathyasira dunbari
	P. equalis
	Thyasira biplicata
	T. flexuosa
	T. gouldi
	T. granulosa
	T. obsoleta
	T. sarsii
	T. succisa
Veneridae	*C. striatula*
	Clausinella fasciata
	Dosinia exoleta
	D. fibula
	D. lupinus
	Gouldia minima
	Mercenaria mercenaria
	Mysia undata

	Petricolaria pholadiformis *Polititapes aureus* *P. rhomboides* *Ruditapes decussatus* *R. philippinarum* *Timoclea ovata* *Turtonia minuta* *Venerupis corrugata* *Venus casina* *V. verrucosa*
Xylophagidae	*Xylophaga dorsalis* *X. nidarosiensis* *X. noradi* *X. praestans*
Yoldiidae	*Microgloma pusilla* *Portlandia arctica* *Yoldia amygdalea* *Y. hyperborea* *Yoldiella annenkovae* *Y. curta* *Y. frigida* *Y. intermedia* *Y. lenticula* *Y. lucida* *Y. nana* *Y. philippiana* *Y. propinqua* *Y. similis* *Y. solidula*