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ECOSYSTEM OVERVIEW:

PACIFIC NORTH COAST INTEGRATED MANAGEMENT AREA (PNCIMA)

APPENDIX F: INVERTEBRATES

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1.0 INTRODUCTION

The purpose of this chapter is to inform the public, planners, as well as oceans, resource and habitat managers on the state of knowledge about marine invertebrates in the Pacific North Coast Integrated Management Area (PNCIMA, Figure F.0) as we presently understand it; the issues surrounding these organisms; and the information gaps with respect to marine invertebrates that need to be addressed to provide informed management decisions.

The number of known marine invertebrate species is estimated to exceed 140,000 (Ruppert and Barnes 1994), and well over 6,000 species are estimated to occur in the North-eastern Pacific Ocean in the vicinity of PNCIMA (Austin 1985). The distribution of marine invertebrates throughout PNCIMA ranges from the intertidal zone to the deep-water abyss and from sheltered coves to the exposed open coast.

Due to their wide and extensive distribution, marine invertebrate communities may be affected by a wide variety of human activities such as: fishing, aquaculture development and facilities, oil and gas exploration and extraction, shipping, coastal community development and expansion, coastal mining activities, and forestry related activities such as pulp and paper waste discharge and log storage.

The state of knowledge for most of these animals is minimal and very fragmented. Historically, the only information on non-harvested species of invertebrates in the PNCIMA area was from the traditional ecological knowledge of First Nations' communities and a very few taxonomic collection surveys of the area. Programs for the systematic and ongoing collection of data on non-harvested invertebrate species have just recently been initiated. More detailed and specific information is available on the commercially harvested species. It is not the intention of this chapter to detail the most up to date commercial fisheries information but instead to direct the reader to a link to the most recent source of this information, usually in the form of commercial fishing plans and science advisory reports.

There are fundamental knowledge gaps for marine invertebrates, starting from: What are the animals in the area (standard taxonomic information)? Where are the animals normally found? What is their basic biology? What is their role in the ecosystem? And what are the impacts of various anthropogenic activities on these animals?

Not all the groups of animals will be addressed in this chapter, but we will try to touch on groups of animals that we know are being impacted and try to put this in context of what this will mean when trying to manage at the ecosystem level.

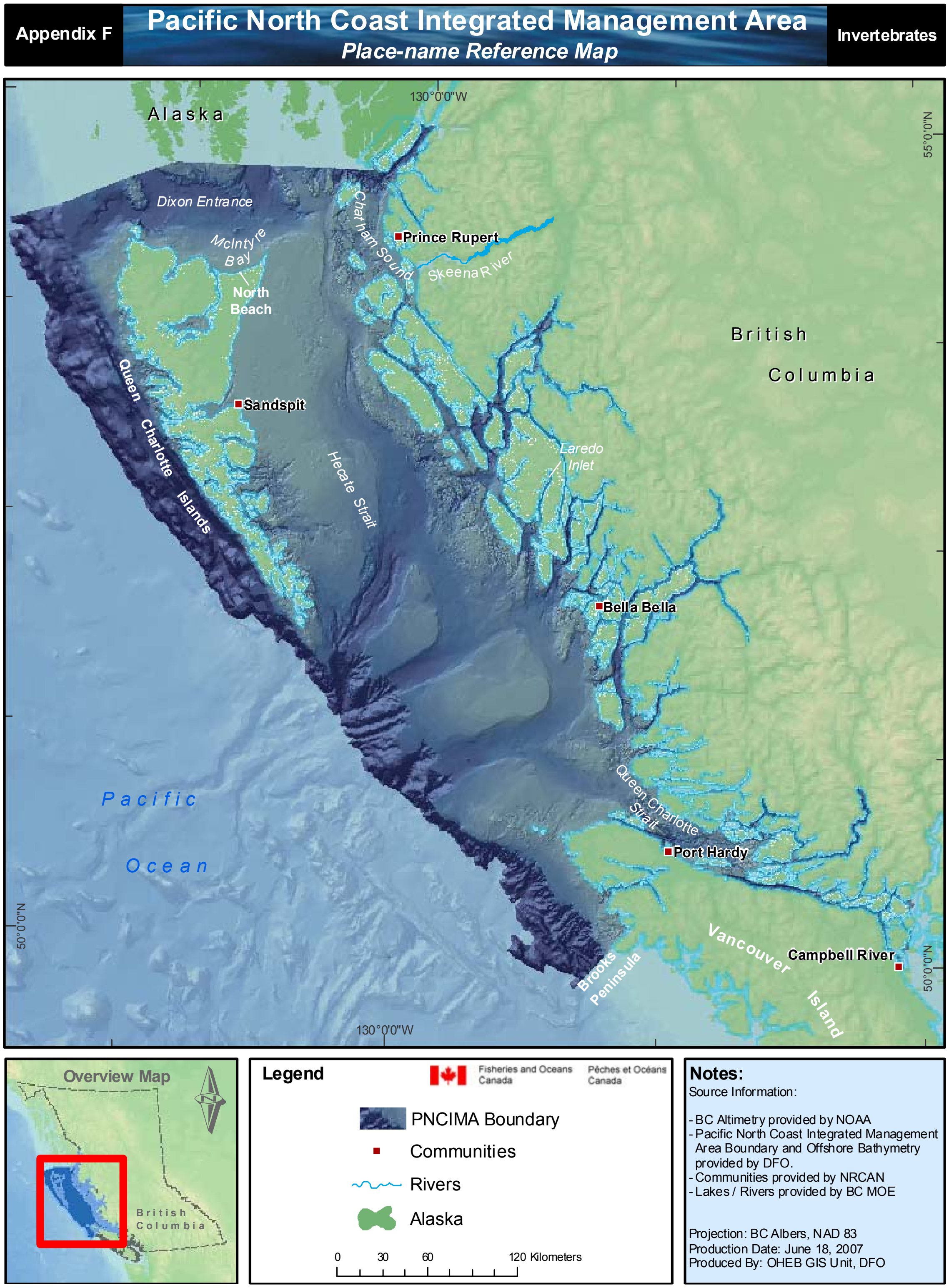

Figure F.0 PNCIMA region showing locations and features of BC waters.

2.0 SPONGES (PHYLUM PORIFERA)

2.1 Biology, Habitat & Ecosystem Linkages

In the North-eastern Pacific Ocean, between central California and southern Alaska, approximately 260 species of sponges are known, of which 7 are rare (Austin 1985). Of the three living classes of sponges (Calcarea, Hexactinellida and Desmospongiae), representatives of each class are found in the PNCIMA area. The location of few well known sponge occurrences is mapped (Chapter 2 Habitat, Map 2.1), but this by no means describes the full extent of their distribution or habitat usage in the area.

Sponges are encountered on a wide variety of substrates from soft mud and sand, to shells, corals, submerged timbers, rocky outcrops, and vertical rock walls (Austin 1985; Ruppert and Barnes 1994; Blake and Scott 1997e). Sponges are sessile organisms, forming unique three-dimensional living habitat structures and occupying area from the intertidal to the deep sea abyss, including seamounts. Sponges take on a variety of growth forms, which appear to be an adaptive response to localized environmental constraints (space, substrate and water currents)(Ruppert and Barnes 1994).

Sponges are capable of reproducing both asexually and sexually, including the ability to brood eggs and release flagellated larvae. They are also able to regenerate themselves after they have been broken or injured (Ruppert and Barnes 1994). There is limited information on the growth rates of the various species of sponges but a few studies are beginning to document this information (Leys *et al.* 2004).

Sponges have internal canal systems that continually filter water, providing a constant flow of food items, from dissolved organic matter to bacteria. As such, sponges' direct interaction with their external environment leaves them vulnerable to the absorption of harmful particles (Austin 1985; Ruppert and Barnes 1994; Blake and Scott 1997e; Lamb and Hanby 2005). Some sponges have acquired the ability to arrest feeding when their surrounding environment has high levels of silt or sediment (Leys *et al.* 2004). However, excessive amounts of sediment may lead to the smothering of the animal and result in death.

Sponges are preyed upon by nudibranchs, chitons, limpets, gastropods and sea stars (Blake and Scott 1997e; Lamb and Hanby 2005).

In PNCIMA, the best known sponge locations are associated with the hexactinellid sponge reefs, which at the time of discovery attracted world-wide attention. The existence and formation of these sponge reefs requires a combination of a unique geological setting (as described in Appendix A: Geology) along with the occurrence of particular Hexactinellida sponge species (Conway 1999; Department of Fisheries and Oceans 2000c). Hexactinellida are typically found in deep water and prefer habitats with high dissolved silica levels, low light levels, cold temperatures and substrates with little to no sediment accumulation (Leys *et al.* 2004). The bioherms, or reefs, created are known to attract a multitude of other invertebrate animals such as tunicates, sea stars, brittle stars, gastropods, polychaetes, amphipods and arthropods (*i.e.,* shrimp, crabs and barnacles). Various fish species have also been noted to use the three-dimensional rigid structures as refugia for themselves and to lay their eggs (Smith and Carlton 1975).

2.2 Status & Management

The fragile nature of sponges makes them highly susceptible to damage from physical impacts. Anthropogenic influences having benthic contact, such as fishing gear (Etnoyer and Morgan 2003), seabed mining, and cable laying, and ones causing sediment deposits, such as paper mills, mines, and aquaculture, can result in extensive sponge damage and mortality. The greatest impact to sponges appears to be from multiple years of high intensity bottom trawl fishing. Fishery management measures have been implemented in the PNCIMA area to preserve known existing reef-forming Hexactinellida sponges (approximately 1000 km^2).

In terms of habitat management issues, large sponge concentrations are considered critical and sensitive areas. To avoid these areas, habitat managers will need to work with industry, for example, to carrying out site evaluations at aquaculture leases.

To date, there has been no commercial harvesting of sponges in British Columbia. The BC Conservation Data Center has "red" listed the Cloud Sponge, *Aphrocallistes vastus* (a Hexactinellida) but this status lacks any means of protection. There are no species listed at this time under SARA legislation.

Sponges can also become a pest, for example within the Demospongiae, there is a shell-burrowing sponge (*Cliona* spp.), which can potentially cause mortalities to oysters, mussels and scallops. To date, aquaculture sites in PNCIMA have yet to note any devastating effects and therefore no management actions have been taken.

2.3 Information Gaps, Uncertainties, Limitations & Variability

There is little or no information on sponges from which to define population trends for these animals in the PNCIMA. To date, the majority of information on sponge distribution has come from data collected during non-directed studies or from commercial trawl bycatch monitoring. Significant information gaps exist for this phylum, partly due to the lack of consistent taxonomic classification and proper identification of species. Identification of sponges is difficult due to: (1) many undescribed species, (2) limited taxonomic literature and (3) historic taxonomic problems (Austin 1985; Ruppert and Barnes 1994; Blake and Scott 1997e). Without this basic information about species present, other questions relevant to management of these species can generally not be addressed.

3.0 HYDROIDS, ANEMONES, SEA PENS, SEA WHIPS, CORALS AND JELLYFISH (PHYLUM CNIDARIA)

3.1 Biology, Habitat & Ecosystem Linkages

Hydroids (Hydrozoans), anemones, sea pens, sea whips, and corals (Anthozoans) and jellyfish (Schyphozoans) are animals that all have a consistent and simple body structure and are taxonomically classified together under the Phylum Cnidaria (Ruppert and Barnes 1994). Cnidarians may be either sessile or mobile as well as either solitary or as part of a colony. They inhabit soft and rocky substrates or are pelagic, from intertidal to deep-sea environments and are found in both infauna and epifauna communities (Bertness *et al. eds*. 2001). Cnidarians exhibit two body forms, one adapted for pelagic existence and the other adapted for an attached, benthic existence.

Almost all cnidarians are carnivorous, feeding on small fishes, crustaceans, oyster spats, larvae and other such organisms (Smith and Carlton 1975; McLachlan and Ayres 1979; Ruppert and Barnes 1994). Mobile species are typically predators seeking out prey, while sessile cnidarians require a continual flow of water in order to bring prey within their reach. Predators on the sessile forms of these animals include sea stars and nudibranchs while other planktonic animal forms are preyed upon by higher tropic organganisms such as fish and marine mammals (McLachlan and Ayres 1979).

Typical developmental period of cnidarians is highly variable, with some taking up to a full year to complete while others develop rather quickly into ciliated larvae or free-swimming sexual medusa (Johnson and Snook 1955; Smith and Carlton 1975; McLachlan and Ayres 1979). Mobile larvae lead to effective distribution of the species. This larval phase may last for a few days to just a few hours before settlement occurs on substrates, where development into adult forms takes place (Johnson and Snook 1955; McLachlan and Ayres 1979). The life span for a few pelagic species is only a year and evidence of this is seen on beaches littered with remains (Smith and Carlton 1975; McLachlan and Ayres 1979), while some coral species are believed to live for hundreds of years.

Of special note in the PNCIMA region are cold-water corals, occupying substrates between the intertidal and deep sea. Like sponges, corals create vertical relief through the formation of three-dimensional living habitat structures. Cold-water coral structures range from small, solitary individuals to large colonial grove and reef habitats. The location of known coral occurrences is mapped in (Chapter 2 Habitat, Map 2.1) but by no means describes the extent of their habitat range. Corals may be referred to as foundation species since they play an important role as habitat modifiers, altering patterns of water, movement and influencing food and larval supply (Bertness *et al. eds*. 2001). The complex branching morphology of many corals creates structures of sufficient size to provide substrate or refuge for other animals (Etnoyer and Morgan 2003). Similar to sponges, live and dead portions of a coral's matrix or lattice framework are used to create substrates and shelter for other corals, sponges, brachiopods, bivalves, crustaceans, bryozoans, crinoids and tunicates (Hall-Spencer *et al.* 2002; Koslow *et al.* 2001).

3.2 Status & Management

To date, these animals are not considered in any fisheries or habitat management strategies, with the exception of corals. Similar to other structural forming invertebrates, anthozoans in PNCIMA are capable of forming extensive structural habitats. The fragile skeletons and upright growth forms make them vulnerable to physical impacts. Similar to sponges, anthropogenic influences having benthic contact (fishing gear, seabed mining, cable laying, etc.) can result in extensive mortality. An initiative to develop a conservation strategy for corals and sponges is in progress.

3.3 Information Gaps, Uncertainties, Limitations & Variability

Detailed life history studies are particularly needed for many Cnidarians. There is currently the possibility of taxonomic problems associated with these animals, where the polyp and medusa stages of the same animal have been described under separate names (Smith and Carlton 1975).

To date, there have been very few research initiatives on these animals in British Columbia. Knowledge of their identity, spatial occurrence, general biology, regeneration abilities and ecosystem significance is limited. Recent synoptic surveys in PNCIMA have discovered new species and new records of species of Anthozoans never before encountered from our waters.

4.0 BRYOZOANS (PHYLUM BRYOZOA)

4.1 Biology, Habitat & Ecosystem Linkages

Bryozoans are very small animals that have a unique food-catching structure composed of tentacles surrounding the mouth called a lophophore (Ruppert and Barnes 1994). Bryozoans are common and abundant colonial animals, commonly known as moss animals, often overlooked due to their very small individual size (approx 0.5 mm) and resemblance to organisms such as hydroids, corals, sponges or seaweeds (Lamb and Hanby 2005). Between 230 and 300 species of the world's 5000 living species of bryozoans are found from central California to southern Alaska (Austin 1985; Ruppert and Barnes 1994; Soule *et al.* 1997; Sloan *et al.* 2001; Lamb and Hanby 2005). Many species are widely distributed and found at all depths, although bryozoans are most abundant in the intertidal (littoral) and the shallow sub-tidal (neritic) zones (Austin 1985; Smith and Carlton 1975; Ruppert and Barnes 1994; Soule *et al.* 1997).

Bryozoans are another phylum capable of forming living habitat structures. Hundreds to thousands of independent individuals live as members of large, structured communities (Ruppert and Barnes 1994; Soule *et al.* 1997). Bryozoans flourish in nearly every marine environment and are often found on surfaces of algae, worm tubes, sponges, shells, rocks, corals, pilings and sandy beaches (Smith and Carlton 1975; Ricketts *et al.* 1968; Ruppert and Barnes 1994; Soule *et al.* 1997; Lamb and Hanby 2005). Encrusting bryozoans are found in turbulent or exposed waters, where they will often take on the form of their substrate. In protected waters, erect forms attach to the substrates by 'roots' or basal discs and often resemble lichens, chicken-wire or long tubes (Smith and Carlton 1975; Ruppert and Barnes 1994; Soule *et al.* 1997). Depending on environmental conditions, bryozoans take on variable forms, often making them difficult to identify (Smith and Carlton 1975; Soule *et al.* 1997). Within the ecosystem, bryozoans provide shelter and habitat for numerous other species, including brittle stars and polychaete worms (Ricketts *et al.* 1968; Lamb and Hanby 2005).

Bryozoans are suspension feeders, making them completely reliant on water currents to bring them nutrients (tiny algae, bacteria and detritus). Considering the continuous intake of water, the health of bryozoans may provide indications of changing water quality (McLachlan and Ayres 1979; Lamb and Hanby 2005). Due to their very diverse forms, there is a range of predator/prey relationships for bryozoans in the marine environment. Some bryozoans are preyed upon by crabs, limpets and nudibranchs, while others are able to defend themselves against settling larvae and larger organisms (Ricketts *et al.* 1968; Ruppert and Barnes 1994).

Bryozoans release their fertilized eggs, or developed mobile larvae, into the water column. Once the animal settles and attaches to a surface, the colony formation takes place by means of asexual budding (Ruppert and Barnes 1994; Blake and Scott 1997a; Lamb and Hanby 2005). Bryozoans are also able to go through phases of degeneration and regeneration, making them adaptable to changes in oceanographic conditions. They are one of the most abundant marine epifauna (Ruppert and Barnes 1994).

4.2 Status & Management

Despite their adaptable nature, bryozoans are susceptible and vulnerable to destructive habitat practices as well as other substrate-disturbing activities. These types of activities have the potential to result in limiting available suitable surfaces for settlement.

Economically, some bryozoans can be major fouling organisms that take over available substrates, thus impacting on ecosystems as a whole, *e.g.*, bryozoans are one of the most important groups of organisms to foul the hulls of ships.

When managing animals within this Phylum, there may be a need to protect certain species and their habitats (*e.g.*, habitat forming structures such as coral-like bryozoans), while at the same time, consideration must be given to controlling pathways that distribute these animals due to their ability to potentially cause various economic hardships. Two known species have been introduced to the Pacific Northwest, including the well-adapted orange encrusting bryozoan (*Schizoporella unicornis*), which was likely introduced from Japan with the Pacific oyster (Lamb and Hanby 2005).

4.3 Information Gaps, Uncertainties, Limitations & Variability

At this time, there is a lack of information on bryozoans in British Columbia to describe what we have, where they are distributed and any population trends in PNCIMA. There is a lack of taxonomic expertise and tools to readily identify what we have and therefore there are no directed programs to collect the kind of detailed information required to address the above-mentioned management issues.

5.0 SEA STARS, BRITTLE STARS, BASKET STARS, SEA CUCUMBERS, SEA URCHINS, AND SAND DOLLARS (PHYLUM: ECHINODERMATA)

5.1 Biology, Habitat & Ecosystem Linkages

Echinoderms are exclusively marine and relatively large animals (at least several centimetres in diameter), characterized by a five-part radial symmetry. The name means 'spiny-skinned' and most of the species have either a granulated or hard calcareous outer covering or calcareous ossicles hidden in the skin (Ruppert and Barnes 1994). They have a distinctive water vascular system, with a single opening and an internal plumbing system of interconnected canals (Lamb and Hanby 2005), which in many echinoderms has become a means to move their tube feet, arms or spines (Ruppert and Barnes 1994).

In the Pacific Northwest, there are approximately 280 to 300 echinoderm species documented (Austin 1985; Lamb and Hanby 2005) out of over 6000 known species (Ruppert and Barnes 1994). The Pacific Northwest has the greatest concentration of sea star species in the world, including 70 endemic species around Vancouver Island (Ruppert and Barnes 1994), in the southern portion of PNCIMA.

Echinoderms are usually found on the bottom during their adult life, but their habitat preferences range considerably, due to their diversity in form and life history characteristics. Some echinoderm species are able to avoid desiccation within the intertidal zone, while others withstand significant pressure at great depths (>4300 m). Some echinoderms can secure themselves onto hard substrates in high current areas, while others bury themselves in sand and mud (Ruppert and Barnes 1994; Bertness *et al. eds*. 2001; Lamb and Hanby 2005). In PNCIMA, some species of sea cucumbers prefer eelgrass habitats, while other sea cucumber species inhabit mussel beds (Lambert 1997). Some sea cucumber species have a specific known distribution range, such as the intertidal tiny black sea cucumber (*Cucumaria vegae*) found only north of the Queen Charlotte Islands (Lamb and Hanby 2005) occupying only a small portion of PNCIMA. Giant red sea cucumbers (*Parastichopus californicus*), found in depths ranging from intertidal to 250 m (Lamb and Hanby 2005), can be found on most substrate types but show preferences for hard substrates and are least abundant on mud and silt (Woodby *et al.* 2000). Sea urchins often have a distinct upper limit to their vertical distribution and some species are concentrated close to the upper limit of their distribution (Jamieson and Francis 1986). Some echinoderms, such as green sea urchins (*Strongylocentrotus droebrachiensis*) are more mobile than a similar species, red sea urchins (*S.*

franciscanus), because they make seasonal migrations between deep and shallow waters (Stocker *et al. eds*. 2001). In general, echinoderm species aggregate, resulting in significantly high population densities in areas with favourable conditions, related to available food and specific reproduction temperatures (Lamb and Hanby 2005).

Most echinoderms are dioecious, with external fertilization (Ruppert and Barnes 1994). For most, the breeding season occurs in the spring to summer and appears to be triggered by environmental factors such as the number of days of bright sunshine, the presence of phytoplankton blooms, and warming water temperatures (Cameron and Fankboner 1986). Urchin spawning season is species specific: green urchins spawn between February and March; red urchins spawn between March and September; while purple urchins (*Strongylocentrotus purpuratus*) spawn between October and December. Generally, the fertilized eggs quickly develop into free-swimming planktonic larvae with various degrees of dispersal, and eventually undergo metamorphosis and settle to the bottom (Ruppert and Barnes 1994). For settled juvenile urchins, their recruitment success tends to be highest where large numbers of adult urchins are present, as the spines of the adults provide protection from predators (Stocker *et al. eds*. 2001). Urchins reach maturity within their first few years and have relatively long life spans of 30 years or more (Ruppert and Barnes 1994).

Echinoderms as a whole have widely diverse feeding habits, including herbivores, carnivores, scavengers, deposit or suspension feeders (Ruppert and Barnes 1994). Sea stars and brittle stars are considered to be relatively major predators. They have adapted on a species-by-species basis to feed on a variety of species including zooplankton, sponges, anemones, hydroids, corals, bryozoans, snails, bivalves, crustaceans, polychaetes, other echinoderms and small fishes (Ruppert and Barnes 1994).

Sea cucumbers are called “cleaners of the benthos” since they use their feeding tentacles to gather up suspended or deposited decaying matter (Jamieson and Francis 1986; Lamb and Hanby 2005). This feeding habit keeps substrates available to settling larvae and fulfills a very important niche by recycling nutrients. Basket stars, feather stars and crinoids are suspension feeders, which are commonly found attached to sponges and corals in order to gain better access to plankton. Sea urchins feed by scraping the surface of substrates on which they live, while seeking out a variety of both plant and animal matter for their diets (Ruppert and Barnes 1994; Lamb and Hanby 2005). Some urchins play a critical roll as grazers in algal habitats and are considered to be keystone species, as they can alter the ecosystem that they live in. Where few predators exist, urchin populations can completely overtake their algal food source, causing a resultant habitat commonly named “urchin barrens” (Lamb and Hanby 2005).

Predators have various effects on echinoderms, including the ability of echinoderms, when stressed, to degenerate and self-amputate or autotomize body parts. While some sea stars loose their arms, many sea cucumbers eject parts of their viscera and associated organs while under attack or distressed (Ruppert and Barnes 1994). Regeneration of lost body parts can range in time from a few days up to a year. This ability to regenerate body parts is likely an important characteristic contributing to the success of echinoderms (Ruppert and Barnes 1994; Lamb and Hanby 2005).

There are a variety of predators on echinoderms, including a sea star, and linking to terrestrial food webs where bears and birds scour the intertidal and feed on such organisms. There is also a demand for echinoderms for human consumption, including traditional First Nations' use, as well as commercial ventures. A well documented ecological relationship exists between sea urchins (prey for otters, consumer of kelp), sea otters (predator on sea urchins) and kelp beds (food for sea urchins) (Estes *et al.* 1978; Breen *et al.* 1982; Duggins 1980; 1983; Jamieson and Francis 1986; Schroeter *et al.* 1996).

5.2 Status & Management

At this time there are three species of echinoderms (one sea cucumber and two sea urchins) that have directed commercial fisheries in the PNCIMA area. The giant red or California sea cucumber (*Parastichopus californicus*) dive fishery expanded north into PNCIMA in 1987, and presently 95 % of the coast wide total allowable catch (TAC) is extracted from there. The fishery is managed by quotas, which are derived from a fixed exploitation rate, and biomass estimates set at conservative levels based on shoreline length (Boutillier *et al.* 1998) or through assessment dive surveys. The fishery also has area restrictions with current commercial harvesting limited to 25 % of the BC coastline, while the remaining portion includes 25 % set aside for research and experimental fisheries and 50 % closure (DFO 2002). Although this fishery is believed to be very precautionary and sustainable, there are concerns regarding localized stock depletion from harvesting pressures (Humble *et al.* 2006). The ability and time it takes for sea cucumbers to recover is not fully understood (Stocker *et al. eds*. 2001), however this is being addressed in some of the experimental fisheries that are testing various exploitation rates (Hand and Rogers 1999) and depletion/recovery experiments to specifically examine recovery dynamics (C. Hand, DFO, Pacific Biological Station, Nanaimo BC, pers. comm., 2006).

Depending on the species, commercially harvested urchin stocks are either considered stable (red urchins) or appear to be rebuilding (green urchins) from past fishery pressures (DFO 2001c; 2003). These fisheries are managed on a quota, based on a fixed exploitation level with biomass levels set through assessment dive survey or extrapolation from the nearest survey and logbook information.

From an ecosystem management perspective the re-introduction of sea otters in PNCIMA will present managers with a new set of challenges, as there will be major conflicts between the management of the recovery of the SARA-listed sea otter and access to sea urchins for First Nations and commercial needs and wants. We have already seen decreased purple urchin abundance and increased algal biomass attributed to the recovery of the sea otter in PNCIMA (Workman 1999).

5.3 Information Gaps, Uncertainties, Limitations & Variability

Despite their significant presence in PNCIMA, there have been no directed research or management implementations for non-commercial species of echinoderms. The biology, life history and role of many non-commercial echinoderms in the Pacific Northwest ecosystems remain unknown.

6.0 FLATWORMS (PHYLUM: PLATYHELMINTHS)

6.1 Biology, Habitat & Ecosystem Linkages

Globally there are about 20,000 species of flatworms (Platyhelminthes), most of which belong to three parasitic classes and a third class, known as free-living flatworms (Turbellaria) consisting of approximately 3000 species (Ruppert and Barnes 1994; Blake and Scott 1997a; Lamb and Hanby 2005). In the Pacific Northwest, there are approximately 126 identified species of Turbellaria but this by no means represents the extent of this group in the Pacific north west coast (Austin 1985; Lamb and Hanby 2005). The known species in this area range in size from 1.2 cm to 6 cm, with larger flatworms commonly found under rocks, on wharf pilings, attached to algae or associated with other invertebrates (Ruppert and Barnes 1994; Blake and Scott 1997a; Lamb and Hanby 2005). Their body colouration commonly resembles their surroundings, making them often difficult to detect in nature. There is great diversity in flatworms, including many of the smaller unknown species being microscopic interstitial forms and likely part of the meiofauna (Blake and Scott 1997a). Turbellarians have a wide variety of locomotory adaptations and are capable of living in soft sediment with low levels of oxygen (Ruppert and Barnes 1994; Lamb and Hanby 2005).

Flatworm reproduction appears to be controlled by day length and temperature. Primarily, sexual reproduction takes place, producing a small number of eggs that undergo direct development and contribute to the plankton community for a short time as meroplankton (McLachlan and Ayres 1979; Ruppert and Barnes 1994). Little is known about the prey of turbellarians but the organism itself may be parasitic or have commensal relationships (Lamb and Hanby 2005). Species will commonly parasitize the guts and body cavities of molluscs, crustaceans, echinoderms and the skin of fishes while other species co-exist in the mantle cavities of molluscs and gills of crustaceans (Ruppert and Barnes 1994). Flatworms are quite versatile, having close to an unlimited capacity for adaptability and as a result, ecologically are very successful (McLachlan and Ayres 1979).

6.2 Status & Management

The only management issue that may be of concern at this time in PNCIMA is related to the expansion and movement of shellfish aquaculture products. During the initial oyster boom on BC's coast in the 1930s, a species of turbellarians, the bivalve flatworm

(*Pseudostylochus ostreophagus*), was introduced and became a predatory pest at local shellfish aquaculture sites. Whether or not this occurs in PNCIMA has yet to be confirmed. However, recent observations have suggested habitat ranges show significant northward extensions for a number of native species (Lamb and Hanby 2005). A risk assessment of the pathway vectors for the spread of these parasites may need to be undertaken and managed accordingly.

6.3 Information Gaps, Uncertainties, Limitations & Variability

Due to difficulty in identifying platyhelminthes in their natural environment, many species are believed to be undiscovered and unrecorded at this time.

7.0 SEGMENTED WORMS AND LEECHES (PHYLUM: ANNELIDA)

7.1 Biology, Habitat & Ecosystem Linkages

There are 3 classes of annelids, of which only two with marine life histories will be outlined, marine leeches (Class Hirudinnea) and polychaete worms (Class Polychaeta). In the Pacific Northwest, there are 11 known species of marine leeches and over 850 known polychaetes (Austin 1985; Smith and Carlton 1975; Blake *et al.* 1997; Lamb and Hanby 2005). Polychaetes, particularly those on our continental shelf and slope, typically comprise 45 to 50% of the total number of species and up to 80% of the total number of individuals in benthic communities (Smith and Carlton 1975; McLachlan and Ayres 1979; Ricketts *et al.* 1968; Ruppert and Barnes 1994; Blake *et al.* 1997; Bertness *et al. eds*. 2001; Lamb and Hanby 2005).

Polychaetes inhabit a variety of substrates, from the intertidal zone to the abyss (Johnson and Snook 1955; Smith and Carlton 1975; Kozloff 1996; Blake *et al.* 1997; Bertness *et al. eds*. 2001). There are sedentary as well as free-living forms capable of swimming, crawling, burrowing, boring and constructing temporary and permanent tubes (Johnson and Snook 1955; Smith and Carlton 1975). Borer species are important in that they break-up hard substrates (shells, rocks, etc.), contribute to the production of sand, and assist in the creation of soft substrate habitats. Burrowing species stabilize sediments and create water vortices, recycling nutrients within the seabed as well as vertically into the water column (Blake *et al.* 1997; Lamb and Hanby 2005). Additionally, burrowers play an important role aerating sediments by moving more oxygenated surface waters to the often anoxic sediments (Blake *et al.* 1997). Burrowing polychaetes have a major role in defining the characteristics of the top layers of the sediments as well as the fundamental structure of the associated community.

Healthy polychaete communities represent major contributions to marine and terrestrial food webs (Lamb and Hanby 2005). Adult polychaete populations are consumed by predators such as other polychaetes, sea stars, molluscs, arthropods, demersal fish, grey whales, shorebirds and humans, while their larvae are a prime food source to zooplankton, fish and baleen whales (Lamb and Hanby 2005; McLachlan and Ayres

1979). Surviving predation and depending on the extent, some polychaetes (*Chaetopterus* spp., *Dodecaceria* spp.) possess the unique ability to regenerate their entire body from a single segment while other polychaete species have varying, but still remarkable, ability for regeneration (Ruppert and Barnes 1994). Predation and other pressures are often the limiting factors of organisms burrowed in the bottom sediments (infaunal populations) (Ruppert and Barnes 1994). The ability to survive predation and regenerate lost body parts gives a definite competitive advantage to polychaetes over other organisms in the same environment. Modes of feeding are closely tied to habitats, errant polychaetes or free-living species can be significant predators and tend to be raptorial carnivores, omnivores or scavengers, while sedentary polychaetes or burrowers and tube dwellers tend towards deposit and filter feeding (Johnson and Snook 1955; McLachlan and Ayres 1979; Blake *et al.* 1997; Bertness *et al. eds*. 2001). Feeding methods are quite variable including the formation of mucus "bags", branchial plumes, "branches" and well developed horny jaws used to capture plankton, small invertebrates (hydroids, sponges, bryozoans, tunicates, echinoderms, molluscs, and crustaceans), detritus and various algal species (Ruppert and Barnes 1994; Blake *et al.* 1997).

This phylum is diverse, including parasitic marine leeches found attached to fishes, particularly flatfish and various invertebrates, as well as other non-parasitic polychaetes (Blake *et al.* 1997; Lamb and Hanby 2005). Mutualistic polychaetes are found associated with a variety of animals, from sessile invertebrates (sponges, corals and bryozoans) to mobile species, such as sea cucumbers, sea stars, snails, chitons, limpets, and within crab branchial cavities. In the mutualistic relationship, which benefits both species, the polychaete hitches rides to new habitats or gains access to food, while the host may be defended by the aggressive acts of the polychaete (Smith and Carlton 1975; Lamb and Hanby 2005; Blake *et al.* 1997).

Polychaetes exhibit more diversity in modes of reproduction and development then any other invertebrate taxa (Johnson and Snook 1955; Lamb and Hanby 2005; McLachlan and Ayres 1979; Ruppert and Barnes 1994; Blake *et al.* 1997). Timing of reproduction may be tied with lunar cycles, tidal fluctuations, temperature, day length, light intensity and salinity (Lamb and Hanby 2005; Blake *et al.* 1997). For some species, spawning may terminate their life cycle, while others are able to reproduce multiple times and alternate between phases of sexual and asexual cycles (Blake *et al.* 1997). Polychaete larvae may spend hours to months drifting in tides and currents until they are triggered by a biochemical or sediment response to migrate to the benthos (Blake *et al.* 1997; Lamb and Hanby 2005).

7.2 <u>Status & Management</u>

In benthic communities, successful opportunistic species such as polychaetes are a good indicator species of changing levels of organic matter (Blake *et al.* 1997). This is an important consideration when studying the implications of anthropogenic disturbances which drastically alter sediments and exposure. Polychaetes are known to rapidly recolonize and rehabilitate areas exposed to waste-water disposal, oil spills, aquaculture-generated wastes and even areas damaged by severe oceanic storms (Lamb and Hanby

2005). On the other hand, polychaetes may become a pest to aquaculture (*i.e.*, oysters) as they are capable of excavating portions of shells allowing for localized accumulation of mud and sediment. As a result, "mud-blisters" form, causing a reduction in the market value for these cultured species (Blake *et al.* 1997).

7.3 Information Gaps, Uncertainties, Limitations & Variability

There are no assessment or management plans for benthic communities, yet a healthy diverse benthic community is a basic building block to healthy, stable, diverse, and productive marine ecosystems. Polychaetes are one of the most important components of the benthic community, as seen from what we know about their diversity, their interactions with other organisms, their adaptability, and their ability to recolonize previously disturbed sediments.

There has been previous work on the taxonomy of polychaetes throughout the world, but not focused on PNCIMA. In 1985, there were an estimated 836 polychaete worms described for the Pacific Northwest. However, there are new species continually being discovered and described (Lamb and Hanby 2005). These rapid developments have resulted in the taxonomy of polychaetes in the Pacific Northwest to be in a state of flux, as there are no directed scientific investigations focussed on these animals or the benthic community as a whole.

8.0 CLAMS, MUSSELS, SNAILS, ABALONE, OCTOPUS, SQUID, AND RELATED ANIMALS (PHYLUM: MOLLUSCA)

8.1 Biology, Habitat & Ecosystem Linkages

This large and conspicuous group contains such diverse organisms as gastropods (snails, limpets, nudibranchs), bivalves (clams, mussels, scallops, oysters), cephalopods (octopus and squid) and chitons. In the Pacific Northwest, there are well over 1400 species in this phylum, including over 900 gastropods, close to 400 bivalves and 60 cephalopod species (Austin 1985; Lamb and Hanby 2005; Scott and Blake 1997; McLean and Gosliner 2006). Molluscs are an important component of intertidal biota and often dominate organism diversity in many habitats (Ricketts *et al.* 1968). Molluscs are found from the intertidal to deep ocean trenches, on protected and exposed shores as well as associated with deep sea hydrothermal vents (Scott and Blake 1997; McLean and Gosliner 2006).

Life history characteristics and reproductive habits vary among molluscan classes. Most molluscs are dioecious and most require warming water temperatures to trigger spawning. A notable exception to this in BC is opal squid, which spawns between December and September with two major peaks of activity happening in March and July. Commercial landings of opal squid have been documented in PNCIMA (Walthers and Gillespie 2002). Spawning aggregations have been reported from a number of areas including the west coast of the Queen Charlotte Islands, Hecate Strait, and in Queen Charlotte Strait (G.E. Gillespie, DFO, Pacific Biological Station, Nanaimo BC, pers.

comm., 2006). Most bivalves have external fertilization, where the eggs and sperm (gametes) are released outside the body for fertilization in seawater (broadcast spawning) and development through planktonic larval stages. Some gastropods are broadcast spawners, while others have internal fertilization, with copulation and nurturing of fertilized eggs inside the adult body cavity (Ruppert and Barnes 1994). Some molluscan species produce extensive egg masses that may be contained in a case, in ribbons or housed inside the mantle cavity of adults during early life stages and then released to surrounding seawater (Jamieson and Francis 1986; Lamb and Hanby 2005). Planktonic larvae disperse in water currents and eventually settle on suitable substrate, where some may remain for life (Jamieson and Francis 1986; Lamb and Hanby 2005; DFO 2004). The life span of some species such as octopus and squid is determined by spawning activity, where females spawn only once (Jamieson and Francis 1986; Ruppert and Barnes 1994; Lamb and Hanby 2005). Growth rates vary among species, but are known to be relatively rapid during the first few years while being influenced by habitat and local environmental conditions (Jamieson and Francis 1986; Lamb and Hanby 2005). Species such as abalone and geoduck are slow growing and long lived, resulting in a large portion of their spawning stock of older and larger individuals.

In general, gastropods creep over and graze the surfaces of hard substrates and marine plants (Ruppert and Barnes 1994; Lamb and Hanby 2005). Many gastropods are herbivores or algae eaters, grazing on kelp and sea grass. Herbivorous molluscs may be impacted by the potential loss of marine plants along the coast, as food availability would be greatly reduced along with the loss of habitat and as a result, would increase their exposure to predators (Lamb and Hanby 2005).

As an exception to most molluscs, cephalopods are active predators, feeding mainly on crustaceans, other molluscs, worms and fishes. Cephalopods are a major component of the diets of toothed whales, pinnipeds (seals and sea lions), marine birds and larger fishes (Jamieson and Francis 1986; Ruppert and Barnes 1994). Predator-prey relationships may vary for particular species of cephalopods since many migrate vertically in the water column between seasons, while others travel on route from southern latitudes northwards, in order to reach feeding grounds at subarctic boundaries. Some species of cephalopods that typically aggregate along cold-water fronts are found in PNCIMA only at particular times of year.

Many molluscs are found in association with other organisms. Bivalves can occur in commensal relationships with sponges, cnidarians, polychaetes, crustaceans, echinoderms and ascidians. Some of these organisms provide protection, shelter and a food source for the mollusc, while they in turn are provided with an expanded water flow and food supply (Lamb and Hanby 2005; Scott and Blake 1997; McLean and Gosliner 2006).

Most clams are primarily suspension or filter feeders and their depths in the substrate are generally determined by the lengths of their siphon. With some species, clams' siphons are found in tunnels created by worms or shrimp, which enables the clam to exist deeper in the substrate than it could on its own (J. Dunham, DFO, Pacific Biological Station, Nanaimo BC, pers. comm., 2006). Clam siphons provide water quality information for the organism and provide for the intake of water and food particles as well as the outflow of water and feces (Jamieson and Francis 1986; Lamb and Hanby 2005). There are a few clams, such as the varnish clam (*Nuttallaria obscurata*) that are selective deposit feeders as well. The foot is extended past the valves (shells) and rotated through the sediments, then material is passed to the oral region when the foot is retracted (Gillespie *et al.* 1999). A common invertebrate clam predator in PNCIMA is Lewis' moonsnail (*Euspira lewisii*), which also preys on other snails (Bernard 1967; Lamb and Hanby 2005). Other clam predators include sea stars (*Pisaster* spp.), crabs, diving ducks, gulls and crows (DFO 2001a; 2001d). In much of PNCIMA, clams are found at the heads of inlets where there is some deposition from river outlets, as well as in bays accumulating suitable clam substrates.

The major native bivalve species in PNCIMA include littleneck clams (*Protothaca staminea*), butter clams (*Saxidomus gigantea*), geoduck clams (*Panopea abrupta*), horse clams (*Tresus capax, T. nuttallii*), razor clams (*Siliqua patula*), cockles (*Clinocardium nuttallii*), Olympia oysters (*Ostrea conchaphila*), weathervane scallops (*Patinopecten caurinus*), spiny scallops (*Chlamys hastata*), pink scallops (*Chlamys rubida*), Pacific blue mussel (*Mytilus trossulus*) and California sea mussels (*Mytilus californianus*). There are numerous other bivalve species found throughout PNCIMA documented in a number of recent exploratory bivalve surveys (Gillespie and Bourne 1998; 2000; Gillespie *et al.* 2004a; Gillespie and Bourne 2005a; 2005b). Introduced or exotic bivalve species include blue or bay mussels (*Mytilus edulis*), Manila clams (*Venerupis philippinarum*) and varnish clams (*Nuttallia obscurata*).

Littleneck clams are likely the most abundant intertidal clam in PNCIMA. They are usually found in the mid to lower intertidal zone on every beach where there is suitable habitat consisting of mixed substrates of gravel, sand and mud (DFO 1999c; Gillespie *et al.* 2004a). Butter clams are widely distributed throughout PNCIMA, occurring on the lower third of the intertidal in mixed substrates. There are extensive populations with a wide range of sizes and age, indicating good recruitment and stability in the stocks (Gillespie and Bourne 1998; 2000; Gillespie *et al.* 2004a; Gillespie and Bourne 2005a; 2005b). The geoduck clam is one of the longest-lived animals in the world (well over 100 years), occurring throughout PNCIMA from the intertidal zone to depths of at least 110 metres. They are buried at least a metre deep in sand, silt, gravel and other soft substrates (DFO 1999c). Horse clams (mainly *Tresus capax*) are common throughout PNCIMA in the lower third of the intertidal zone (Gillespie *et al.* 2004a). Razor clams are found on sandy surf-swept beaches from the mid-intertidal zone to subtidal depths of 20 m at substrate depth of up to 25 cm. In PNCIMA, there is a large population of razor clams on Haida Gwaii at North Beach near Massett (DFO 2001b). Cockles are found throughout PNCIMA in the lower half of the intertidal, and very shallow in soft substrates. Cockles are particularly important to First Nations as a food source, especially on the North Coast (Gillespie and Bourne 2005a). Olympia oysters, a SARA-listed species, have been found in a few isolated areas of the PNCIMA, particularly in lagoons, where they remain continually immersed in water, even during low tide. Since lagoon habitats are fairly rare, these areas warrant particular attention. Weathervane scallop distribution is typically patchy throughout its range, but there is a notable population in Dixon Entrance, off the north coast of Haida Gwaii (Lauzier and Bourne 2006).

On high energy, wave-swept rocky exposed shores in PNCIMA, highly structured sea mussel beds provide habitat for nearly 300 other species. Sea mussels, *Mytilus californianus,* are a keystone species, providing a unique structure for a spatially highly complex community, often with several layers in the bed (Seed and Suchanek 1992; Suchanek 1979). The gooseneck barnacles (*Pollicipes polymerus*) are often interspersed in the mussels beds, forming a distinctive *Pollicipes-Mytilus* community (Lauzier 1999a; 1999b). Mussel growth rates are extremely variable, dependent on availability of food, intertidal elevation, temperature and mussel density (Gillespie 1999a; Jamieson and Francis 1986; Lamb and Hanby 2005). Sea mussels are long lived (50 to 100 years) and if greatly disturbed or destroyed, take from 5 to 100 plus years to recover to a climax community (Gillespie 1999a). The rate of recovery is dependant on the size, season and intensity of the disturbance, as well as predation by sea stars, whelks, fish, birds and marine mammals.

Over 35 species of molluscs have been introduced into BC waters, both intentionally and accidentally. Blue mussels, for example, were introduced via aquaculture and today have adapted into complicating hybrids (Lamb and Hanby 2005). The most successful introduced bivalve aquaculture product here in BC is the Pacific oyster (*Crassostrea gigas).* This species has recently been introduced into the PNCIMA area through the First Nations Turning Point initiative. Manila clams were inadvertently introduced to BC in the 1930s, with imported Japanese oyster seed, and the varnish clam was also inadvertently introduced into BC waters in the early 1990s. Both species are fairly widespread in the south coast, with reports of Manila clams in the central coast as far north as Laredo Inlet (52° 59'N) and varnish clams at the northernmost extent of Vancouver Island (Gillespie *et al.* 2004a). Manila clams have become the dominant clam in the commercial fishery in southern BC. They are harvested in PNCIMA where there are sufficient populations and where water quality testing programs are conducted. Due to their position high up in the intertidal zone, and their shallow substrate depths, Manila clams are particularly vulnerable to winter mortality, which can remove significant proportions of the population when frost is accompanied by night-time low tides (DFO 2001a). Varnish clams have spread rapidly through southern BC waters. They occur higher in the intertidal zone than Manila clams, but there is evidence of some overlap and competition between the two species (Gillespie *et al.* 2001). However, varnish clams are pedal-selective deposit feeders as well as suspension feeders (Gillespie *et al.* 1999), and occupy a slightly different niche than Manila clams.

8.2 Status & Management

Currently there are seven commercial mollusc fisheries in PNCIMA consisting of approximately twelve species.

The geoduck clam fishery began in BC in 1976, expanded to the north coast in 1980, and continues today to be one of BC's most valuable fisheries (DFO 2000b; Fisheries and

Oceans Canada 2002a; 2002d). The geoduck fishery is managed by quota, based on a fixed exploitation level applied against a bed abundance estimate based on survey and historic extrapolated log book information. Each geoduck bed has a limit reference point which does not allow the bed to be fished down below 50% of it's virgin density. Geoducks are harvested individually by divers with the use of a directed water jet or "stinger". The use of this gear is believed by some to disturb habitat, in particular exposing juvenile geoducks that are among older individuals to potential predators such as fish, crabs and sea stars (Jamieson and Francis 1986).

In the southern part of PNCIMA, there are adequate concentrations of pink and spiny scallops to support commercial fisheries. Due to a lack of information required to actively manage the fishery, the commercial fishery reverted to an experimental fishery to allow assessment and management frameworks to be developed as the fishery developed. The vast majority of the scallop fishery in PNCIMA is carried out using a unique scallop trawl (Fisheries and Oceans Canada 2000c; 2005; Lauzier *et al.* 2005).

Opal squid in BC are fished primarily as bait for the sablefish, crab and halibut fisheries, along with a small market interest as a food product. Opal squid landings are highly variable from year to year, with the late 1990's showing an increase in landings from the north coast (DFO 1999e; Fisheries and Oceans Canada 2006). It is not known whether the change in the pattern of landings is due to a change in squid distribution, markets, or other factors. Other squid species have had pilot fisheries in BC, but there is little information on available stock size, biological characteristics or fisheries interactions (DFO 1999d).

Another mollusc currently harvested under experimental licence is octopus (Fisheries and Oceans Canada 2000b).

In the late 1990's, there was a proposal to harvest sea mussels through the development of a fishery in PNCIMA. Following an evaluation, it was concluded that the fishery was undesirable due to a number of factors, including sea mussel longevity, their sensitivity to disturbances with their bed structures as "important reservoirs of biological diversity", as well as the keystone species role of the sea mussel (Gillespie 1999a).

Intertidal clam landings have been recorded since the turn of the century and have had great importance to First Nations peoples. In general, five species of intertidal clams comprise the major portion of commercial, recreational and First Nations landings coastwide (DFO 1999b; 1999c; 2001d; Fisheries and Oceans Canada 2000a). Razor clams are harvested only in PNCIMA where they occur in sufficient densities using a quota system based on a fixed exploitation rate applied against surveyed biomass estimates (DFO 2001b). Commercial harvesting of intertidal clams in PNCIMA primarily focuses on Manila clams due to market preferences. Other clam species are important and harvested by First Nations, including cockles, butter clams and littleneck clams. For the most part, the north coast has remained closed to commercial clam harvesting since 1963. Clam fisheries in PNCIMA include Joint Management Plans with the Council of Haida Nations and the Heiltsuk Tribal Council for specific areas in the north and central coasts. Many of the closures in the north coast are the result of concerns regarding water quality and paralytic shellfish poisoning, which potentially creates human health risks (Fisheries and Oceans Canada 2002e). Like many fisheries, commercially harvested intertidal clams are controlled by minimum size limits and total allowable catches (TAC). The TAC is set using a fixed exploitation rate applied to the most recent assessment survey stock biomass estimate of legal-sized clams. The minimum legal-size limit for clams is set to allow for the organisms to spawn at least once before they are subject to fishing pressure.

Two mollusc species, the Olympia oyster (*Ostrea conchaphila*) and Northern or pinto abalone (*Haliotis kamtschatkana*) are the only marine invertebrates currently listed under SARA. The Olympia oyster is designated Vulnerable (COSEWIC 2004). The animals are characterized as being small in size and slow growing, while unknowns include population size and trend estimates (Gillespie 1999b). As part of the SARA process, a management plan must be in place within three years after the listing of the species (due date is June 2008).

The abalone is listed as threatened. All fishing activities (First Nations, commercial and sports) for abalone remains closed due to conservation concerns since December 1990. Abalone surveys currently take place in PNCIMA and at this time are showing no evidence of abalone population recoveries (DFO 2004). Poaching continues to be a significant threat to the recovery of populations, as does the reintroduction of sea otters in the PNCIMA area. A recovery strategy and action plan has been drafted, but the effectiveness of enforcement and enhancement measures may ultimately determine whether the stocks will have the opportunity to recover (DFO 2004). A re-evaluation of the status of these animals is due in 2008.

8.3 <u>Information Gaps, Uncertainties, Limitations & Variability</u>

Considering the extent and diversity of the mollusc phylum, only a relatively few species that have been commercial fished or ones with harvesting potential, have been studied. Many of these species significantly contribute to various trophic levels as well as community structures, but many unknowns remain as to their particular roles and values in ecosystems.

9.0 PHYLUM: ARTHROPODA

9.1 <u>Biology, Habitat & Ecosystem Linkages</u>

Arthropods include more described species than the rest of the animal kingdom combined. There are three major divisions of arthropods or subphyla named Chelicerata, Crustacea and Uniramia. Considering their diversity, wide distribution, and high abundance, arthropods have succeeded in virtually every habitat supporting life and are often among the most prominent residents (Johnson and Snook 1955; Ricketts *et al.* 1968).

With more than 38,000 known species, the subphylum Crustacea includes the most familiar marine arthropods, such as shrimp, crab, barnacles, copepods, amphipods, etc. (Ruppert and Barnes 1994). Crustaceans are found in a variety of habitats from the intertidal zone, estuaries, bays and inlets to open ocean pelagic environments and the deep-sea abyss. Some barnacles, for example, are entirely sessile as adults and form a major component of intertidal communities (Ricketts *et al.* 1968). Adult prawns (*Pandalus platyceros*), although mobile, show limited migration activity and result in hundreds of localized adult stocks, while other shrimp species, such as pink shrimp (*P. jordani*), show substantial changes in distribution throughout the year (Stocker *et al. eds*. 2001; DFO 1999f). Many smaller crustaceans are inconspicuous and often intimately associated with organisms such as anemones, sponges and marine plants, in which they are able to conceal themselves (Lamb and Hanby 2005). Another example of species associations in a slightly different context involves hermit crabs. Hermit crabs have soft unprotected abdomens that require empty snail shells or other shelters for protection.

In the marine environment, the majority of crustaceans can be characterized as highly mobile benthic megafauna. One distinguishing characteristic is their chitinous exoskeleton. This provides protection and extreme strength while somewhat limiting their mobility. As adults, some arthropods are solitary dwellers and their success is mainly due to their preference to remain hidden in crevices, under rocks, in abandoned shells or by attaching debris to their exoskeleton in attempts to become camouflaged (McLachlan and Ayres 1979). Like other benthic invertebrates, some arthropod activities result in oxygen mixing at or in the bottom sediments, encouraging the development and enhancement of later successional stages (Bertness *et al. eds*. 2001). On the other hand, early successional stages provide foraging opportunities for crustaceans (shrimp and prawns) which are limited to consuming small epibenthic invertebrates (Bertness *et al. eds*. 2001).

The life history and biology is similar for most marine crustaceans (with the exception of habitat preferences and vertical migrations in the water column). Typically during the late spring, crustaceans grow incrementally by moulting or shedding. This moulting process may serve to recycle nutrients from benthic sediments back into invertebrate and fish communities (Phillips and Lauzier 1997). During this soft-shell period (a few weeks), newly moulted organisms become highly vulnerable to natural predation, injury and death (DFO 2000a).

Crustaceans can be suspension or deposit feeders, in addition to being significant predators and foragers in BC waters (Ricketts *et al.* 1968; Blake and Scott 1997b; 1997c; 1997d; Bertness *et al. eds*. 2001; Lamb and Hanby 2005; Johnson and Snook 1955; Butler 1980). They can also be parasites as we see in the parasitic barnacle, *Sylon*, which infects prawns and other shrimp in PNCIMA (Bower and Boutillier 1988).

Copepods, mysids and euphausiids, are important components of marine ecology, serving as linkages between phytoplankton and higher trophic levels (Bertness *et al. eds*. 2001; Johnson and Snook 1955). The migration activity of numerous crustaceans indicate that they are also active predators, feeding on small benthic and pelagic organisms such as diatoms, polychaetes, annelids, copepods, amphipods, euphausiids, mysids, and other crustaceans (Boutillier and Nguyen 1999). Larger crustaceans are typically opportunistic foragers fulfilling integral roles in marine ecosystems. Crustaceans extract from ecosystems, yet they often consume only a portion of their prey, leaving remains of their prey for other benthic scavenging organisms (Bertness *et al. eds*. 2001). Digging prey or some other predatory action by predators, can cause incidental mortality to other non-prey organisms, contributing to spatial patchiness within communities (Bertness *et al. eds*. 2001). As seen with some polychaetes, some crustaceans have the ability to regenerate limbs consumed by predators, likely contributing to their success (McLachlan and Ayres 1979). Crustaceans are prey to various predators at different ages and life cycle stages. Predators include marine mammals, birds, most fish species, cephalopods, crustaceans and other invertebrates. Juvenile Tanner crabs (*Chionoecetes tanneri*) are frequently and consistently found in fish stomachs, and it would appear that this species occupies a keystone role in the benthic food chain on the continental slope. Early Tanner crab instars redistribute nutrients from the bottom sediments to the demersal fish community in the water column (Gillespie *et al.* 2004b). The potential for over fishing of these crustacean predators may result in an increase crustacean prey populations while conversely, the over fishing of commercial crustacean prey species has the potential to play a limiting role in crustacean predator abundance.

In terms of reproduction, only a few commercial crustacean species have been studied in BC. For example, the pandalid shrimp found in PNCIMA protandric hermaphrodism, starting as males and then becoming females in the final year or two of their lives (DFO 1999g). Spawning typically takes place in late autumn to early winter with females brooding their eggs adhered to their abdomen throughout the winter (DFO 1999g). Certain species have planktonic larvae with limited mobility and remain pelagic for approximately three months while other arthropods have little to no pelagic larval stage. Species with pelagic larval stages, are frequently encountered in channels and near estuaries, and may show sensitivities to habitat alterations such as debris from coastal log storage and effluent discharge (Conlan and Ellis 1979; Booth 2000; Waldichuk 1979). Sessile crustaceans such as barnacles are highly successful colonizers as a result of their early maturity and ability to produce close to a million embryos per adult per season (Johnson and Snook 1955; Lamb and Hanby 2005).

British Columbian shrimp are susceptible to numerous parasites and diseases such as parasitic isopods and viral infections (Dunham and Boutillier 2001). Another parasitic barnacle, the black clawed crab parasitic barnacle (*Loxothylacus panopaei*) infects crabs. There are similar other parasitic barnacle species that infect hermit crabs and sea stars, but they have not been studied in any detail (Lamb and Hanby 2005). Parasitic isopods infest the bodies of larger crustaceans, forming relatively large bulges on the sides of shrimp, crab and fishes (Johnson and Snook 1955; Lamb and Hanby 2005). Often leaving their host, parasitic isopods may actively swim and search out a replacement host, leaving their former host with scars as evidence of parasitic attack (Lamb and Hanby 2005). Stained Prawn Disease (SPD), a rickettsia-like infection, is a parasite that has been detected in British Columbia waters, specifically in prawns located in Howe Sound and the Strait of Georgia. No cases have been reported within the PNCIMA region, and no causative agent has been determined (Bower *et al.* 1996).

Popularly called sea lice and whale lice, some arthropod parasites are strangely modified in structure according to their distinctive habit (Johnson and Snook 1955; Ricketts *et al.* 1968). Sea lice are parasitic copepods found on the skin, fins, gills and buccal cavity of marine fishes and all have variable success according to seawater surface salinity and temperature (Jones and Nemec 2003). Parasitic amphipods (*Cyamus* spp.), or whale lice, as well as free-living barnacles, parasitize grey whales and humpback whales (Ellis 1980). Some shrimp species harbour larval stages of parasitic worms (Austin 1985; Butler 1980; Lamb and Hanby 2005).

Commensal relationships involving arthropods are fairly common. One amphipod (*Orchomene recondita*) lives in the digestive system of sea anemones while others (*Hyperia*) hitch rides on various jellyfish (Lamb and Hanby 2005). Shrimp species are commonly found in boot and cloud sponges, while juveniles may seek shelter beneath urchin spines (Lamb and Hanby 2005). In an extraordinary relationship, box crabs (*Lopolithodes foraminatus*) and red king crabs (*Paralithodes camtschatica*) appear to harbour developing eggs of black-tail liparid, or snail fish, in their gill cavities (Hart 1982). Commensal relationships among non-commercial crab species found in PNCIMA have been reviewed by Hart (1982). Of particular note, the pea crab (*Pinnixia faba*) inhabits the cavity of the varnish clam which has caused some processing and marketing problems for the varnish clam (Gillespie *et al.* 2001).

9.2 Status & Management

There are over 87 species of shrimp present in BC waters and only seven are commercially-harvested in the shrimp trap and trawl industry. In PNCIMA, shrimp and prawn fisheries primarily take place in only a few North Coast inlets and offshore areas of the central coast. Shrimp stocks in BC have been assessed off the west coast of Vancouver Island since 1972 (Martell *et al.* 2000). For the nearshore shrimp stocks, index sites were established in 1997 along the coast and range from Chatham Sound in the north to the southern end of Vancouver Island in the Strait of Georgia. These nearshore index sites have a mix of annual and biannual fishery independent surveys. The primary objective of the surveys is to index shrimp biomass (Rutherford *et al.* 2004). The shrimp trawl fishery is managed using a fixed harvest rate based on the shrimp biomass determined from the fishery independent surveys. The commercial prawn fishery is managed using a female spawner escapement index. The fishery is closely monitored and monthly index reference points are established to ensure female spawning stocks are protected. The timing of egg hatch varies by area, and it is critical to understand when egg hatch is complete to allow for an opening of the fishery that protects breeding females sufficiently to allow for successful larval release. In most areas prawn stocks are considered healthy but fully exploited (DFO 1999f). In 1998, PNCIMA accounted for over 25% of the total coastwide commercial prawn catch (DFO 1999f).

There are five crab species fished in BC, Dungeness crab being the most significantly harvested. North coast Dungeness crab stocks are managed as two populations interacting to some extent. In PNCIMA, the Skeena River estuary and Hecate Strait/McIntyre Bay are two of six major Dungeness fishing areas (Fisheries and Oceans Canada 2002c). Typically, crab fisheries are managed by size and sex restrictions, in addition to some areas by season and gear restrictions (DFO 2000a). Experimental fisheries are licensed on large deeper-water species (Tanner crabs) to evaluate potential fisheries, since they have been sporadically fished in PNCIMA in the past. Additional crab species and their stocks are not currently assessed in BC and little published information is available, since they are not extensively commercially fished. Crabs are sensitive to pollutants such as pulp mill effluent and have been suggested as candidate species for monitoring marine ecosystem health (Yunker and Cretney 1995).

Since the 1970s, goose barnacles (*Pollicipes polymerus*) have been the only barnacle species commercially harvested in BC. Goose barnacles have long been a traditional food source for First Nations (Arima 1983; Ellis and Wilson 1981; Ellis and Swan 1981). In the early stages of the previous commercial fishery, there was limited harvesting in PNCIMA. However, due to logistics, the fishery continued only outside PNCIMA. Overall stock status of goose barnacles is unknown as there are very limited data available from assessments. However, they are abundant in selected but limited habitats of the rocky exposed open coast. The impact of harvesting is not fully understood and the fishery temporarily closed due to conservation and environmental concerns, and re-opened under scientific license in areas outside PNCIMA (DFO 1999a; Fisheries and Oceans Canada 2002b).

Since 1994, research into the euphausiid fishery has included acoustic surveys to assess biomass. This fishery takes place only outside PNCIMA with no intention to expand the fishery into new areas or increase the set 500 ton total allowable catch (TAC)(Fisheries and Oceans Canada 2003).

Another issue in PNCIMA includes controlling pathways that would cause spread of parasites and diseases. One parasite in particular, the shrimp parasitic barnacle (*Sylon hippolyte*) infects the spot prawn (*Pandalus platyceros*) in northern BC waters in PNCIMA, but not in southern BC waters. Therefore management action is required to contain this significant parasite and restrict movement of live prawns from these areas (Bower and Boutillier 1988).

9.3 <u>Information Gaps, Uncertainties, Limitations & Variability</u>

Although sightings have not yet occurred in the PNCIMA region, there is some concern over the anticipated arrival of the exotic/introduced European green crab (*Carcinus maenas*). Green crabs feed upon juvenile crabs of other species, including Dungeness and red rock crabs, and may compete for food sources. At the moment, Brooks Peninsula appears to be acting as a natural barrier to pelagic larvae, but since these organisms are quite mobile, European green crabs remain a potential threat to the PNCIMA region. The ecosystem impacts caused by a significant green crab population are presently unknown.

In total, there are close to 45 invasive arthropods in British Columbia waters, but their presence in PNCIMA are unknown (Carlton 1979).

To date, some arthropod groups have not been reported from northern latitudes but since there has been inadequate sediment and deep-water studies in BC, it would be unfair to assume that additional species do not occur in PNCIMA (Austin 1985). Future studies on monitoring parasites and other isolated diseases in invertebrates may be one mechanism to detect possible changes in the ecosystem and in marine environmental quality.

10.0 SUB-PHYLUM: UROCHORDATA

10.1 Biology, Habitat & Ecosystem Linkages

Commonly known as ascidians, tunicates or sea squirts, there are three classes of urochordates, two adapted for planktonic existence and a third forming living benthic habitat structures. In the Pacific Northwest, there are 82 ascidians documented of the approximate 3000 species worldwide (Austin 1985; Ruppert and Barnes 1994; Lambert *et al.* 2001). Although there are 14 planktonic species reported from the cold temperate NE Pacific, their occurrence is rare north of southern California (Austin 1985).

Few urochordates are solitary, while the majority are colonial. Colonies are made up of a few to hundreds of individual zooids, which may function independently or become integrated into an organized system (Ruppert and Barnes 1994). The majority of species are found in shallow coastal waters attached to the sides and under-surfaces of rigid substrates such as rocks, shells, pilings, ship bottoms, logs and seaweeds (Johnson and Snook 1955). Deeper-water species (up to 200 m) exist and, due to available habitat, are typically fixed in mud or sand by stalks or "roots" (Ruppert and Barnes 1994). Ascidians may be found in large clusters (*i.e.*, on gorgonian corals) or form large colonies that can reach several centimetres in thickness (Ruppert and Barnes 1994). Like many benthic invertebrates, sessile ascidians compete with sponges, sea anemones, corals, hydroids and bryozoans for substratum and when successful, may occupy substantial space (Bertness *et al. eds*. 2001; Smith and Carlton 1975; Ricketts *et al.* 1968).

Structurally, ascidians have two openings or siphons, and a body covering (tunic) or muscle bands in their body wall that provides structural support (Ruppert and Barnes 1994; Blake *et al.* 1996). Their siphons, one for in-current and the other for out-current, pass a significant amount of water through the body (up to 173 litres of water per 24 hours), and are used for filter feeding, gas exchange and mobility by a form of "jet propulsion" (Ruppert and Barnes 1994; Johnson and Snook 1955; Blake *et al.* 1996). Tunicates are highly successful planktonic grazers and are adaptable to unpredictable fluctuations in phytoplankton abundance, as they ingest a wide range of size and type of particles (Alldredge and Madin 1982). These traits have paved the way for rapid, exponential population increases when food supply is at a high. During periods of low food supply, they can survive without reproducing (Alldredge and Madin 1982). For some, reproduction can occur year round, but the majority breed during the summer months and reach sexual maturity in only a few weeks (Lambert *et al.* 2001; Ricketts *et* *al.* 1968; Blake *et al.* 1996). Both asexual (budding) and sexual reproduction takes place. Most colonies cross-fertilize for greater success through broadcast spawning (Ruppert and Barnes 1994; Blake *et al.* 1996). Although during their larval stage individuals have distinguishing chordate characteristics, these degenerate as adults making them an important invertebrate to NE Pacific ecosystems (Ruppert and Barnes 1994; Blake *et al.* 1996). The typical life span for ascidians range from 1 to 3 years, but some colonies have been known to live longer (Ruppert and Barnes 1994).

Ascidians host pea crabs, clams, amphipods and copepods, although the later can be a parasitic relationship (Ricketts *et al.* 1968; Bertness *et al. eds*. 2001; Blake *et al.* 1996). Although the tunic on ascidians acts as a physical and/or chemical deterrent, predation by flatworms, echinoderms, molluscs and three species of salmon (pink, chum and sockeye) on solitary and colonial forms occurs (Landingham *et al.* 1998; Blake *et al.* 1996).

10.2 Status & Management

Currently there are six invasive tunicates in BC, although none are yet known to exist in PNCIMA. Invasive tunicates have the potential to smother and overgrow other organisms and substrates, out-compete established species for food, as well as predate other benthic species larvae (Lambert *et al.* 2001). Many introduced species are associated with shipping and vessel traffic and, since there is significant vessel traffic in PNCIMA, the threat from the presence of invasive ascidians should be considered a significant issue. Risk assessments are currently being undertaken in the south coast region on four invasive ascidians occurring in BC waters.

10.3 Information Gaps, Uncertainties, Limitations & Variability

In PNCIMA, both deep-water and interstitial habitats have not been adequately investigated, as some un-described species have yet to be defined while others await their collection (Austin 1985; Blake and Scott 1997a). The presence of invasive species has only begun to be assessed in the south coast and considering some species ability to rapidly disperse, they may already have a strong presence in PNCIMA or have the potential to pose as a significant threat in the near future.

11.0 CONCLUSIONS

Throughout this chapter, a common theme has emerged from the information gaps identified for each phylum or group of invertebrates, and that is the lack of information on non-harvested invertebrate species. Some urchins, sea mussels (*Mytilus californianus*), and juvenile Tanner crabs (*Chionoecetes tanneri*) have been identified as keystone species, playing a critical role in the structure and composition of natural communities. The keystone role was determined only after investigations on the harvesting potential of particular species. What is not known is how many other invertebrate species have either keystone roles or other major functions in the overall marine environment. There is very little known on what marine invertebrates exist in PNCIMA, where they are located, and what roles they play in the marine ecosystem. There is awareness that marine invertebrates play an essential role in energy flow due to their relative positions in the food web. However, the extent and mechanisms of energy flow through marine ecosystems is not well understood.

In order to assess, plan and manage the impacts of human activities on the marine environment, building blocks are needed for a structured approach in understanding the complexities of the marine ecosystem. The basic steps to this structured approach would include:

1. An inventory of distinct marine communities.
2. The location, size and extent of those communities.
3. An understanding of the role and cumulative effects of those communities to the overall functioning and productivity of the marine ecosystem.
4. An understanding of the vulnerability and sensitivity of marine communities to human activities and other potential perturbations.

The marine invertebrates have a major role in the energy pathways of the marine environment. There are many knowledge gaps in the taxonomy, distribution, and abundance of marine invertebrates, with a subsequent lack of understanding on how many of the ecosystem processes function. These limitations need to be addressed in order to make informed management decisions.

12.0 GLOSSARY

Asexual budding – Offspring are produced by growing out of the body of the parent and is genetically identical to the parent.

Calcareous – Hard covering containing calcium carbonate.

Chitinous exoskeleton – A tough, protective, semitransparent substance, primarily a nitrogen-containing polysaccharide (chitin), forming the principal component of arthropod exoskeletons (the outer layer which serves not only as a protective covering over the body but also as a surface for muscle attachment, a water-tight barrier against desiccation and a sensory interface with the environment).

Climax community – The stage in community succession where the community has become relatively stable through successful adjustment to its environment.

Commensal relationships – The relationship between two kinds of organisms in which one obtains food or other benefits from the other without damaging or benefiting it.

Copulation – Mating.

Demersal – Organisms located at or just above the sea floor.

Dioecious – To have separate sexes.

Epifauna – Organisms living on the seabed surface.

Estuary – An inlet or arm of the sea; especially the wide mouth of a river, where the tide meets the current.

Gametes – Reproductive cells; sperm and egg cells in animals.

Gorgonian – Corals having a horny calcareous branching skeleton.

Keystone species – A species that has a key role in an ecosystem, affecting many other species, and whose removal leads to a series of extinctions within the ecosystem.

Megafauna – Large plants.

Metamorphosis – A change in body form.

Mutualistic – An interaction between two species in which both species benefit.

Ossicles – The numerous small plates that constitute the echinoderm skeleton. Ossicles are composed of a form of calcium carbonate known as calcite.

Phylum – A major group within a kingdom. Members of a phylum share a common structure and organization.

Planktonic – Drifting small organisms that inhabit the water column of the ocean.

Protandric hermaphrodism – Undergo a change of sex in mid-life.

Rickettsia-like infection – A parasitic micro-ogranism, intermediate between bacteria and viruses associated with infection.

Sedentary – Remaining or living in one area, not moving freely.

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