British Columbia Echinoids: A Synopsis of Information on their Taxonomy, Occurrences, Distribution, Threats and General Status

P.D.G. Boutillier, G.E. Gillespie and J.A. Boutillier

Fisheries and Oceans Canada
Science Branch, Pacific Region
Pacific Biological Station
Nanaimo, British Columbia
V9T 6N7

2018

Canadian Technical Report of
Fisheries and Aquatic Sciences 3281

Fisheries and Oceans Canada | Pêches et Océans Canada

Canada

Canadian Technical Report of Fisheries

and Aquatic Sciences 3281

2018

British Columbia Echinoids: A Synopsis of Information on their Taxonomy, Occurrences, Distribution, Threats and General Status.

by

Palmira D.G. Boutillier, Graham E. Gillespie and James A. Boutillier

Fisheries and Oceans Canada
Science Branch, Pacific Region
Pacific Biological Station
3190 Hammond Bay Road
Nanaimo, British Columbia V9T 6N7

Cat. Fs97-6/3281E ISBN 978-0-660-28355-5 ISSN 0706-6457
Cat. Fs97-6/3281E-PDF ISBN 978-0-660-28354-8 ISSN 1488-5379

Correct citation for this publication:

Boutillier, P.D.G., G.E. Gillespie and J.A. Boutillier. 2018. British Columbia Echinoids: A Synopsis of Information on their Taxonomy, Occurrences, Distribution, Threats and General Status. Can. Tech. Rep. Fish. Aquat. Sci. 3281: vi + 67 p.

TABLE OF CONTENTS

LIST OF TABLES

ABSTRACT

Boutillier, P.D.G., G.E. Gillespie and J.A. Boutillier. 2018. British Columbia Echinoids: A Synopsis of Information on their Taxonomy, Occurrences, Distribution, Threats and General Status. Can. Tech. Rep. Fish. Aquat. Sci. 3281: vii + 67 p.

The information in this report is intended to be a first step in understanding the extant biodiversity of Echinoids in the federally and provincially regulated marine waters off British Columbia on the west coast of Canada. The information is intended to inform Federal and Provincial Agencies responsible for the management of anthropogenic activities within these waters, of the nature, extent and condition of the biodiversity and how these anthropogenic activities threaten the existence of these animals.

General status ranking (GSR) assessments are conducted by integrating the best available information on taxonomy, population size, distribution, trends and threats, to evaluate general status of each species.

During the 2010 GSR assessment process, 19 species of echinoids were identified within BC coastal waters. Six species were classified as having Secure rankings, 12 Undetermined and one species that is considered Sensitive.

RESUME

Boutillier, P.D.G., G.E. Gillespie and J.A. Boutillier. 2018. British Columbia Echinoids: A Synopsis of Information on their Taxonomy, Occurrences, Distribution, Threats and General Status. Can. Tech. Rep. Fish. Aquat. Sci. 3281: vii + 67 p.

Les informations contenues dans ce rapport constituent un premier pas dans la compréhension de la biodiversité des échinoïdes existants dans les eaux marines, sous réglementation fédérale et provinciale, de la Colombie-Britannique, sur la côte ouest du Canada. Les informations visent à informer les agences fédérales et provinciales, responsables de la gestion des activités anthropiques dans ces eaux, de la nature, de l'étendue et des conditions de la biodiversité et de la façon dont ces activités anthropiques menacent l'existence de ces animaux.

Les évaluations de la situation générale (ESG) sont menées en incluant les meilleures informations disponibles sur la taxonomie, la taille de la population, la répartition, les tendances et les menaces, afin d'évaluer la situation générale de chaque espèce.

Au cours du processus ESG de 2010, 19 espèces d'échinoïdes ont été identifiées dans les eaux côtières de la Colombie-Britannique. Six espèces ont été classées comme sécures, 12 indéterminés et une espèce a été classée comme sensible.

INTRODUCTION

The General Status of Species in Canada is a process that came into effect through the Accord for the Protection of Species at Risk (1996, revised 1998). The accord documents the commitment from federal, provincial and territorial Ministers to protect species at risk of extinction. The General Status of Species in Canada addresses the Minister's commitment under the accord to "establish complementary legislation and programs that provide for effective protection of species at risk throughout Canada, and that will: a) address all native wild species" and "j) monitor, assess and report regularly on the status of all wild species." The activities of the accord are coordinated through the Canadian Endangered Species Conservation Council (CESCC) which is composed of federal and provincial ministers responsible for wildlife conservation and provides direction to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The accord is one part of a three part strategy for the protection of species at risk in conjunction with the Species at Risk Act (SARA) and the Habitat Stewardship Program for Species at Risk.

The General Status of Species in Canada is assessed every five years and reported on through the Wild Species report series (www.wildspecies.ca). The first report was Wild Species 2000 (CESCC 2001) which assessed Canada's freshwater fishes (Agnatha, Chondrichthyes and Osteichthyes), amphibians (Amphibia), reptiles (Reptilia), birds (Aves), mammals (Mammalia), butterflies (Lepidoptera), ferns (Filicales) and orchids (Orchidaceae). The second report, Wild Species 2005 (CESCC 2006) assessed Canada's vascular plants (Tracheophyta), freshwater mussels (Unionida), crayfishes (Astacidae and Cambaridae), dragonflies and damselflies (Odonata), tiger beetles (Cicindelidae) and marine fishes (Agnatha, Chondrichthyes and Osteichthyes) as well as updating information on the species groups from Wild Species 2000 (CESCC 2001). Wild Species 2010 (CESCC 2011) assessed lichens, mosses, spiders (Araneae), predaceous diving beetles (Dytiscidae), ground beetles (Carabidae, including the reassessment of tiger beetles), lady beetles (Coccinellidae), bumblebees (*Bombus* spp.), black flies (Simuliidae), horse flies (Tabanidae), mosquitoes (Culicidae), and some selected macromoths (Lepidoptera); the report also reassessed some groups from previous reports. Results of this ranking process were reported in Wild Species 2015 (CESCC 2016), along with ranks for selected macrofungi, macrolichens, bryophytes (Marchantiophyta, Bryophyta and Anthocerotophyta), vascular plants, sponges (Porifera), corals (Anthozoa), freshwater bivalves, terrestrial and freshwater snails and slugs (Gastropoda), spiders, mayflies (Ephemeroptera), dragonflies and damselflies, stoneflies (Plecoptera), grasshoppers and relatives (Dermaptera, Orthoptera, Notoptera, Phasmida, Mantodea, Blattodea, and Isoptera), lacewings (Neuroptera), beetles (Coleoptera), ants (Formicidae), bees (Anthophila), yellowjacket wasps (Vespidae), caddisflies (Trichoptera), moths and butterflies (Lepidoptera), scorpionflies (Mecoptera), black flies, mosquitoes, horse flies, bee flies (Bombyliidae), flower flies (Syrphidae), decapods (Decapoda), sea cucumbers (Holothuroidea), sea urchins (Echinoidea), fishes, amphibians, reptiles, birds, and mammals.

General status assessments are completed by integrating the best possible information on population size, distribution, trends and threats, to evaluate general status of the species. All species are classified under one of the overall general status rankings: Extirpated, Extinct, At Risk, May Be At Risk, Sensitive, Secure, Undetermined, Not Assessed, Exotic, or Accidental. The assessments provide information on the level of perceived risk for individual species and overall species groups and areas where more information is needed. They also provide information on possible candidates for formal status assessment by COSEWIC and possible inclusion under SARA.

The Guidelines for Assessing the General Status of Wild Species in Canada, Version 2.0, prepared by the National General Status Working Group (NGSWG) in January 2003 (NGSWG 2003) states that:

> "(t)he process of assigning general status for Canada's wild species is, by necessity, a coarse-filter approach to evaluating species' status. The general status ranking system does not negate or replace the need for more detailed ranking systems (e.g. Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessment process), or those designed to assess specific taxonomic groups (e.g. Partners in Flight ranking system for birds). It is hoped however, that the general status ranks will be useful in examining overall trends in species' status across a broad range of taxonomic groups and through time."

In 2008, a new round of general status assessments was initiated for inclusion in the Wild Species 2010 report. Fisheries and Oceans Canada (DFO), Pacific Region received funding through the Species At Risk program to rank all species of corals, decapods, holothuroids, echinoids and reef-building sponges in Canada's Pacific waters. This request included developing regional species lists, assembling and outlining the available information on species and providing species ranks based on the general status ranking procedure. Throughout this document this process will be referred to as the General Status Ranking (GSR) process.

METHODS

The GSR guidelines and criteria are outlined in the Guidelines for Assessing the General Status of Wild Species in Canada (NGSWG 2003) and follow the procedure laid out in Harper *et al.* (1996). They are based on ranking systems set out by the International Union for Conservation of Nature, the Convention on International Trade in Endangered Species of Wild Fauna and Flora and the Conservation Data Centres and Natural Heritage Programs of NatureServe.

The ranking system uses seven criteria for evaluation: population size, distribution, number of occurrences, population trend, distribution trend, threats to population, and threats to distribution (habitat) (Table 1). Each criterion is rated on a scale from worst to best, so an A score suggests the worst case for species conservation and a D score suggests the best case for species conservation. Therefore, species with a

large number of A scores are the most at risk of extinction or extirpation and species with a large number of D scores are most secure and stable under present conditions. Occasionally there is a category where two scores are equally appropriate. In this case a range is given (e.g. A/B). A score of x is used when the criteria rank is Unknown. NGSWG (2003) states that "(t)he criteria presented here should be used as guidelines to focus and align common approaches to general status assessments. This approach is vital given the range of taxonomic diversity of wild species in Canada. For example, some criteria and their rating scales are not applicable to some taxonomic groups (e.g. invertebrates and marine fishes). Also, some taxonomic groups may have more extensive data than others (e.g. birds)."

Criteria and scores proposed in Harper *et al.* (1996) and NGSWG (2003) were adapted to fit within the restraints of the data and the life history of the marine invertebrate groups selected for the 2010 GSR process. Raw data for the Pacific Region marine invertebrate GSR process were collected from museums, DFO databases, researchers, literature and other data sources (see Acknowledgements for details) to address the scoring criteria.

Table 1. Proposed criteria and rating scale (score) for the general status of all wild species, adapted from Harper *et al.* (1996) and NGSWG (2003).

	Rating Scale (Score)			
Criteria	**A**	**B**	**C**	**D**
Population Size (Popln.)	Very Small (<1000)	Small (1001-3000)	Medium (3001-10,000)	Large (>10,000)
Population Trend (P. Trend)	Rapidly declining (>50%)	Declining (>20%)	Stable (fluctuations)	Increasing (any rate)
Distribution Trend (D. Trend)	Rapidly declining (>50%)	Declining (>20%)	Stable (fluctuations)	Increasing (any rate)
Geographic Distribution (Distn.)	Very Restricted (<3%)	Restricted (4-10%)	Regional (11-50%)	Widespread (>50%)
Number of Occurrences (# Occ.)	Very Restricted (<5)	Restricted (6-20)	Regional (21-100)	Widespread (>101)
Threats to Population (P. Threats)	Extreme (>50%)	Moderate (<50%)	Limited (mitigated)	None (no effect)
Threats to Distribution (D. Threats)	Extreme (>50%)	Moderate (<50%)	Limited (mitigated)	None (no effect)

Population Size (Popln.)

Population Size represents the current estimate of the total number of mature individuals capable of reproduction (Harper *et al*. 1996). The proposed scores are as follows: A= very small (<1000 mature individuals), B= small (1001-3000 mature individuals), C= medium (3001-10000 mature individuals), D= large (>10000 mature individuals). These metrics are not very useful when dealing with marine invertebrate species.

For the marine invertebrate groups selected for the 2010 GSR process the criterion Population Size included any comments or data that revolved around an actual population size or comparative population size among similar species. This category was generally ranked as unknown, unless dealing with a commercially fished species.

Geographic Distribution (Distn.)

Geographic Distribution represents the current percentage of the provincial/territorial/ocean region area contained within the shortest continuous imaginary boundary which can be drawn to encompass all the known, inferred or projected sites of occurrence, excluding cases of vagrancy (Harper *et al*. 1996). The proposed scores are as follows: A=very restricted (<3% of area), B= restricted (4-10% of area), C= regional (10-50% of area), D= widespread (>50% of area).

For the marine invertebrate groups selected for the 2010 GSR process the criterion Distribution was not able to be defined in the manner suggested by Harper *et al.* (1996) and a more qualitative approach was used. A score of D or Widespread was given when a species was distributed coastwide and found in both inshore and offshore locations. A score of C or Regional was given when a species was distributed coastwide but restricted to either inshore (continental shelf) or offshore (continental slope and deeper) locations. A score of A or Very Restricted was given when a species was only distributed in one small area (usually representing either the northern or southern extent of the species distribution). A score of B or Restricted was given when a species was distributed somewhere in between categories A and C.

Number of Occurrences (# Occ.)

Number of Occurrences represents the estimated number of sites where the species currently persists and the basis for including this attribute as an indicator is that very few site occurrences would make a species very susceptible to any number of ecological disturbances, both predictable and unpredictable (Harper *et al*. 1996). The proposed scores are as follows: A=very restricted (<5 sites), B= restricted (6-20 sites), C= regional (21-100 sites), D= widespread (>101sites).

For the marine invertebrate groups selected for the 2010 GSR process the criterion Number of Occurrences was defined as the number of unique coordinate locations within BC waters. If the species is commercially harvested then this category is not useful as there will be many species records and unique locations (Most likely D = widespread). For commercial species perhaps information on how many management areas contain the species in question is a more informative statistic. For large biogenic structures like sponge reefs and bioherms, the number of distinct reefs was used as Number of Occurrences.

Species Distribution Maps are provided in the individual species summaries. These maps only provide Occurrence site information collected from Museums, the

literature and DFO Research Surveys. They do not reflect data collect from commercially harvested species. Commercial harvest information will be addressed in the comments and references under the individual species summary.

Population Trend (P. Trend)

Population Trend represents the estimated change in the number of mature individuals over time (over 10 years or 3 generations)(Harper *et al*. 1996). The proposed scores are as follows: A= rapid decline (>50%), B= decline (>20%), C= stable (including natural fluctuations), D= increasing (any rate). This was the working definition used for the select marine invertebrate groups chosen in the 2010 GSR process but there was very little available information on this metric.

Distribution Trend (D. Trend)

Distribution Trend represents the decrease in the Canadian range of the species over time (over 10 years or 3 generations)(Harper *et al*. 1996). The proposed scores are as follows: A= rapid decline (>50%), B= decline (>20%), C= stable (including natural fluctuations), D= increasing (any rate). This was the working definition used for the select marine invertebrate groups chosen for the 2010 GSR process but there was very little available information on this metric.

Threats to Population (P. Threats)

Threats to Population represents the observed, inferred, or projected mortality and includes effects of direct exploitation, harassment, exotic species, or ecological interactions with predators, competitors, pathogens or parasites which may result in population declines (Harper *et al*. 1996). The proposed scores are as follows: A= extreme: significant, affect more than half the population, and are unmitigated, B= moderate: also serious, but affect less than half the population or are mitigated by some level of human protection, C= limited: less significant to population viability, or are being mitigated through protective measures, D= none. This was the working definition used for the select marine invertebrate groups chosen for the 2010 GSR process.

Threats to Distribution (D. Threats)

Threats to Distribution represents the observed, inferred, or projected habitat alterations (loss, conversion, degradation, or fragmentation) which may result in population declines (Harper *et al*. 1996). The proposed scores are as follows: A= extreme: significant, affect more than half the population, and are unmitigated, B= moderate: also serious, but affect less than half the population or are mitigated by some

level of human protection, C= limited: less significant to population viability, or are being mitigated through protective measures, D= none. This was the working definition used for the select marine invertebrate groups chosen for the 2010 GSR process.

Threats to Distribution are considered Extreme if a species is found in intertidal to shallow waters 0-200m, because these depths are likely to have more effects associated with climate change and anthropogenic influences. If a species is known from deep waters (>200m) the Threats to Distribution are considered Limited.

General Status Categories (Ranks)

General status categories (Table 2) are the overall ranks given to species after all the criteria have been assessed and are meant to reflect the species conservation status. NGSWG (2003) states that "(g)eneral status categories are necessarily somewhat broad. There are two main reasons for this. The large number of species covered precludes the detailed and intensive species assessments that would inform a finer-scaled system and there is variation in the amount of information available for different species." The information analysed and conclusions reached through the GSR process refer only to a species status. Each region does its own GSR assessments and they are combined nationally in the Wild Species report series. For the Pacific Region process we looked at species occurring in British Columbia (BC) marine waters.

After the Regional GSR process was completed, the CESCC adopted a different ranking system, developed by NatureServe (Table 3)(CESCC 2016). Regional General Status Ranks were translated into the NatureServe ranking system and National ranks were developed. We include a summary and NatureServe ranks at both Regional and National levels for completeness.

Species Information

Higher taxonomic classification, valid scientific name, synonymy and AphiaID are from the World Register of Marine Species (WoRMS)(WoRMS Editorial Board 2018; http://www.marinespecies.org), accessed March 2018. Taxonomic Serial Numbers (TSN) are from the Integrated Taxonomic Information System (ITIS) (http://www.itis.gov). English common names are from literature or WoRMS; French common names are those provided by CESCC (2016) or WoRMS.

Species Distribution Maps provide only information collected from Museums, the literature and DFO Research Surveys.

Comments

Canada committed to monitor, assess and report regularly on the status of all wild species initially in 1996 under the Accord for the Protection of Species at Risk. Canada

has furthered this commitment to protection and management of aquatic biodiversity through the enactment of: the Species at Risk Act; the Oceans Act allowing for implementation of Marine Protected Areas: and in recent changes to the Federal Fisheries Act for enhanced protection of Sensitive benthic habitats.

The initial work on this report concluded in 2010, with the provision of a GSR by the lead author. However, the value and extent of information which went into the 2010 GSR has much broader applications in meeting DFO's mandate. It was therefore decided to present this information in this series of reports that are intended to aid in our understanding of the extent of biodiversity of marine invertebrates in the federally and provincially regulated marine waters off British Columbia on the west coast of Canada. This information is intended to inform Federal and Provincial Agencies responsible for the management of anthropogenic activities within these waters, of the nature, extent and condition of some of the biodiversity and how these anthropogenic activities threaten the existence of this animals.

Subsequent modification to this initial work has been largely confirmation and editorial, but the other authors have attempted to update taxonomic changes or personal communications that could be strengthened by subsequent publications. As such, editorial comments, where required, are included in species summaries.

Reviewer comments, where available, are included in species summaries.

Table 2. General Status Ranks (NGSWG 2003).

General Status Rank	Rank Title	Definition
0.1	Extirpated	Species that have disappeared from (or are no longer present in) a given geographic area (in this context Canadian Pacific marine waters) but occur in other areas.
0.2	Extinct	Species that are extirpated worldwide (i.e., they no longer exist anywhere).
1	At Risk	Species for which a formal detailed risk assessment (COSEWIC assessment or provincial or territorial equivalent) has been completed and that have been determined to be at risk of extirpation or extinction (i.e., Endangered) or is likely to become at risk of extirpation or extinction if limiting factors are not reversed (i.e., Threatened).
2	May Be At Risk	Species that may be at risk of extirpation or extinction and are therefore candidates for a detailed risk assessment by COSEWIC or provincial or territorial equivalents.
3	Sensitive	Species that are not believed to be at risk of extirpation or extinction but may require special attention or protection to prevent them from becoming at risk.
4	Secure	Species that are not believed to belong to the categories At risk, May be at risk, Extirpated, Extinct, Accidental and Exotic. This category includes some species that show a trend of decline in numbers in Canada but remain relatively widespread or abundant. In such instances, the decline will be highlighted by an asterisk and an associated comment.
5	Undetermined	Species for which insufficient data, information, or knowledge is available with which to reliably evaluate their general status.
6	Not Assessed	Species that are known or believed to be present in the geographic area in Canada to which the general status rank applies but have not yet been assessed.
7	Exotic	Species that have been moved beyond their natural range as a result of human activity. In this report, Exotic species have been purposefully excluded from all other categories.
8	Accidental	Species occurring infrequently and unpredictably outside their usual range.

Table 3. NatureServe Status Ranks (CESCC 2016).

Rank	Category	Description
Geographic Range		
N	National	Indicates a rank at the national level in Canada.
S	Subnational	Indicates a rank at the level of a province, territory, or ocean region in Canada.
Conservation Status		
X	Presumed Extirpated	Species is believed to be extirpated from the jurisdiction (nation, province, territory, or ocean region). Not located despite intensive searches of historical sites and other appropriate habitat, and virtually no likelihood that it will be rediscovered.
H	Possibly Extirpated	Known from only historical records but still some hope of rediscovery. There is evidence that the species may no longer be present in the jurisdiction, but not enough to state this with certainty. Examples of such evidence include: (1) that a species has not been documented in approximately 20-40 years despite some searching and/or some evidence of significant habitat loss or degradation; (2) that a species has been searched for unsuccessfully, but not thoroughly enough to presume that it is no longer present in the jurisdiction.
1	Critically Imperiled	At very high risk of extirpation in the jurisdiction due to very restricted range, very few populations or occurrences, very steep declines, severe threats, or other factors.
2	Imperiled	At high risk of extirpation in the jurisdiction due to restricted range, few populations or occurrences, steep declines, severe threats, or other factors.
3	Vulnerable	At moderate risk of extirpation in the jurisdiction due to a fairly restricted range, relatively few populations or occurrences, recent and widespread declines, threats, or other factors.
4	Apparently Secure	At a fairly low risk of extirpation in the jurisdiction due to an extensive range and/or many populations or occurrences, but with possible cause for some concern as a result of local recent declines, threats, or other factors.
5	Secure	At very low or no risk of extirpation in the jurisdiction due to a very extensive range, abundant populations or occurrences, with little to no concern from declines or threats.
U	Unrankable	Currently unrankable due to lack of information or due to substantially conflicting information about status or trends.
NR	Unranked	National or subnational conservation status not yet assessed.
NA	Not Applicable	A conservation status rank is not applicable because the species is not a suitable target for conservation activities. It includes exotic species (that have been moved beyond their natural range as a result of human activity), hybrids, or long distance migrants (accidental species occurring infrequently and unpredictably outside their usual range).
Qualifier		
?	Inexact Numeric Rank	Denotes inexact numeric rank. This designation should not be used with any of the X, H, U, NR or NA conservation status ranks.
B	Breeding	Conservation status refers to the breeding population of the species in the nation, province, territory, or ocean region.
N	Non-breeding	Conservation status refers to the non-breeding population of the species in the nation, province, territory, or ocean region.
M	Migrant	Conservation status refers to the migrant population of the species in the nation, province, territory, or ocean region.

RESULTS

Deliverables for the 2010 GSR process were Microsoft Excel spreadsheets for each marine invertebrate group (corals, decapods, holothuroids, echinoids and reef-building sponges) with scores and comments for each ranking criteria for all species found in BC marine waters; species groups other than echinoids will be documented in separate reports. Additional relevant information beyond that required for the ranking criteria was collected and included in GSR products. GSR information for each of the echinoid species is found in the species summaries. Information for each species is presented in document format and associated maps that were created to judge distribution are included as well.

During the GSR process 19 species of echinoids were identified within BC coastal waters (Table 4). Echinoids, or sea urchins and sand dollars, are a monophyletic group and include all members from Class Echinoidea (Phylum Echinodermata).

The Echinoid GSR resulted in six Secure rankings, 12 Undetermined and one species that is considered Sensitive (Table 4, Table 5). Eighty-four percent of echinoid species have an Unknown Population Size and 58% have an Unknown Distribution (Table 6, Table 7). Fifty-three percent of Number of Occurrences are Unknown with the remainder spread across the rating scale. For echinoid species, 89% of the Population Trends and 95% of the Distribution Trends are Unknown. Threats to Population are Unknown for 74% of echinoid species. Threats to Distribution are considered Limited (C) for 63% of species and Extreme (A) for 37%. NatureServe ranks for Pacific Canadian echinoids are included in Table 8; these include six species ranked as Secure, one species ranked as Vulnerable and 12 species designated as Unrankable.

Threats

Some threats to population and/or distribution were common amongst species groups. Threats common amongst species are described here; a header indicator is included in species summaries and unique threats or details are discussed in each species summary. Common threats to population and/or distribution include:

Harvest: Two species (*Mesocentrotus franciscanus* and *Strongylocentrotus droebachiensis*) are harvested commercially. There was historic interest in developing commercial harvest of *Strongylocentrotus purpuratus*.

Predation: Re-introduction and range expansion of Sea Otters (*Enhydra lutris*) have impacted and will continue to impact current populations of shallow water urchins, particularly *M. franciscanus*. Next to humans, Sea Otters are the most important predator on sea urchins in BC (Breen 1980). After the re-introduction of Sea Otters on the northwest coast of Vancouver Island, urchin abundance decreased and algal biomass increased (Breen *et al*. 1982, Watson 1993).

Bycatch: Urchins that occupy habitat impacted by directed fisheries for other species may be impacted, particularly if the footprint of those fisheries increases.

Anthropogenic Disturbances: Anthropogenic activities that may impact urchin populations include activities such as: bottom tending fishing, aquaculture, log storage, marine cable and pipeline installation, finfish aquaculture, oil and gas exploration, mineral mining and wind farms, which have the potential to impact habitat by causing alterations, possible waste discharges and spills, and include unknown impacts (e.g., electromagnetic radiation from wind farms). Deep water species could be susceptible to anthropogenic sources of pollution such as deep sea dumping and exploration for deep water fisheries, oil and gas or mineral mining. Nearshore habitats and the species they support are susceptible to anthropogenic sources of pollution, increases in sedimentation and coastal development.

Global Climate Change: Climate change is affecting the oceans and poses many potential threats to marine species including changes to seawater temperature, salinity, density, sea levels, ambient light, pH, currents, circulation and oxygen concentration. Effects of increases in sea temperatures on sublittoral sea-bed species include increased abundance and extension of distribution of southern species alongside reduced abundance and retreat in the distribution of northern species (Hiscock *et al*. 2004). For northern species, the effects of rising sea temperatures are likely to decrease survival of adults, decrease successful gonad development, more broods will lead to reduced reproductive output, and there will be a decrease in larval development, larval settlement and larval survival. A potentially important effect of climate change might be to alter the abundance and type of meroplanktonic organisms that are the food of other marine life.

Deep-sea Resource Exploration: Deep-sea megafauna dwell in a highly stressful environment under extreme hydrological conditions, such as high pressure, low temperature, low salinity, low oxygen, minimum water currents, absence of light, and low sedimentation rates (Rodrigues *et al.* 2001). This makes them highly vulnerable to any slight change or disturbance in their habitat, leading to mortality and decrease in numbers. Impacts will be most serious in areas directly disturbed during mining.

Anoxia: Chan et *al.* (2008) discuss an anoxia event which occurred off the coast of Oregon in 2006 where near complete mortality of macroscopic benthic invertebrates occurred and sulfide-oxidizing bacterial mats formed in shallow (50 m) waters (an event not seen in five previous decades of available records). DFO (2009) notes that oxygen concentrations in bottom waters of the BC continental shelf dropped markedly in 2008, compared to 2006.

Table 4. Echinoid species list and Regional General Status Ranks.

#	Class	Order	Family	Scientific Name	GSR
1	Echinoidea	Camarodonta	Strongylocentrotidae	*Mesocentrotus franciscanus*	4
2	Echinoidea	Camarodonta	Strongylocentrotidae	*Strongylocentrotus droebachiensis*	4
3	Echinoidea	Camarodonta	Strongylocentrotidae	*Strongylocentrotus fragilis*	4
4	Echinoidea	Camarodonta	Strongylocentrotidae	*Strongylocentrotus pallidus*	4
5	Echinoidea	Camarodonta	Strongylocentrotidae	*Strongylocentrotus purpuratus*	3
6	Echinoidea	Cidaroida	Ctenocidaridae	*Aporocidaris fragilis*	5
7	Echinoidea	Cidaroida	Ctenocidaridae	*Aporocidaris milleri*	5
8	Echinoidea	Clypeasteroida	Dendrasteridae	*Dendraster excentricus*	4
9	Echinoidea	Echinothurioida	Echinothuriidae	*Sperosoma biseriatum*	5
10	Echinoidea	Echinothurioida	Echinothuriidae	*Sperosoma giganteum*	5
11	Echinoidea	Holasteroida	Pourtalesiidae	*Ceratophysa ceratopyga valvaecristata*	5
12	Echinoidea	Holasteroida	Pourtalesiidae	*Cystocrepis setigera*	5
13	Echinoidea	Holasteroida	Pourtalesiidae	*Echinocrepis rostrata*	5
14	Echinoidea	Holasteroida	Pourtalesiidae	*Pourtalesia tanneri*	5
15	Echinoidea	Holasteroida	Pourtalesiidae	*Pourtalesia thomsoni*	5
16	Echinoidea	Holasteroida	Urechinidae	*Antrechinus drygalskii perfidus*	5
17	Echinoidea	Holasteroida	Urechinidae	*Cystechinus loveni*	5
18	Echinoidea	Spatangoida	Aeropsidae	*Aeropsis fulva*	5
19	Echinoidea	Spatangoida	Schizasteridae	*Brisaster latifrons*	4

Table 5. Summary of Regional General Status Ranks (as defined in Table 2) for echinoids.

Rank		# Species
1	**At Risk**	0
2	**May Be At Risk**	0
3	**Sensitive**	1
4	**Secure**	6
5	**Undetermined**	12
6	**Not Assessed**	0
7	**Exotic**	0
8	**Accidental**	0
	Total	19

Table 6. Summary of ranking criteria (Table 1) and total scores for echinoids.

Ranking	Ranking Criteria						
Scores	Popln.	Distn.	# of Occ.	P. Trend	D. Trend	P. Threats	D. Threats
A	0	0	2	0	0	0	7
A/B	0	0	0	0	0	0	0
B	0	0	0	1	1	1	0
B/C	0	0	0	0	0	0	0
C	0	3	2	1	0	4	12
C/D	0	2	0	0	0	0	0
D	3	3	5	0	0	0	0
x	16	11	10	17	18	14	0
Total	19	19	19	19	19	19	19

Table 7. Echinoid species list, General Status Ranking Criteria and Scores (Table 1).

#	Scientific Name	Popln.	Distn.	# Occ.	P. Trend	D. Trend	P. Threats	D. Threats
1	*Mesocentrotus franciscanus*	D	D	D	B	B	B	A
2	*Strongylocentrotus droebachiensis*	D	C/D	D	C	x	C	A
3	*Strongylocentrotus fragilis*	x	D	D	x	x	x	A
4	*Strongylocentrotus pallidus*	x	D	D	x	x	x	A
5	*Strongylocentrotus purpuratus*	x	C	C	x	x	C	A
6	*Aporocidaris fragilis*	x	x	x	x	x	C	C
7	*Aporocidaris milleri*	x	x	x	x	x	C	C
8	*Dendraster excentricus*	D	C	C	x	x	x	A
9	*Sperosoma biseriatum*	x	C	A	x	x	x	C
10	*Sperosoma giganteum*	x	x	x	x	x	x	C
11	*Ceratophysa ceratopyga valvaecristata*	x	x	x	x	x	x	C
12	*Cystocrepis setigera*	x	x	x	x	x	x	C
13	*Echinocrepis rostrata*	x	x	A	x	x	x	C
14	*Pourtalesia tanneri*	x	x	x	x	x	x	C
15	*Pourtalesia thomsoni*	x	x	x	x	x	x	C
16	*Antrechinus drygalskii perfidus*	x	x	x	x	x	x	C
17	*Cystechinus loveni*	x	x	x	x	x	x	C
18	*Aeropsis fulva*	x	x	x	x	x	x	C
19	*Brisaster latifrons*	x	C/D	D	x	x	x	A

Table 8. NatureServe ranks (Table 3) for Canadian Pacific echinoid species (CESCC 2016).

Scientific Name	Canada	Pacific	Western Arctic Ocean	Eastern Arctic Ocean	Atlantic
Mesocentrotus franciscanus	N5	S5		SU	
Strongylocentrotus droebachiensis	N5	S5	SU	S5	S5
Strongylocentrotus fragilis	N5	S5			
Strongylocentrotus pallidus	N5	S5	SU		S5
Strongylocentrotus purpuratus	N3	S3			
Aporocidaris fragilis	NU	SU			
Aporocidaris milleri	NU	SU			
Dendraster excentricus	N5	S5			
Sperosoma biseriatum	NU	SU			
Sperosoma giganteum	NU	SU			
Ceratophysa ceratopyga	NU	SU			
Cystocrepis setigera	NU	SU			
Echinocrepis rostrata	NU	SU			
Pourtalesia tanneri	NU	SU			
Pourtalesia thomsoni	NU	SU			
Antrechinus drygalskii	NU	SU			
Cystechinus loveni	NU	SU			
Aeropsis fulva	NU	SU			
Brisaster latifrons	N5	S5			

SPECIES SUMMARIES

Scientific Name: *Mesocentrotus franciscanus* (A. Agassiz, 1863)

Higher Taxonomic Classification: Echinodermata, Echinoidea, Camarodonta, Strongylocentrotidae
Pacific Region Species Code (Hart): 6BC (as *Strongylocentrotus franciscanus*).
TSN: 157971 (as *Strongylocentrotus franciscanus*).
AphiaID: 591102.
Synonyms: *Strongylocentrotus franciscanus* (A. Agassiz, 1863)
Toxocidaris franciscana A. Agassiz, 1863
Toxocidaris franciscanus A. Agassiz, 1863
Common Name: Red Sea Urchin, Giant Red Sea Urchin, oursin rouge.

Proposed General Status Ocean Rank: 4 = Secure
This species is abundant and widespread throughout coastal BC with an annual commercial fishery (Lambert and Austin 2007, Leus *et al*. 2014, DFO 2016a). Although Sea Otter range expansion is predicted to have significant consequence to urchin stocks, historical records indicate the ability to co-exist and a balance is expected to be established. It is predicted that some areas will never be inhabited by Sea Otters and the Red Sea Urchin stocks there will persist in high numbers.

Population Size: D = Large
Conservative estimates of biomass in 2009 for mature individuals put coastwide stocks in excess of 185,000 metric tons with the majority of mature individuals weighing between 246-816 g. Coastwide Total Allowable Catch (TAC) for the 2009/2010 fishing season were 4,583 metric tons however due to market demands less than half the TAC is expected to be harvested. (Leus and Hand, pers. comm., 2010).

Distribution: D = Widespread
Red Sea Urchins are found from Baja California (including the Gulf of California) to Alaska, the Aleutian Islands and Hokkaido, Japan (Campbell and Harbo 1992, DFO 2016a). *Mesocentrotus franciscanus* is present in BC waters coastwide both inshore and offshore with most records from 0-50 m. Habitat preference is for shallow rocky areas with high water flow and low fresh water exposure.

Number of Occurrences: D = Widespread
Harvest and survey data for this species indicate widespread occurrences throughout coastal BC. Red Sea Urchin presence has been confirmed in 25% of all coastline in BC. (Leus and Hand, pers. comm., 2010)

Population Trend: B = Declining
Red Sea Urchins are a primary food source for Sea Otters (Watson and Estes 2011). Stocks have decreased to near zero within a few years of otter habitation at one research site (unpublished DFO data 1995-2009). As Sea Otter populations continue to increase and expand, it is expected that Red Sea Urchin populations will decline. Urchin

populations in areas without otters are assumed to be relatively constant (Leus and Hand, pers. comm., 2010).

Distribution Trend: B = Declining
Approximately 6% of known Red Sea Urchin stocks in the North Coast (north of Cape Caution) and 23% in the South Coast exist within Sea Otter population ranges. Sea Otter range expansion is predicted to result in impacts to >50% of Red Sea Urchin stocks when otters reach carrying capacity (Leus and Hand, pers. comm., 2010).

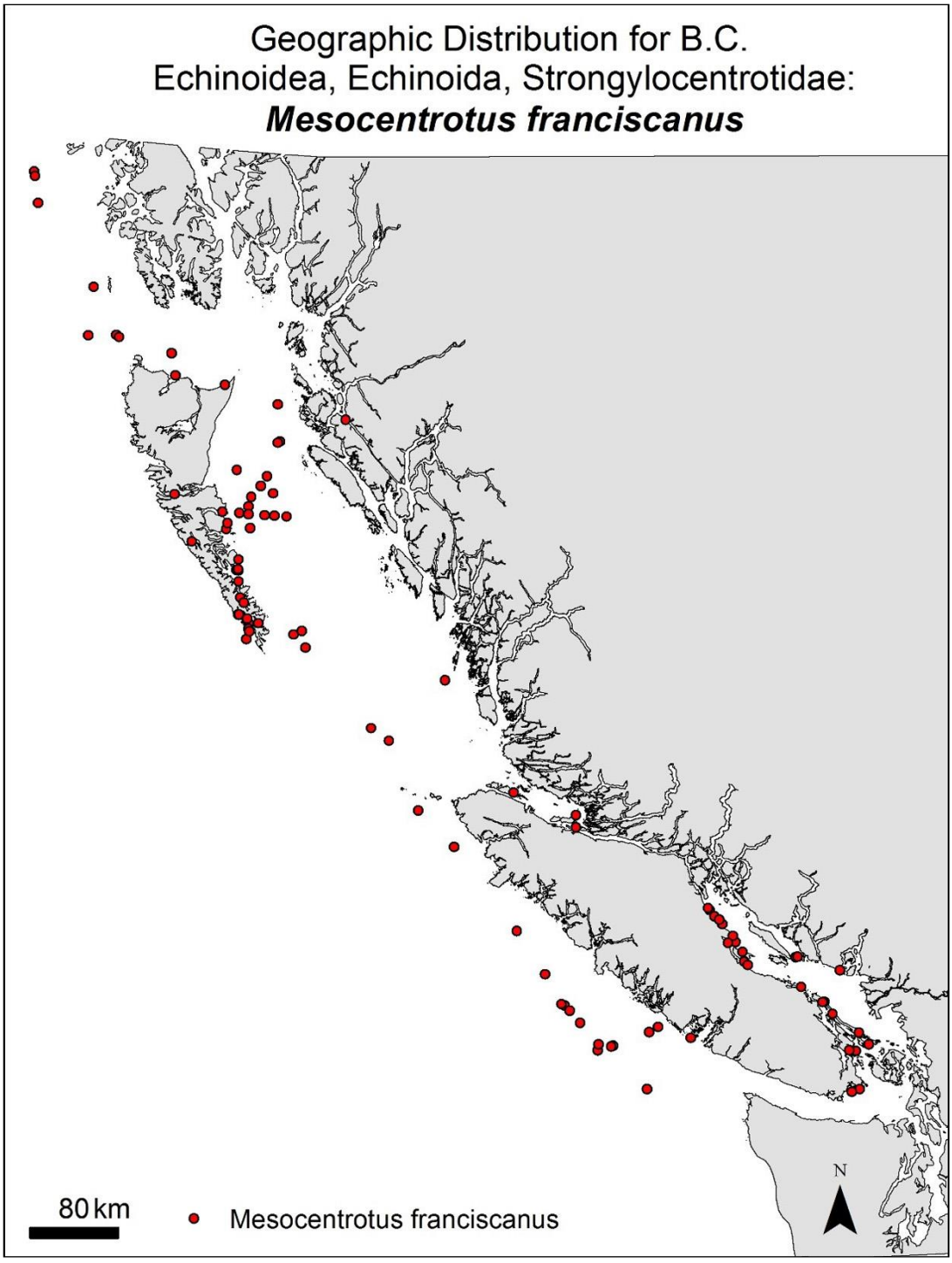
Threats to Population: B= Moderate
Harvest: Leus and Hand (pers. comm., 2010) state that commercial harvest is regulated and stocks are currently under-utilized. Red Sea Urchins have been harvested commercially in British Columbia since the 1970's. The harvest increased rapidly in the early 1980s on the South Coast, but after 1992, it was reduced and stabilized by quotas (Lambert and Austin 2007). The fishery is well regulated in BC, with a harvest rate of 2% of the estimated population allowed each year, as of 2004.
Predation: Predation by Sea Otters currently affects less than half the Red Sea Urchin populations coastwide, however this number is expected to exceed 50% based on current trends (Leus and Hand, pers. comm., 2010). Where otter populations are established on the west coast of Vancouver Island and Central Coast, it is likely that greater than 50% of Red Sea Urchin stocks have been consumed; an ecological balance has not been established.

Threats to Distribution: A= Extreme
Harvest: The commercial dive fishery has minimal or no impact. Declining populations from Sea Otter predation have a positive influence on habitat by increasing kelp cover and primary productivity. Studies in areas where Sea Otters have been long established have shown that once a balance between Sea Otter and sea urchin populations is reached, sea urchin stocks are expected to occur at low densities and be made up of smaller and cryptically located individuals (Breen et al. 1982; Estes and Duggins 1995; Kvitek et al. 1998; Pearse and Hines 1987; Watson and Estes 2011),
Anthropogenic Disturbances
Global climate change
Anoxia

Other Relevant Information: Ebert and Southan (2003) estimate the largest Red Sea Urchins in BC to be 200 years of age; as a species they show no signs of senescence (Ebert 2008). These characteristics have not been observed in other species of urchins. *Mesocentrotus franciscanus* is the largest sea urchin of this genus (Lambert and Austin 2007). In southern BC, *M. franciscanus* gonads ripen between March and September, and spawning usually peaks in May and ends by late June. Metamorphosis from echinopluteus larva to juvenile occurs 40-152 days after fertilization, depending on water temperature. Juveniles are usually found under the canopy of adult spines or adjacent to adults; only one-third are found away from adults. Sea Otters prey heavily on this species, allowing kelp to flourish and provide sheltered habitat for fish, marine mammals and invertebrates. In areas without Sea Otters, *M. franciscanus* can remove most of the

seaweed and attached animals to create an urchin barren, leaving only the few species inedible to them.

Editorial Comments: The most recent information on Sea Otter distribution in BC (Nichol 2015; DFO 2015) indicated continued expansion of their range and increased abundance in both northern and southern BC. Sea otter expansion in BC has impacted Red Sea Urchin stocks in some commercially fished areas and resulted in a drop to some area quotas for the 2016/17 season. (DFO 2017).
Since 2007 the coastwide commercial TAC has remained relatively constant at approximately 4,536 tonnes (ten million pounds)(DFO 2017). Market demand for BC red sea urchin decreased dramatically starting in 2006 due to competition from an illegal, unregulated and unreported fishery in Russia. As a result, landings in BC dropped to below one half of the TAC between 2006 and 2011. Market conditions starting improving in 2012 and 80% of the TAC was landed over the last few seasons.
In 2016, sick or dying urchins were observed along the North and Central coasts of BC (DFO 2017). Some urchins were still attached to the substrate but were missing all or a portion of their spines; some had already died. Preliminary examination of samples suggested the urchins were suffering from ‘bald urchin disease’; a condition that has been reported in species of urchins worldwide (Feehan and Sheibling 2014). Increasing sea temperature could lead to an increase in frequency of disease outbreaks due to decreased host immunity, increased virulence of pathogens or pathogen range expansion (Burge et al. 2014).
Tatarenko and Poltaraus (1993) placed the Red Sea Urchin in their newly described genus *Mesocentrotus*, see also Kober and Bernardi (2013). ITIS does not yet reflect this change.


Geographic Distribution for B.C.
Echinoidea, Echinoida, Strongylocentrotidae:
Mesocentrotus franciscanus
80 km
Mesocentrotus franciscanus
N

Scientific Name: *Strongylocentrotus droebachiensis* (O.F. Müller, 1776)

Higher Taxonomic Classification: Echinodermata, Echinoidea, Camarodonta, Strongylocentrotidae
Pacific Region Species Code (Hart): 6BB.
TSN: 157969.
AphiaID: 124321.
Synonyms: *Echinometra droebachiensis* (O.F. Müller, 1776)
Echinus (*Toxopneustes*) *droebachiensis* (O.F. Müller, 1776)
Echinus (*Toxopneustes*) *dübenii* L. Agassiz in L. Agassiz & Desor, 1846
Echinus (*Toxopneustes*) *duebenii* L. Agassiz in L. Agassiz & Desor, 1846
Echinus chlorocentrotus Des Moulins, 1837
Echinus dröbachiensis O.F. Müller, 1776
Echinus droebachiensis O.F. Müller, 1776
Echinus granularis Say, 1827 non Lamarck, 1816
Echinus granulatus Gould, 1841
Echinus pictus (Norman, 1869)
Echinus subangularis Fleming, 1829
Euryechinus droebachiensis (O.F. Müller, 1776)
Euryechinus granulatus (Gould, 1841)
Strongylocentrotus chlorocentrotus (Des Moulins, 1837)
Strongylocentrotus chlorocentrotus Brandt, 1835
Strongylocentrotus Draebachiensis
Strongylocentrotus droehbachiensis
Strongylocentrotus pictus (Norman, 1869)
Toxopneustes carnosus A. Agassiz, 1864
Toxopneustes droebachiensis (O.F. Müller, 1776)
Toxopneustes neglectus (Lamarck, 1816)
Toxopneustes pictus Norman, 1869
Common Name: Green Sea Urchin, Sea Egg, Northern Sea Urchin, oursin vert.

Proposed General Status Ocean Rank: 4 = Secure
This is a commercially exploited species with a wide distribution and large population size (DFO 2016b,c). Threats caused by the fishery to the population and distribution are mitigated by fisheries management actions.

Population Size: D = Large
Green Sea Urchins periodically undergo population explosions in BC and Nova Scotia (Lambert and Austin 2007). Within BC, population estimates of mature individuals were approx. 6,000,000 from the Oct. 2008 survey in Stephenson Islets, Stubbs Island and Plumper Islands (Area 12; Waddell and Perry 2012) and ~175,000 from the Mar. 2009 survey at Fulford Reef (Area 19; Waddell 2017). These are only 2 of many locations where green urchins can be found (Waddell, pers. comm., 2010).

Distribution: C/D = Regional to Widespread
Green Sea Urchins are a widespread Arctic and northern boreal species; in the Pacific they are distributed from the Arctic Ocean to Washington and the Sea of Japan, and from Hudson Bay, Greenland, Iceland and northern Europe to Chesapeake Bay, Scotland and the western Baltic Sea in the Atlantic. Depth range is 0-300 m, but they are most common in 0-50 m. *Strongylocentrotus droebachiensis* is present from bycatch and non-target surveys in BC waters coastwide both inshore and offshore from 0-270 m with 81% of records collected between 0-150 m. They prefer areas with high current, and rocky substrates, and tend to avoid sand and/or mud substrates (Waddell, pers. comm., 2010).

Number of Occurrences: D = Widespread
Historically, Green Sea Urchins were commercially fished throughout coastal BC with the exception of the west coast of Haida Gwaii and Portland Inlet. Although Green Sea Urchins still occur in all of these locations, currently they are only commercially fished in portions of Queen Charlotte and Johnstone Straits, the southern Gulf Islands and Haro Strait, where they are larger and more abundant (DFO 2016c). This is mostly due to poor market conditions, ease of access and therefore lower costs to harvesters to fish (Waddell, pers. comm., 2010).

Population Trend: C = Stable
Limited information is available as only two sites are surveyed regularly due to limited funding of this small fishery (Waddell, pers. comm., 2010). Green Sea Urchins at Fulford Reef in Pacific Fisheries Management Area (PFMA) 19 have decreased since March 2008 but this is a small population that has been heavily targeted (Waddell et al. 2010). The much larger population in the Stephenson Islets area (PFMA 12) increased to its highest level in October 2008 (254.4 ± 100.4 t) since it was first surveyed in 1995 (96.5 ± 28.5 t)(Waddell and Perry 2012). Fishing pressure has been severely reduced over the last five years due to poor market conditions in Japan (its major market; Waddell and Perry 2010), therefore populations are most likely stable or increasing. state that "the urchin fishery in British Columbia harvested about 250 tons in 1986, peaked at about 1000 in 1992, then dropped back to 250 by 1995 (Lambert and Austin 2007, DFO 2016b,c). Declining landings and catch per unit effort followed and management restrictions were implemented in 1992 followed by quota limitation in 1994 and an Individual Vessel Quota system in 1995 (Workman 1999, DFO 2016b,c). The harvest was capped at about 175 tons per year in 1996, recent Total Allowable Catches are just over 200 tons (DFO 2016b,c). Landings had not approached Total Allowable Catch levels for many years, but virtually the entire allowable catch was landed in the 2015/2016 season.

Distribution Trend: x = Unknown
Not enough information available to determine a trend for this time frame. Commercial fishing had been restricted to PFMAs 12, 13, 18 and 19, and harvesters are not exploring for new populations in other areas at this time. This has been the best source of distribution information as funding or resources to explore the BC coast are lacking (Waddell, pers. comm., 2010).

Threats to Population: C= Limited
Harvest: Fishing effort has decreased substantially over recent years due to poor market conditions in Japan caused by a competitive Russian fishery for Green Sea Urchins; however, effort and total landings increased in the 2015/2016 season (DFO 2016c).
Parasites: Occasional large-scale mortalities of Green Sea Urchins along parts of the Atlantic Coast of Nova Scotia between 1992 and 1995 have been linked to the marine amoeba, *Paramoeba invadens*, whose prevalence appears to be enhanced by water temperatures greater than 10°C (Schiebling and Hennigar 1997). This amoeba has not been observed on the Pacific Coast of Canada to date.
Predation: Expanding Sea Otter populations may eventually become a threat to Green Sea Urchin populations, although they tend to prefer Red Sea Urchins. It is currently not a concern. Green Sea Urchins are also preyed upon by sea stars (e.g., *Pycnopodia helianthoides*), crabs and large fish (e.g., Wolfeel, *Anarrhichthys ocellatus*)(DFO 2016c).

Threats to Distribution: A= Extreme
Predation: Expanding Sea Otter populations may eventually become a threat to Green Sea Urchin distribution, although they tend to prefer Red Sea Urchins. It is currently not a concern.
Anthropogenic Disturbances
Global climate change
Anoxia

Other Relevant Information: Dense populations of urchins can graze off all the kelps and most of the other non-calcareous seaweeds on the bottom (Lambert and Austin 2007). Urchins will also eat much of the animal life attached to the bottom. This overgrazing transforms a kelp forest into an open, level bottom with low species diversity. Population increases may be due low abundance of predators, such as Sea Otters and with widespread mortality of sea stars along the Canadian Pacific Coast 2013 - present (Hewson et al 2014 and Schultz et al 2016) Sunflower Sea stars (*Pycnopodia helianthoides*), or an increase in water temperature, resulting in more rapid growth and settlement of larvae with associated decreases in larval predation. *Strongylocentrotus droebachiensis* feeds primarily on fixed algae and depends on season and locality, but also on small gastropods, barnacles, dead fish, diatoms and detritus (Lambert and Austin 2007). Feeding rates can vary with different species of algae; Bull kelp (*Nereocystis luetkeana*) can be ingested at a rate of 207 mg/hour, but thin green Sea Lettuce at only 17 mg/hour.
In the San Juan Islands individuals can be ripe from January to June with a peak of spawning from March to April (Lambert and Austin 2007). In BC GSU can have ripe gonads pretty much throughout the year. GSU are only landed if they have ripe gonads, otherwise there is no point to fish. Janet Lochead (2018) looked at GSU landings by month from 2008-2009 to 2017-18, and most landings are between Sept – Feb, with spawning usually occurring March in BC, but almost all recent years also had landings in July and August.

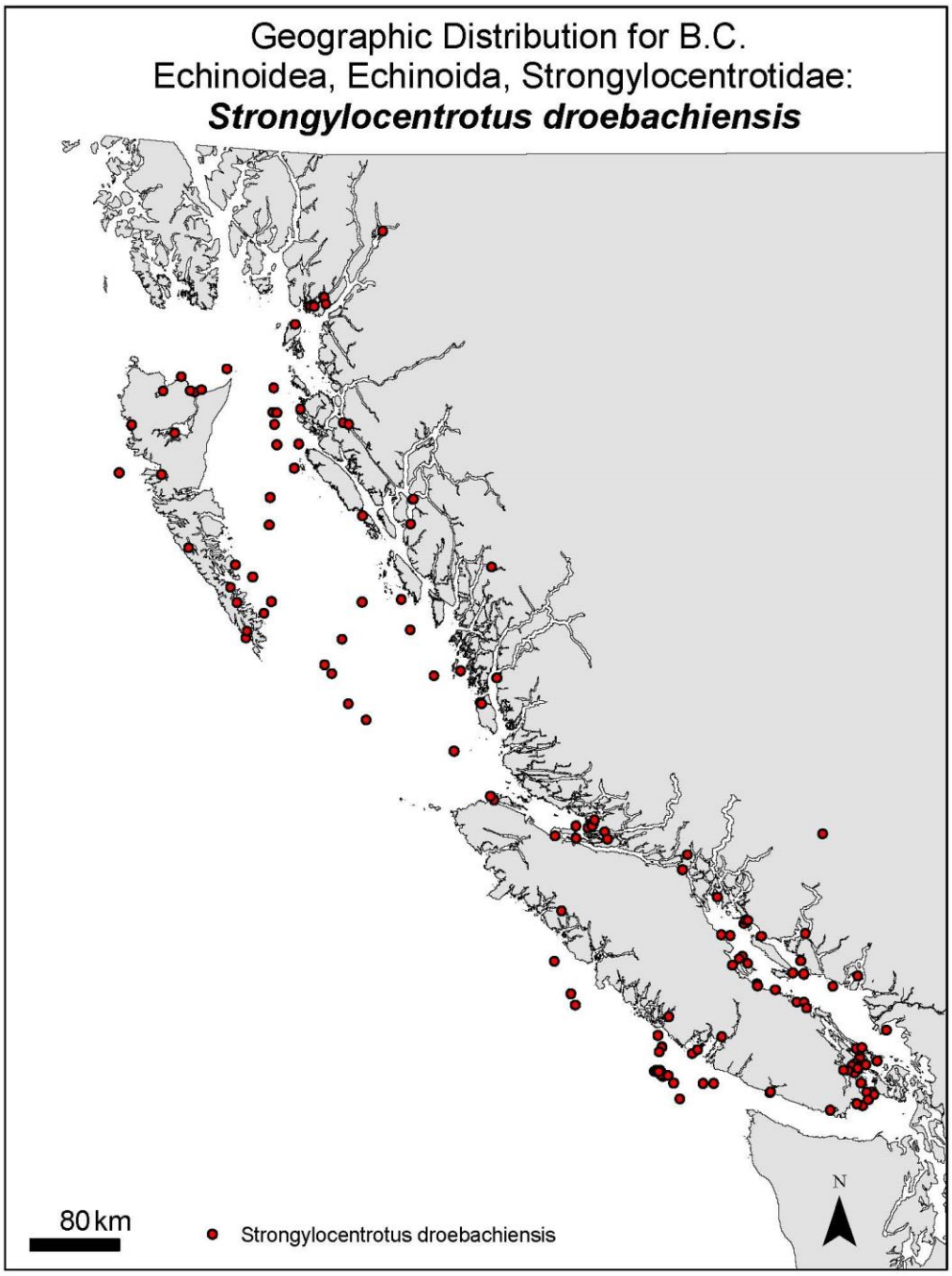
Embryonic and juvenile development vary depending on temperature and food supply. *S. droebachiensis* larvae are tolerant of lower salinity which could relate to the adult distribution being shallower and in more coastal areas. Green Sea Urchins tend to have rather patchy distributions, and appear to be more mobile than the Red Sea Urchin (*M. franciscanus*), with which they are often found. Green Sea Urchins may make seasonal migrations between deep and shallow water depths. Green Sea Urchin growth rates are not consistent, and vary considerably depending on food availability. It takes about four years for a Green Sea Urchin to reach the test diameter of 55 mm (the minimum legal size in BC.)(Munk 1992). Maximum test diameter was greater than 100 mm, maximum age in BC is unknown (DFO 2016c). They begin to sexually mature in BC at approximately 25 mm. Green Sea Urchins are also of importance to First Nations, who harvest them for food, social and ceremonial purposes (DFO 2016c).

Editorial Comments: The most recent information on Sea Otter distribution in BC (Nichol 2015; DFO 2015) indicated continued expansion of their range and increased abundance in both northern and southern BC.

Markets for green sea urchins have rebounded since the low market demand from 2004-2012. In 2016 PFMAs 11 and 20 were re-opened to commercial harvest. There is renewed interest in expanding to other areas of the coast, however the smaller size of this species and lower densities found elsewhere, combined with FN interests, are the three factors now limiting the expansion of the fishery.

There is presently further evidence of occurrence of Green Sea Urchins which indicates its distribution is similar to that of Red Sea Urchins and as such future ranking for Distribution should be D = Widespread.

.


Geographic Distribution for B.C.
Echinoidea, Echinoida, Strongylocentrotidae:
Strongylocentrotus droebachiensis
80 km
Strongylocentrotus droebachiensis
N

Scientific Name: *Strongylocentrotus fragilis* Jackson, 1912

Higher Taxonomic Classification: Echinodermata, Echinoidea, Camarodonta, Strongylocentrotidae
Pacific Region Species Code (Hart): 6AF (as *Allocentrotus fragilis*).
TSN: 157967 (as *Allocentrotus fragilis*).
AphiaID: 569742.
Synonyms: *Allocentrotus fragilis* (Jackson, 1912)
Toxocidaris fragilis (Jackson, 1912)
Common Name: Pink Sea Urchin, Fragile Sea Urchin, oursin fragile.

Proposed General Status Ocean Rank: 4 = Secure
This species is widespread and abundant within BC waters.

Population Size: x = Unknown
No Information Available

Distribution: D = Widespread
Distributed along the west coast of North America from Haida Gwaii to Baja California; 50-1260 m (Lambert and Austin 2007). *Strongylocentrotus fragilis* is present in BC waters coastwide and offshore from 69-853 m with 76% of records collected between 100-250 m. Most *S. fragilis* were found in Queen Charlotte Sound, Hecate Strait and offshore on the west coast of Vancouver Island and west and north coasts of Graham Island, Haida Gwaii. Very few records from inside waters of the Strait of Georgia. Usually dredged from soft bottoms, but have also been observed by ROV on rocks and cobble and mixed with *Strongylocentrotus pallidus* (Lambert and Austin 2007).

Number of Occurrences: D = Widespread
There are 1,378 records of *S. fragilis* in BC representing 1,354 unique coordinate locations. Thirty-six records are from museums, 34 of which are expert identified. The remainder of the records are from DFO surveys and literature.

Population Trend: x = Unknown
Not enough information to determine a trend.

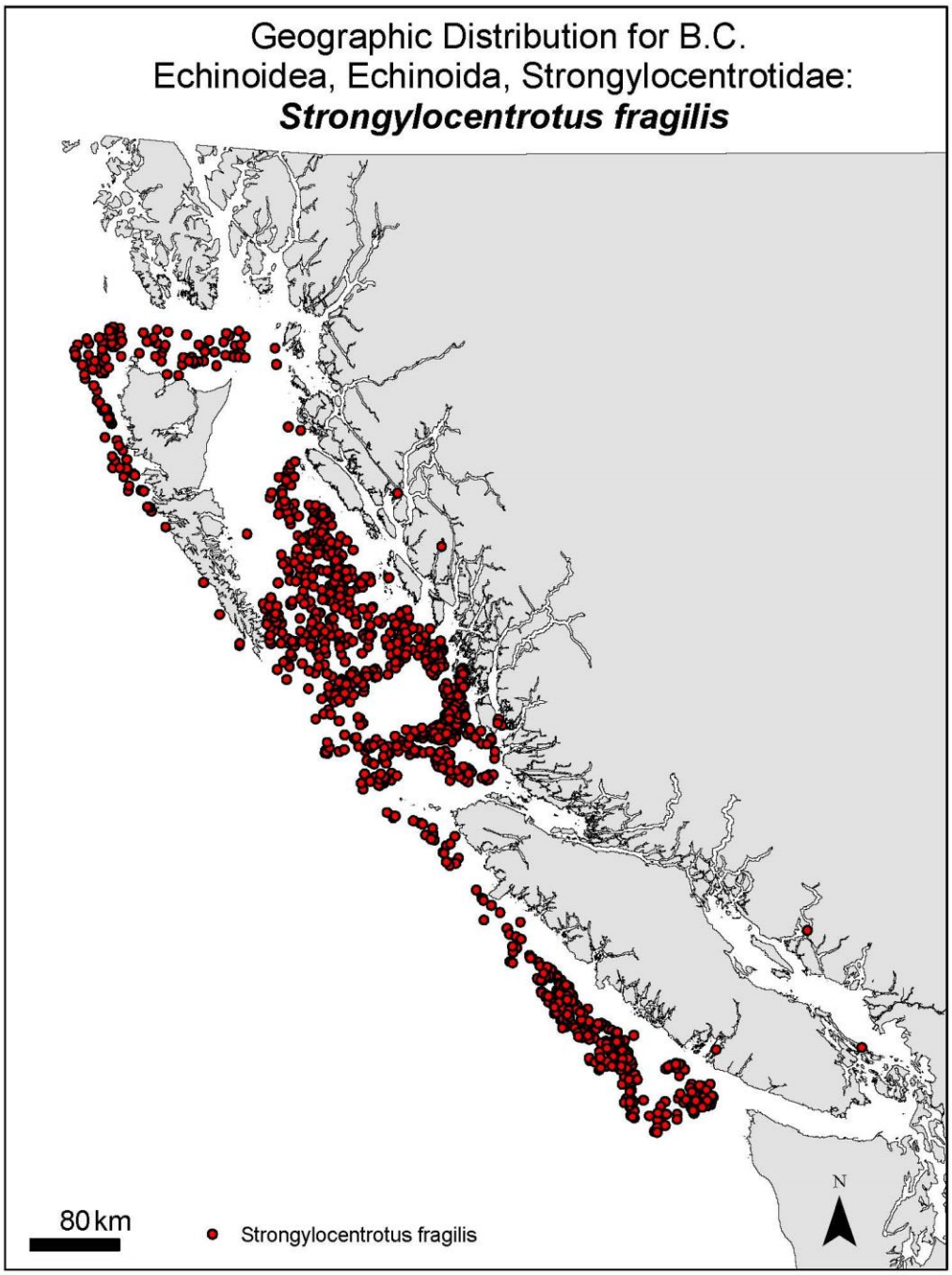
Distribution Trend: x = Unknown
Records from depths below the RBCM limit of 550 m are mostly from DFO deep water ecology (Tanner crab) and groundfish surveys and fall within the overall depth distribution known for the species which extends to 1,260 m.

Threats to Population: x = Unknown
Bycatch: This mid- to deep water species can be caught as bycatch in commercial trawl fishing events.

Threats to Distribution: A= Extreme
Anthropogenic Disturbances
Global climate change
Anoxia

Other Relevant Information: *Strongylocentrotus fragilis* feeds on bottom detritus such as decomposing seaweeds, diatoms, sponge spicules and foraminifera (Lambert and Austin 2007). Gonads of *S. fragilis* are well developed from September until they spawn in January or February. In another study, data suggest that *S. fragilis* had a semi-annual spawning in early spring and early autumn. Average age is 7.5 years. This species is attracted to low-intensity light, able to climb over most obstacles placed in its path, and could withstand starvation for 3 weeks and remain in good condition (at 4 weeks, they become weaker).

Editorial Comments: Mortenson (1942) moved *fragilis* from *Strongylocentrotus* to *Allocentrotus*; recent molecular studies by Biermann (1998) and Biermann *et al*. (2003) returned this species to *Strongylocentrotus* (Lambert and Austin 2007). ITIS does not yet reflect this change.


Geographic Distribution for B.C.
Echinoidea, Echinoida, Strongylocentrotidae:
Strongylocentrotus fragilis
80 km
Strongylocentrotus fragilis
N

Scientific Name: *Strongylocentrotus pallidus* (G.O. Sars, 1871)

Higher Taxonomic Classification: Echinodermata, Echinoidea, Camarodonta, Strongylocentrotidae
Pacific Region Species Code (Hart): 6BA.
TSN: 157972.
AphiaID: 124324.
Synonyms: *Strongylocentrotus droebachiensis sachalinica* Döderlein, 1906
Strongylocentrotus droebachiensis var. *sachalinica* Döderlein, 1906
Strongylocentrotus echinoides A. Agassiz & H.L. Clark, 1907
Strongylocentrotus sachalinicus Döderlein, 1906
Strongylocentrotus sachalinicus Clark, 1912
Toxocidaris echinoides (A. Agassiz & H.L. Clark, 1907)
Toxocidaris sachalinica (Döderlein, 1906)
Toxopneustes pallidus G.O. Sars, 1872
Common Name: White Sea Urchin, Pale Sea Urchin, oursin pâle.

Proposed General Status Ocean Rank: 4 = Secure
This species is widespread and abundant within BC waters.

Population Size: x = Unknown
Strongylocentrotus pallidus is common on Arctic coasts (Lambert and Austin 2007). Bluhm et al. (1998) state that the mean abundance of *S. pallidus* in the Barents Sea, Arctic, was 3.6 individuals m^{-2} with a maximum of 25.5 individuals.

Distribution: D = Widespread
Strongylocentrotus pallidus is present in BC waters coastwide both inshore and offshore from 0-490 m with 46% of records collected between 50-100 m. Many *S. pallidus* were found in Hecate Strait, Queen Charlotte Sound and offshore Barkley Sound, Vancouver Island. Lambert and Austin (2007) state that it has a similar distribution to *Strongylocentrotus droebachiensis* (a widespread Arctic and northern boreal species; from the Arctic Ocean to Oregon and the Sea of Japan in the Pacific, and from Hudson Bay, Greenland, Iceland, northern Europe to Chesapeake Bay, USA, Scotland and western part of Baltic Sea in the Atlantic). It also occurs on the east coasts of Kamchatka and Greenland; in the Pacific on the Asiatic coast to Korea (38°N) and on the North American coast to Oregon (44°N); in the Atlantic to Massachusetts Bay, Iceland, Shetland Islands and Norway. In the Arctic it is most common at 50-150 m on clay, shells, gravel and stones with the seaweeds *Laminaria*, *Fucus*, *Desmarestia* and red algae, and also on substrates with bryozoans and sponges (Lambert and Austin 2007).

Number of Occurrences: D = Widespread
There are 135 records of *S. pallidus* in BC representing 131 unique coordinate locations. 46 records are from museums, 41 of which are expert identified. The remainder of the records are from DFO surveys and literature.

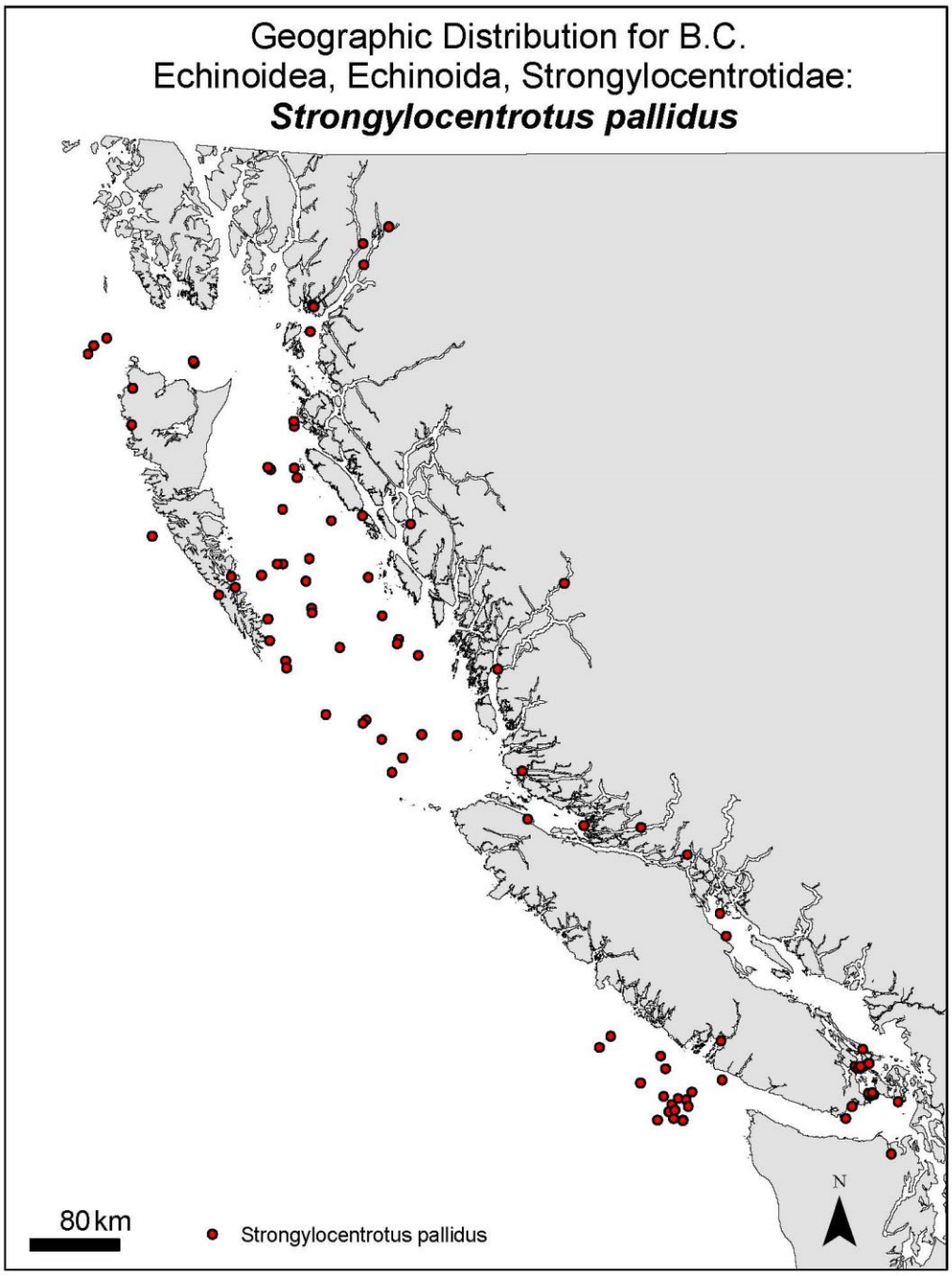
Population Trend: x = Unknown
Not enough information to determine a trend.

Distribution Trend: x = Unknown
Not enough information to determine a trend.

Threats to Population: x = Unknown
Bycatch: This mid to deep water species can be caught as bycatch in commercial trawl fishing events.

Threats to Distribution: A= Extreme
Anthropogenic Disturbances
Global climate change
Anoxia

Other Relevant Information: Most studies indicate an omnivorous diet (Lambert and Austin 2007), including single-celled benthic organisms, such as foraminifera and diatoms, and the remains of various animals such as barnacles, bryozoans, hydroids and amphipods. At Friday Harbour, San Juan Islands, larvae appear in the plankton about mid-March. Larvae metamorphose and settle in 63 days. *Strongylocentrotus pallidus* and *S. droebachiensis* can hybridize. Differences in salinity tolerance of larvae of *S. pallidus* and *S. droebachiensis* could relate to adult distribution; Green Sea Urchins are more tolerant of low salinities and are distributed shallower and in more coastal areas than the deeper-water White Sea Urchin. White Sea Urchins are long-lived: an individual with a 45 mm test diameter was estimated to be 45 years old. Bluhm et al. (1998) state that *S. pallidus* is a widespread epibenthic species in high-Arctic waters and is characterized by slow growth, low mortality, high longevity and low productivity.


Geographic Distribution for B.C.
Echinoidea, Echinoida, Strongylocentrotidae:
Strongylocentrotus pallidus
80 km
Strongylocentrotus pallidus
N

Scientific Name: *Strongylocentrotus purpuratus* (Stimpson, 1857)

Higher Taxonomic Classification: Echinodermata, Echinoidea, Camarodonta, Strongylocentrotidae
Pacific Region Species Code (Hart): 6BD.
TSN: 157975.
AphiaID: 240747.
Synonyms: *Echinus purpuratus* Stimpson, 1857
Loxechinus purpuratus (Stimpson, 1857)
Toxocidaris purpuratus (Stimpson, 1857)
Common Name: Purple Sea Urchin, Purple Spined Sea Urchin, oursin pourpre.

Proposed General Status Ocean Rank: 3 = Sensitive
Purple Sea Urchins are characterized by long life (>50 years), patchy distribution, slow and variable growth, low and periodic recruitment (Workman 1999). They are sedentary and display density dependant spawning success (Allee effect); characteristics indicative of a species susceptible to over-exploitation, which in turn dictates a very cautious approach to fisheries development. *Strongylocentrotus purpuratus* appears less abundant than other urchin species in BC and the range extension of Sea Otters along the west coast where *S. purpuratus* is primarily found lead to the tentative conclusion that this species be ranked as Sensitive.

Population Size: x = Unknown
Campbell and Harbo (1992) state that many dives were required to find appreciable densities of Purple Sea Urchins. In areas where *S. purpuratus* was found sub-tidally, densities ranged from 3 to 130 m^{-2}.

Distribution: C = Regional
Strongylocentrotus purpuratus is present coastwide in BC waters from exposed, inshore locations from 0-24 m. Worldwide distribution is from Sitka Alaska to Cedros Island Mexico; juveniles have been recorded as deep as 161 m but adults normally live from the low intertidal zone down to about 30 m (Lambert and Austin 2007). Many adults live in depressions or burrows in rocky intertidal areas; generations of urchins have excavated burrows, eroding rock by the action of their teeth and spines. *Strongylocentrotus purpuratus* is the common intertidal sea urchin of exposed and semi-protected rocky habitats on the west coast of North America (Workman 1999). It is common in the lower intertidal, typically in areas of moderate to strong wave action or tidal surge; they have also been reported from boulder fields, tide pools in eelgrass beds, and exposed sandstone flats.

Number of Occurrences: C = Regional
There are 31 records of *S. purpuratus* in BC representing 25 unique coordinate locations. 26 records are from museums, 20 of which are expert identified. The remainder of the records are from literature. These are not DFO records.

Population Trend: x = Unknown
A limited experimental fishery ran between 1989-1992; concerns over compliance with the terms of the experimental harvest permit and local depletion lead to a closure of the fishery (Workman 1999).

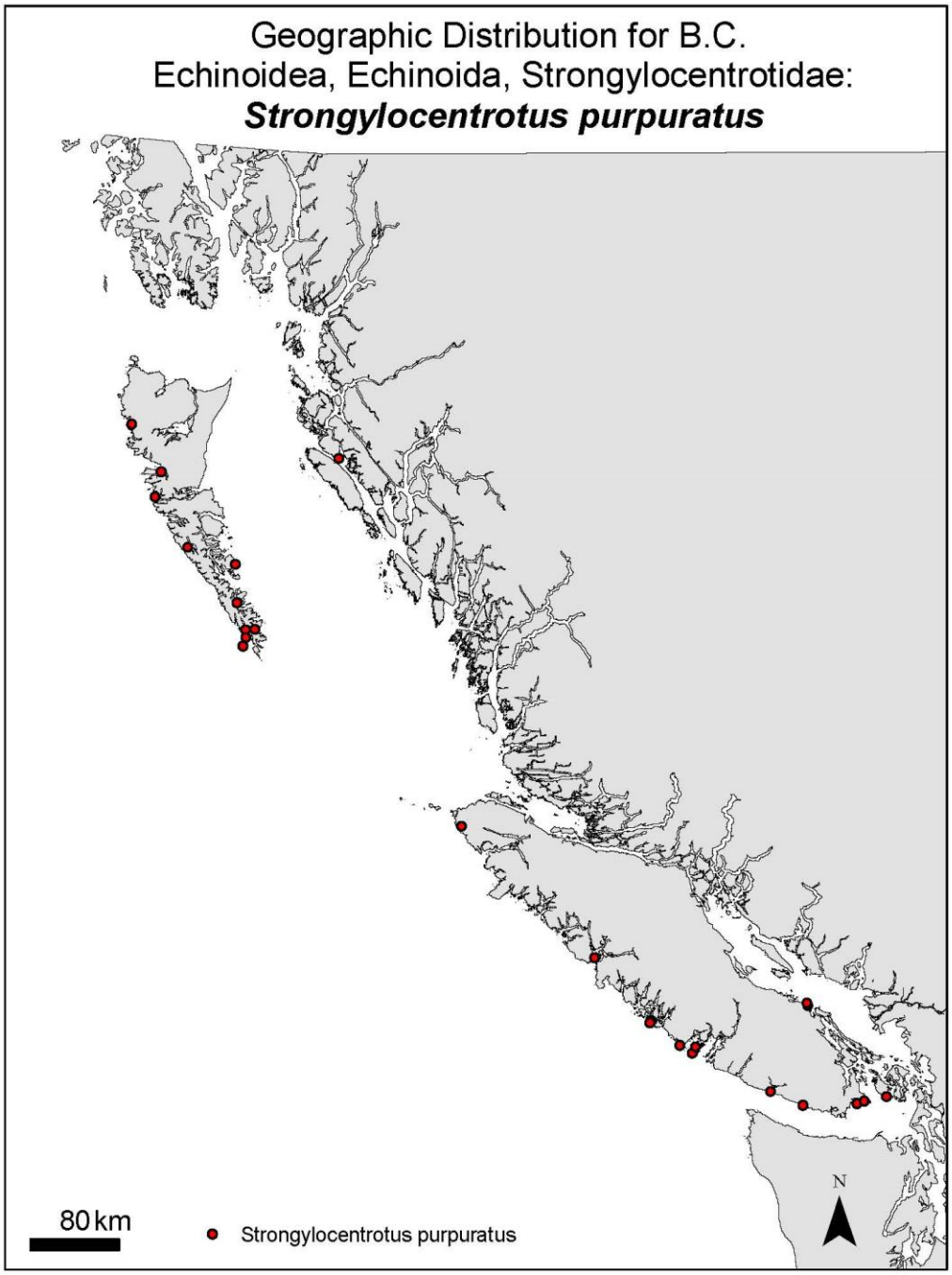
Distribution Trend: x = Unknown
Not enough information to determine a trend.

Threats to Population: C= Limited
Harvest: The roe of *S. purpuratus* is reportedly very similar to that of highly desirable domestic Japanese species, but so far there have been only limited fisheries in California, Oregon and British Columbia (Lambert and Austin 2007). Without proper restraints, this species could be rapidly fished out. A small experimental fishery ran between 1989 and 1992 in BC, when concerns over compliance with the terms of the experimental harvest permit and local depletion led to closure of the fishery (Workman 1999). There is presently no commercial Purple Sea Urchin fishery in BC waters. They are likely taken in the recreational fishery and possibly poaching (due to their easy intertidal access).
Predation: Sea stars (*Pisaster ochraceus, Pycnopodia helianthoides*) and Sea Otters are the major natural predators on *S. purpuratus* in BC waters (Workman 1999).

Threats to Distribution: A= Extreme
Anthropogenic Disturbances
Global climate change
Anoxia

Other Relevant Information: *Strongylocentrotus purpuratus* is omnivorous and opportunistic and usually feeds on attached or drifting seaweeds (Lambert and Austin 2007). They also feed on encrusting organisms and on detritus brought into their burrows. Most stay in their burrows and rely on drifting algae for food, which they snare with their tube feet. They also defend their burrows against other sea urchins by partially emerging and pushing the intruder away without using their pedicellaria. Ripe specimens occur on the outer coast of Juan de Fuca Strait from December to May, but most spawn in April. Females typically shed three to six million eggs; if well fed, they can shed this volume two or three times in a two-month interval. North of Monterey, California, larvae require 63 to 86 days from fertilization to metamorphosis in temperatures less than 15°C. Urchins can begin gamete production at two years old and 24 mm in diameter; most urchins over 40 mm are reproductive. *Strongylocentrotus purpuratus* is able to tolerate a wide range of temperatures from 2°C to 23°C because it is adapted to live intertidally. It is less tolerant of differences in salinity and low levels of dissolved oxygen (Workman 1999). The Purple Sea Urchin has been designated as a high-priority organism by the National Human Genome Research Institute because of its close relationship to vertebrates.

Editorial Comments: The most recent information on Sea Otter distribution in BC (Nichol 2015; DFO 2015) indicated continued expansion of their range and increased abundance in both northern and southern BC.


Geographic Distribution for B.C.
Echinoidea, Echinoida, Strongylocentrotidae:
Strongylocentrotus purpuratus
80 km
Strongylocentrotus purpuratus
N

Scientific Name: *Aporocidaris fragilis* A. Agassiz & H.L. Clark, 1907

Higher Taxonomic Classification: Echinodermata, Echinoidea, Cidaroida, Ctenocidaridae
Pacific Region Species Code (Hart): n/a.
TSN:157845 (as *Aporocidaria fragilis*) an error in the spelling of the genus.
AphiaID: 513112.
Synonyms: *Dorocidaris fragilis* (A. Agassiz & H.L. Clark, 1907)
Plegiocidaris fragilis (A. Agassiz & H.L. Clark, 1907)
Common Names: Long-spined Sea Urchin, Friable Sea Urchin, oursin friable.

Proposed General Status Ocean Rank: 5 = Undetermined
There are no records of this species in BC waters. However it is found in very deep water (up to 4,000 m) which represents a relatively unknown ecosystem.

Population Size: x = Unknown
No Information Available

Distribution: x = Unknown
Bering Sea to the Shumagin Islands, Alaska and to the southern tip of Kamchatka, 3,000-4,000 m (Lambert and Boutillier 2011). They speculated that this species might be found in deep water off BC.

Number of Occurrences: x = Unknown
No records of *Aporocidaris fragilis* collected in BC waters.

Population Trend: x = Unknown
Not enough information to determine a trend.

Distribution Trend: x = Unknown
Not enough information to determine a trend.

Threats to Population: C= Limited
Due to lack of information on populations and threats in BC waters, threats to population are projected from literature pertaining to related species and habitat, rather than directly observed.
Anthropogenic Disturbances

Threats to Distribution: C= Limited
Due to lack of information on populations and threats in BC waters, threats to distribution are projected from literature pertaining to related species and habitat, rather than directly observed.
Deep Sea Resource Exploration
Global climate change

Editorial Comments: Mironov et al. (2015) placed *Aporocidaris* in the family Ctenocidaridae.

Scientific Name: *Aporocidaris milleri* (A. Agassiz, 1898)

Higher Taxonomic Classification: Echinodermata, Echinoidea, Cidaroida, Ctenocidaridae
Pacific Region Species Code (Hart): n/a.
TSN: n/a.
AphiaID: 160784.
Synonyms: *Porocidaris milleri* A. Agassiz, 1898
Plegiocidaris milleri (A. Agassiz, 1898)
Common Name: Long-spined Sea Urchin, Miller's Sea Urchin, oursin de Miller.

Proposed General Status Ocean Rank: 5 = Undetermined
There are no records of this species in BC waters. However, it is found in very deep water (up to 4,000 m) which represents a relatively unknown ecosystem.

Population Size: x = Unknown
No Information Available

Distribution: x = Unknown
Panama to Acapulco, Mexico; 900-4,300 m (Lambert and Boutillier 2011). They speculated that this species might be found in BC in deep water. This species is also known from shallow Antarctic waters (McClintock 1994).

Number of Occurrences: x = Unknown
No records of *Aporocidaris milleri* collected in BC waters.

Population Trend: x = Unknown
Not enough information to determine a trend.

Distribution Trend: x = Unknown
Not enough information to determine a trend.

Threats to Population: C= Limited
Due to lack of information on populations and threats in BC waters, threats to population are projected from literature pertaining to related species and habitat, rather than directly observed.
Anthropogenic Disturbances

Threats to Distribution: C= Limited
Due to lack of information on populations and threats in BC waters, threats to distribution are projected from literature pertaining to related species and habitat, rather than directly observed.
Deep Sea Resource Exploration
Global climate change

Other Relevant Information: *Aporocidaris milleri* in Antarctica were both carnivores and scavengers feeding on polychaetes, forams, hydroids, gastropods and amphipods (McClintock 1994).

Editorial Comment : Mironov et al. (2015) placed *Aporocidaris* in the family Ctenocidaridae.

Scientific Name: *Dendraster excentricus* (Eschscholtz, 1831)

Higher Taxonomic Classification: Echinodermata, Echinoidea, Clypeasteroida, Dendrasteridae
Pacific Region Species Code (Hart): 6CD.
TSN: 158010.
AphiaID: 513215.
Synonyms: *Dendraster excentricus elongatus* H.L. Clark, 1935
Dendraster excentricus var. *elongatus* H.L. Clark, 1935
Echinarachnius (*Dendraster*) *excentricus* (Eschscholtz, 1831)
Echinarachnius excentricus (Eschscholtz, 1831)
Scutella excentrica Eschscholtz, 1831
Common Name: Pacific Sand Dollar, West Coast Sand Dollar, Common Sand Dollar, Sand Dollar, Sand Cookie, Sea Biscuit, Eccentric Sand Dollar Sea Urchin, oursin excentrique.

Proposed General Status Ocean Rank: 4 = Secure
This species is widespread and abundant within BC waters.

Population Size: D = Large
Dendraster excentricus can occur in densities as high as 629 m^{-2} in sand (Lambert and Austin 2007).

Distribution: C = Regional
This species is usually found along sheltered shores on sandy beaches near the low tide mark; Juneau, Alaska, to northern Baja California; 0-90 m (Lambert and Austin 2007). *Dendraster excentricus* is present coastwide in BC waters mostly from inshore locations and northern Hecate Strait. It is known from depths of 0 - 176 m with most records collected between 0 - 50 m. In the Strait of Georgia and Puget Sound they tend to be intertidal and shallow subtidal (RBCM collection 0-9 m), but on the more exposed outer coast they live deeper (Lambert and Austin 2007).

Number of Occurrences: C = Regional
There are 167 records of *D. excentricus* in BC representing 89 unique coordinate locations. 98 records are from museums, 78 of which are expert identified. The remainder of the records are from DFO surveys and literature.

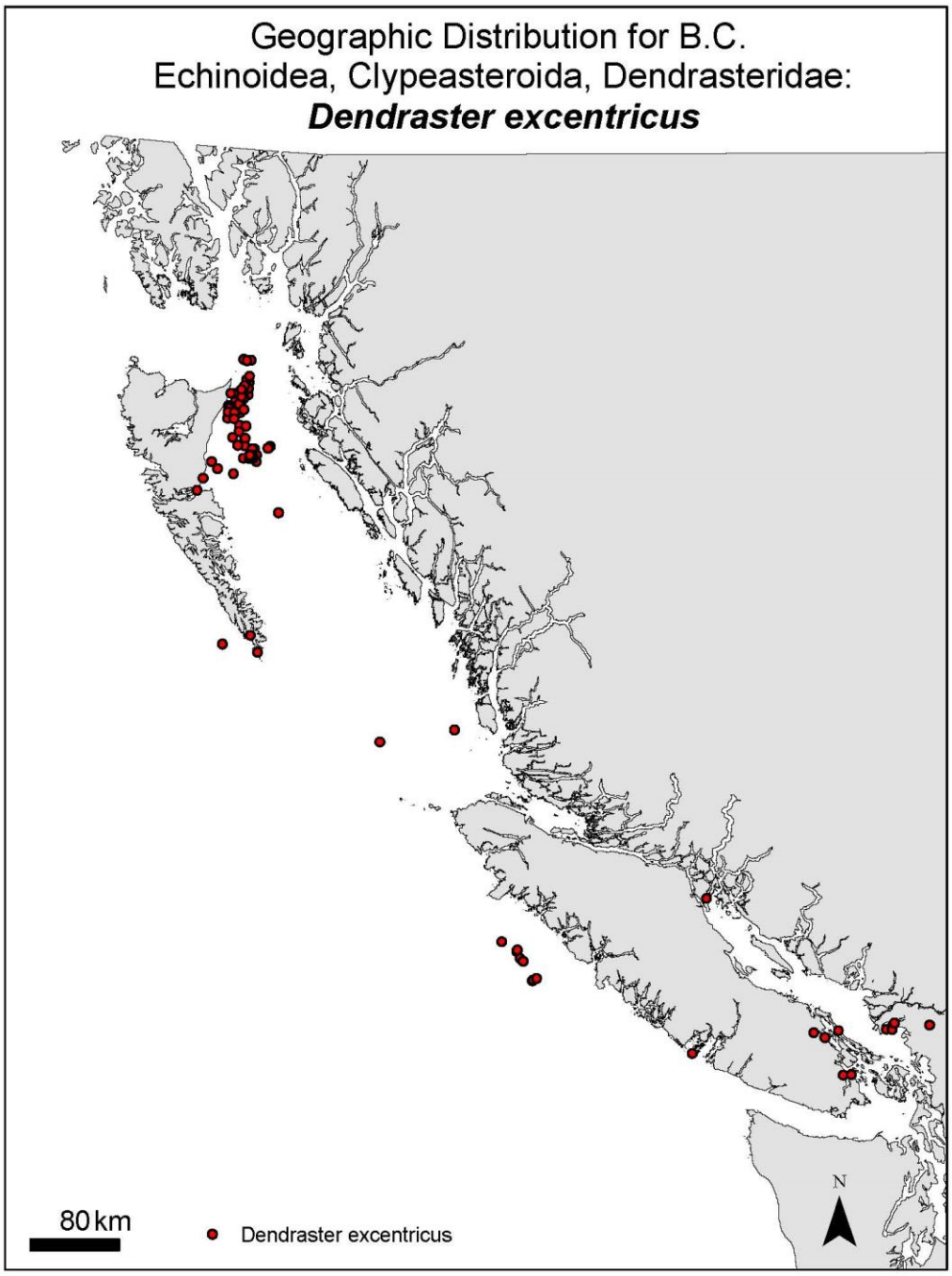
Population Trend: x = Unknown
Not enough information to determine a trend.

Distribution Trend: x = Unknown
There are 9 records from between 256-971 m depth off the WCVI in Esperanza Canyon and QC Sound. They are from commercial trawl bycatch data for Superorder Gnathostomata of which *D. excentricus* is the only member within BC waters. These are likely misidentifications or data entry errors.

Threats to Population: x = Unknown
Predation: Glaucous-winged Gulls (*Larus glaucescens*) are a predator; they break the tests of exposed individuals and eat the soft parts (Lambert and Austin 2007). Distribution in the intertidal zone greatly reduces predation by asteroids, particularly Sunflower Star (*Pycnopodia helianthoides*), Vermillion Star (*Mediaster aequalis*) and Giant Pink Star (*Pisaster brevispinus*), all of which eat sand dollars but live in adjacent subtidal areas. Predation by asteroids appears to be a sufficient factor to prevent *D. excentricus* from occupying physiologically acceptable subtidal habitats (Birkeland and Chia 1971).

Threats to Distribution: A= Extreme
Due to the lack of information available on threats to the distribution of *D. excentricus* in BC waters, threats to distribution are projected from literature pertaining to related species and habitat, rather than direct observation.
Anthropogenic Disturbances
Climate Change on Intertidal: Climate-change may increase storminess which may modify communities, particularly intertidal communities, to those characteristic of more wave-exposed conditions (Hiscock *et al*. 2004).
Climate Change on Food: A potentially important effect of climate change might be to alter the abundance and type of meroplanktonic organisms that are the food of other marine life (Hiscock *et al*. 2004).

Other Relevant Information: *Dendraster excentricus* is primarily a suspension feeder (Lambert and Austin 2007). In the San Juan Islands, spawning usually occurs from mid April to July but potentially from late March to late summer. The growth rate is fairly steady until about the fifth year, when it slows greatly. Animals of 5-9 years are similar in size; few live longer than nine years. When exposed by the tide, sand dollars bury themselves, but at high tide the posterior half protrudes from the sand in a semi-vertical position. Pacific sand dollars move towards shore during calm conditions, and move into deeper water during rough conditions.


Geographic Distribution for B.C.
Echinoidea, Clypeasteroida, Dendrasteridae:
Dendraster excentricus
80 km
Dendraster excentricus
N

Scientific Name: *Sperosoma biseriatum* Doderlein, 1901

Higher Taxonomic Classification: Echinodermata, Echinoidea, Echinothurioida, Echinothuriidae
Pacific Region Species Code (Hart): 6AM.
TSN: 157864.
AphiaID: 220659.
Synonyms: n/a.
Common Name: Soft Sea Urchin, Double-rowed Sea Urchin, oursin bisérié.

Proposed General Status Ocean Rank: 5 = Undetermined
Little is known about the population status of S. *biseriatum.* However, what is known suggests that it is uncommon in BC waters with limited distribution and/or that it is not easily gathered using conventional collecting methods. However, it is a deep water species and this habitat does not have a lot of survey effort.

Population Size: x = Unknown
No Information Available

Distribution: C = Regional
Sperosoma biseriatum is present in BC waters offshore on the continental slope from northern Vancouver Island and mid Haida Gwaii from trawl mid-depths of 1,774-2,125 m (Lambert and Boutillier 2011). The type locality is the Indian Ocean near African coast at a depth of 1,019 m in ooze or blue clay. Previously known from the type locality and Atka Island in the Bering Sea at 1,019-3,500 m (D'yakonov 1969); also deep off Vancouver Island (Austin 1985). New records extend its BC distribution from Nootka Sound to Graham Island, Haida Gwaii at 1,625-2,125 m (Lambert and Boutillier 2011).

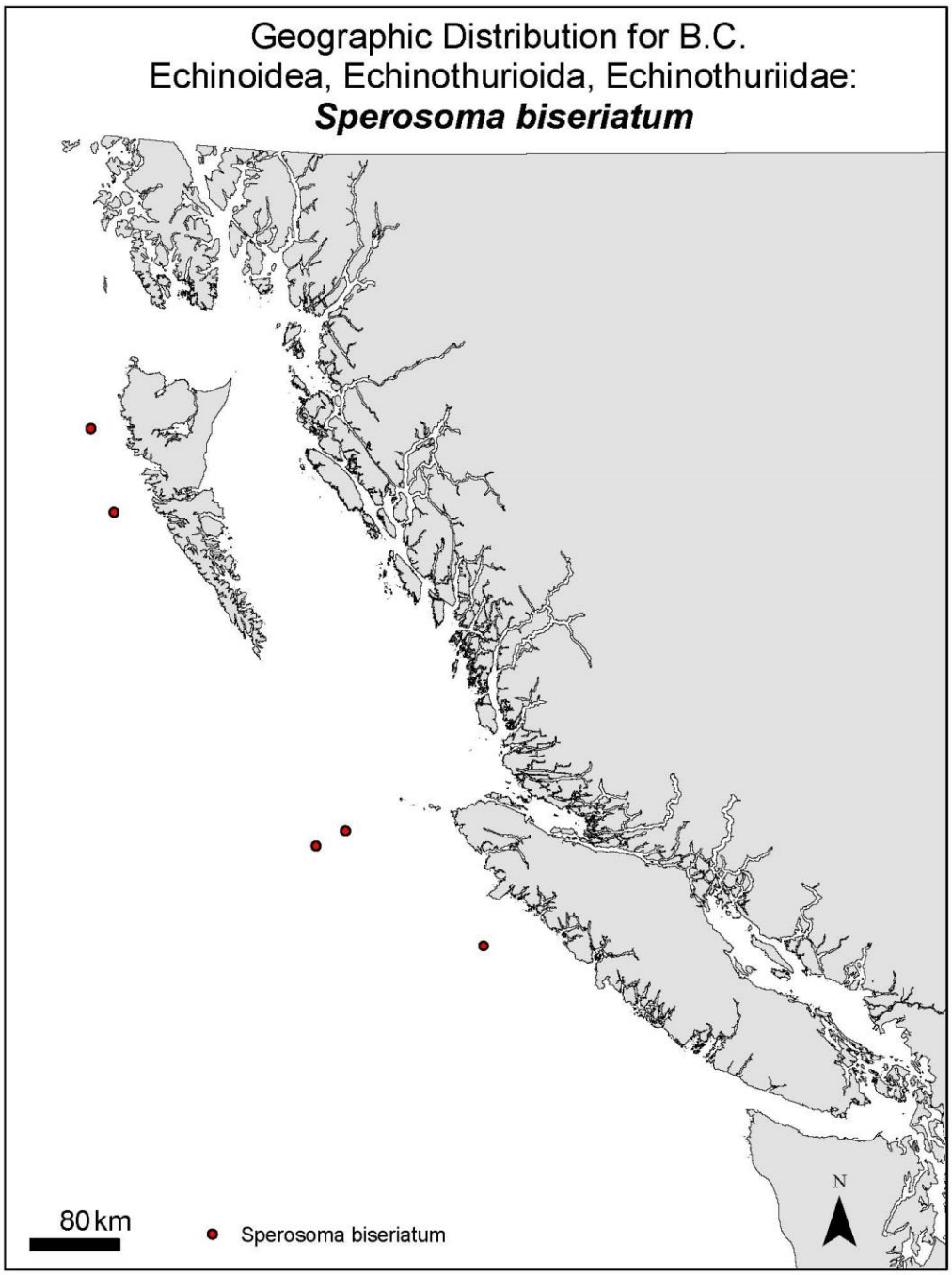
Number of Occurrences: A = Very Restricted
There are five unique records of *S. biseriatum* in BC from the RBCM collection, all of which were identified by Phil Lambert in 2007.

Population Trend: x = Unknown
Not enough information to determine a trend.

Distribution Trend: x = Unknown
Not enough information to determine a trend.

Threats to Population: x = Unknown
Due to lack of information on populations and threats in BC waters, threats to population are projected from literature pertaining to related species and habitat, rather than directly observed.
<u>Anthropogenic Disturbances</u>

Threats to Distribution: C= Limited
Due to lack of information on populations and threats in BC waters, threats to distribution are projected from literature pertaining to related species and habitat, rather than directly observed.
Deep Sea Resource Exploration
Global climate change


Geographic Distribution for B.C.
Echinoidea, Echinothurioida, Echinothuriidae:
Sperosoma biseriatum
80 km
Sperosoma biseriatum
N

Scientific Name: *Sperosoma giganteum* Agassiz and Clark, 1907

Higher Taxonomic Classification: Echinodermata, Echinoidea, Echinothurioida, Echinothuriidae
Pacific Region Species Code (Hart): n/a.
TSN: 157865.
AphiaID: 513555.
Synonyms: n/a.
Common Name: Soft Sea Urchin, Giant Sea Urchin, oursin géant.

Proposed General Status Ocean Rank: 5 = Undetermined or misidentified
There are no records of this species in BC waters. It is included in this list because it has been found in Japan and in Oregon. However the Oregon records are under question due to the smaller size of the organism collected (Lambert and Boutillier 2011). It could be a misidentification of the smaller *S. biseriatum* which is confirmed in BC waters, also at depth. *Sperosoma giganteum* is found in very deep water up to 3,000 m which represents a relatively unknown ecosystem.

Population Size: x = Unknown
No Information Available

Distribution: x = Unknown
The type locality is Station 5082, off Omai Saki Light, Honshu Island, Japan; 1,211 m (Agassiz and Clark 1907). Distribution includes the type locality off Japan and off Oregon; 2,090-3,000 m (McCauley and Carey 1967). The Oregon specimens were all smaller than the type (320 mm diameter) at 112-160 mm; they could perhaps be misidentifications of the smaller *S. biseriatum* (Lambert and Boutillier 2011).

Number of Occurrences: x = Unknown
No records of *Sperosoma giganteum* found in BC waters

Population Trend: x = Unknown
Not enough information to determine a trend.

Distribution Trend: x = Unknown
Not enough information to determine a trend.

Threats to Population: x = Unknown
Due to lack of information on populations and threats in BC waters, threats to population are projected from literature pertaining to related species and habitat, rather than directly observed.
<u>Anthropogenic Disturbances</u>

Threats to Distribution: C= Limited
Due to lack of information on populations and threats in BC waters, threats to distribution are projected from literature pertaining to related species and habitat, rather than directly observed.
Deep Sea Resource Exploration
Global climate change

Scientific Name: *Ceratophysa ceratopyga valvaecristata* Mironov, 1975

Higher Taxonomic Classification: Echinodermata, Echinoidea, Holasteroida, Pourtalesiidae
Pacific Region Species Code (Hart): n/a.
TSN: 158052.
AphiaID: 160792.
Synonyms: *Pourtalesia ceratopyga* A. Agassiz, 1879 (*partim*)
Common Name: Deep Sea Urchin, Horned Sea Urchin, oursin cornu.

Proposed General Status Ocean Rank: 5 = Undetermined
There are no records of this species in BC waters. However, it is known from Alaska and California in very deep water (4,200-6,320 m) which represents a relatively unknown ecosystem.

Population Size: x = Unknown
No Information Available

Distribution: x = Unknown
The known distribution of *C. c. valvaecristata* is the northern Pacific from Japan to Alaska and off California; 4,200-6,320 m (Mironov 1976, Lambert and Boutillier 2011)

Number of Occurrences: x = Unknown
No records of *Ceratophysa ceratopyga valvaecristata* found in BC waters.

Population Trend: x = Unknown
Not enough information to determine a trend.

Distribution Trend: x = Unknown
Not enough information to determine a trend.

Threats to Population: x = Unknown
Due to lack of information on populations and threats in BC waters, threats to population are projected from literature pertaining to related species and habitat, rather than directly observed.
Anthropogenic Disturbances

Threats to Distribution: C= Limited
Due to lack of information on populations and threats in BC waters, threats to distribution are projected from literature pertaining to related species and habitat, rather than directly observed.
Deep Sea Resource Exploration
Global climate change

Scientific Name: *Cystocrepis setigera* (A. Agassiz, 1898)

Higher Taxonomic Classification: Echinodermata, Echinoidea, Holasteroida, Pourtalesiidae
Pacific Region Species Code (Hart): n/a.
TSN: 158054.
AphiaID: 513214.
Synonyms: *Echinocrepis setigera* A. Agassiz, 1898
Common Name: Deep Sea Urchin, Bristly Sea Urchin, oursin hispide.

Proposed General Status Ocean Rank: 5 = Undetermined
There are no records of this species in BC waters. However, it is known from Mexico in very deep water (2,876-4,072 m) which represents a relatively unknown ecosystem.

Population Size: x = Unknown
No Information Available

Distribution: x = Unknown
The type locality is ALBATROSS Station 3399 off Galera Point, Ecuador (Lambert and Boutillier 2011). The known distribution is the Panamic Region, 2,875-3,435 m and off Mexico, 2,876-4,072 m (Lambert and Boutillier 2011).

Number of Occurrences: x = Unknown
No records of *Cystocrepis setigera* found in BC waters, though Lambert and Boutillier (2011) included it as a hypothetical species.

Population Trend: x = Unknown
Not enough information to determine a trend.

Distribution Trend: x = Unknown
Not enough information to determine a trend.

Threats to Population: x = Unknown
Due to lack of information on populations and threats in BC waters, threats to population are projected from literature pertaining to related species and habitat, rather than directly observed.
Anthropogenic Disturbances

Threats to Distribution: C= Limited
Due to lack of information on populations and threats in BC waters, threats to distribution are projected from literature pertaining to related species and habitat, rather than directly observed.
Deep Sea Resource Exploration:
Global climate change

Editorial Comments: Some authors (e.g., Lambert and Austin 2007) considered *Echinocrepis* valid at the subgeneric level (*Cystocrepis* (*Ecinocrepis*) *setigera*); WoRMS does not (WoRMS Editorial Board 2018).

Scientific Name: *Echinocrepis rostrata* Mironov, 1973

Higher Taxonomic Classification: Echinodermata, Echinoidea, Holasteroida, Pourtalesiidae
Pacific Region Species Code (Hart): n/a.
TSN: 158057.
AphiaID: 513000.
Synonyms: n/a.
Common Name: Deep Sea Urchin, Beaked Sea Urchin, oursin rostré.

Proposed General Status Ocean Rank: 5 = Undetermined
There is one record of this species from BC waters. It is known from very deep water from 3,315-5,020 m which represents a relatively unknown ecosystem.

Population Size: x = Unknown
Echinocrepis rostrata is a common epibenthic echinoid and bioturbator, known to occur in distributions ranging from near random to patchy across eastern North Pacific seafloor (Lauerman *et al*. 1996, Vardaro *et al*. 2009).

Distribution: x = Unknown
The known distribution is from the Aleutian Trench to Baja California, 3,315-5,020 m (Mironov 1973, Lambert and Boutillier 2011). There is a single record off BC (Lambert and Boutillier 2011).

Number of Occurrences: A = Very Restricted
There is one record of *Echinocrepis rostrata* in BC waters off the northwest coast of Vancouver Island near Tucker Seamount in 3,470 m; Station 4147 of Mironov (1973)(Lambert and Boutillier 2011).

Population Trend: x = Unknown
Not enough information to determine a trend.

Distribution Trend: x = Unknown
Not enough information to determine a trend.

Threats to Population: x = Unknown
Due to lack of information on populations and threats in BC waters, threats to population are projected from literature pertaining to related species and habitat, rather than directly observed.
Anthropogenic Disturbances

Threats to Distribution: C= Limited
Due to lack of information on populations and threats in BC waters, threats to distribution are projected from literature pertaining to related species and habitat, rather than directly observed.
Deep Sea Resource Exploration

Global climate change

Other Relevant Information: Vardaro and Smith (2009) used *Echinocrepis rostrata* in their study of climate variation and bioturbation on the sea floor in the abyssal North Pacific because it is common at the study site and leaves distinctive trails that allow quantification of the amount of sediment covered. *E. rostrata* is unlikely to broadcast spawn or reproduce seasonally. Ruhl (2007) states that *E. rostrata* exhibited negative relationships between body size and abundance over time indicating recruitment of new small individuals to the existing population over interannual timescales. Ruhl (2008) used *E. rostrata* as one of 10 mobile epibenthic echinoderms to demonstrate that there is evidence for non-random, resource-driven change present for an epibenthic megafauna community in the abyssal north-eastern Pacific.

Scientific Name: *Pourtalesia tanneri* Agassiz, 1898

Higher Taxonomic Classification: Echinodermata, Echinoidea, Holasteroida, Pourtalesiidae
Pacific Region Species Code (Hart): n/a.
TSN: 158049.
AphiaID: 513483.
Synonyms:
Common Name: Deep Sea Urchin, Tanner's Sea Urchin, oursin de Tanner.

Proposed General Status Ocean Rank: 5 = Undetermined
There are no records of this species in BC waters. However, it is known from California and possibly Alaska in very deep water (1,450-3,954 m) which represents a relatively unknown ecosystem.

Population Size: x = Unknown
No Information Available

Distribution: x = Unknown
The known distribution is Gulf of California to Galapagos and Chile, 1,450-2,380 m (Mortensen 1950, Lambert and Boutillier 2011). Mironov (1976) described the distribution as California to Peru; also possibly Gulf of Alaska and in the Bering Sea near the Aleutians, 1,820-3,954 m (Lambert and Boutillier 2011). The species is potentially present in deep water off BC but not yet reported.

Number of Occurrences: x = Unknown
No records of *Pourtalesia tanneri* found in BC waters.

Population Trend: x = Unknown
Not enough information to determine a trend.

Distribution Trend: x = Unknown
Not enough information to determine a trend.

Threats to Population: x = Unknown
Due to lack of information on populations and threats in BC waters, threats to population are projected from literature pertaining to related species and habitat, rather than directly observed.
Anthropogenic Disturbances

Threats to Distribution: C= Limited
Due to lack of information on populations and threats in BC waters, threats to distribution are projected from literature pertaining to related species and habitat, rather than directly observed.
Deep Sea Resource Exploration
Global climate change

Scientific Name: *Pourtalesia thomsoni* Mironov, 1976

Higher Taxonomic Classification: Echinodermata, Echinoidea, Holasteroida, Pourtalesiidae
Pacific Region Species Code (Hart): n/a.
TSN: 158050.
AphiaID: 513003.
Synonyms:
Common Name: Deep Sea Urchin, Thompson's Sea Urchin, oursin de Thomson.

Proposed General Status Ocean Rank: 5 = Undetermined
There are no records of this species in BC waters (Lambert and Boutillier 2011). However, it is known from Alaska to California in very deep water (3,315-4,321 m) which represents a relatively unknown ecosystem.

Population Size: x = Unknown
No Information Available

Distribution: x = Unknown
The known distribution is the northern Pacific from Alaska to California, 3,315-4,321 m. The type locality is Station 4265, off Baja California, 3,315-3,340 m (Mironov 1973, Lambert and Boutillier 2011). This species could potentially could occur off BC.

Number of Occurrences: x = Unknown
No records of P*ourtalesia thomsoni* found in BC waters.

Population Trend: x = Unknown
Not enough information to determine a trend.

Distribution Trend: x = Unknown
Not enough information to determine a trend.

Threats to Population: x = Unknown
Due to lack of information on populations and threats in BC waters, threats to population are projected from literature pertaining to related species and habitat, rather than directly observed.
Anthropogenic Disturbances

Threats to Distribution: C= Limited
Due to lack of information on populations and threats in BC waters, threats to distribution are projected from literature pertaining to related species and habitat, rather than directly observed.
Deep Sea Resource Exploration
Global climate change

Scientific Name: *Antrechinus drygalskii perfidus* (Mironov, 1976)

Higher Taxonomic Classification: Echinodermata, Echinoidea, Holasteroida, Urechinidae
Pacific Region Species Code (Hart): n/a.
TSN: n/a.
AphiaID: 571632.
Synonyms: *Urechinus drygalskii perfidus* Mironov, 1976
Common Name: Drygalski's Sea Urchin, oursin de Drygalski.

Proposed General Status Ocean Rank: 5 = Undetermined
There are no records of this species in BC waters. However, it is included in Lambert's (2007) Checklist of the Echinoderms of British Columbia and is known from very deep water (4,990-5,740 m) in the Gulf of Alaska, south of the Aleutian Islands and near the Kurile-Kamchatka Trench (Mironov *et al*. 2015) which represents a relatively unknown ecosystem.

Population Size: x = Unknown
No Information Available

Distribution: x = Unknown
Included in Lambert's (2007) Checklist of the Echinoderms of British Columbia but not in Lambert and Boutillier (2011).

Number of Occurrences: x = Unknown
No records of *Antrechinus drygalskii perfidus* found in BC waters.

Population Trend: x = Unknown
Not enough information to determine a trend.

Distribution Trend: x = Unknown
Not enough information to determine a trend.

Threats to Population: x = Unknown
Due to lack of information on populations and threats in BC waters, threats to population are projected from literature pertaining to related species and habitat, rather than directly observed.
Anthropogenic Disturbances

Threats to Distribution: C= Limited
Due to lack of information on populations and threats in BC waters, threats to distribution are projected from literature pertaining to related species and habitat, rather than directly observed.
Deep Sea Resource Exploration
Global climate change

Reviewer Comments: *Antrechinus drygalskii* was not included in Lambert and Boutillier (2011) because the nearest record was in the middle of the Pacific, south of the Aleutians and very deep (~5000 m)(P. Lambert, pers. comm., 2010).

Editorial Comments: Mironov (1976) and Mironov *et al*. (2015) included *perfidus* in the genus *Utrechinus* at the species level. Although WoRMS (WoRMS Editorial Board 2018) and associated web resources document the sub-specific designation and synonymy with *Antrechinus*, other web resources (e.g., ITIS) still place it in *Urechinus*.

Scientific Name: *Cystechinus loveni* A. Agassiz, 1898

Higher Taxonomic Classification: Echinodermata, Echinoidea, Holasteroida, Urechinidae
Pacific Region Species Code (Hart): n/a.
TSN: n/a.
AphiaID: 568594.
Synonyms: *Cystechinus purpureus* A. Agassiz & H.L. Clark, 1907
Urechinus loveni (A. Agassiz, 1898)
Common Name: Pyramid Sea Urchin, Lovén's Sea Urchin, oursin de Lovén.

Proposed General Status Ocean Rank: 5 = Undetermined
There are no records of this species in BC waters. However, it is present off Oregon and from the Bering Sea in very deep water (1,571-4,800 m) which represents a relatively unknown ecosystem.

Population Size: x = Unknown
No Information Available

Distribution: x = Unknown
The known distribution is variously described as: Bering Sea to Mexico (Agassiz and Clark 1907); off Magdalena Bay, Baja California, 3,219 m (Clark 1913); northern Pacific, Acapulco and Lower California to Bering Sea and Okhotsk Sea [*sic*], 3,070-3,610 (Mortensen 1950); and off Oregon, 2,600-2,833 m in green gray mud (McCauley and Carey 1967). USNM collection includes records from Atka Island to northwestern Channel Islands, CA, 3,230-4,080 m. Not collected in BC yet, but occurs to the north and south, therefore would be expected here in deep water (Lambert and Boutillier 2011).

Number of Occurrences: x = Unknown
No records of *Cystechinus loveni* found in BC waters.

Population Trend: x = Unknown
Not enough information to determine a trend.

Distribution Trend: x = Unknown
Not enough information to determine a trend.

Threats to Population: x = Unknown
Due to lack of information on populations and threats in BC waters, threats to population are projected from literature pertaining to related species and habitat, rather than directly observed.
<u>Anthropogenic Disturbances</u>

Threats to Distribution: C= Limited
Due to lack of information on populations and threats in BC waters, threats to distribution are projected from literature pertaining to related species and habitat, rather than directly observed.
Deep Sea Resource Exploration
Global climate change

Editorial Comments: The generic placement of this species remains uncertain. Some literature or online resources (*e.g.*, ITIS) place it in *Urechinus*, but Mooi and David (1996) re-analyzed that genus and found and found that three clustered separately. They returned these to *Cystechinus* (Lambert and Boutillier 2011); this arrangement has been followed by WoRMS and associated web resources.

Scientific Name: *Aeropsis fulva* (A. Agassiz, 1898)

Higher Taxonomic Classification: Echinodermata, Echinoidea, Spatangoida, Aeropsidae
Pacific Region Species Code (Hart): n/a.
TSN: 158097.
AphiaID: 513094.
Synonyms*: Aerope fulva* A. Agassiz, 1898
Aeropsis sibogae Koehler, 1914
Aeropsis weberi Koehler, 1914
Common Name: Oblong Sea Urchin, Tawny Heart Sea Urchin, oursin rougeâtre.

Proposed General Status Ocean Rank: 5 = Undetermined
There are no records of this species in BC waters. However, it is known from Oregon and the Gulf of Alaska in very deep water (1,465-5,200 m) which represents a relatively unknown ecosystem.

Population Size: x = Unknown
No Information Available

Distribution: x = Unknown
Known distribution variously described as: off Costa Rica, Colombia and Ecuador, 2,149-3,241 m (Agassiz 1904); Bering Sea, off Oregon, coast of Peru, Colombia and Malay Archipelago, 2,148-5,200 m (McCauley and Carey 1967); Japan, Bering Sea, Gulf of Alaska, off BC, Gulf of Panama, 1,463-5,390 m (Mironov 1976); 1,465-5,200 m (Mortensen 1950). Expected off BC at appropriate depths but not found by Lambert and Boutillier (2011).

Number of Occurrences: x = Unknown
No records of *Aeropsis fulva* were collect in this study in BC waters; however, it was noted by Lambert and Boutillier (2011) that this species is documented off BC by Mironov (1976).

Population Trend: x = Unknown
Not enough information to determine a trend.

Distribution Trend: x = Unknown
Not enough information to determine a trend.

Threats to Population: x = Unknown
Due to lack of information on populations and threats in BC waters, threats to population are projected from literature pertaining to related species and habitat, rather than directly observed.
<u>Anthropogenic Disturbances</u>

Threats to Distribution: C= Limited
Due to lack of information on populations and threats in BC waters, threats to distribution are projected from literature pertaining to related species and habitat, rather than directly observed.
Deep Sea Resource Exploration
Global climate change

Scientific Name: *Brisaster latifrons* (A. Agassiz, 1898)

Higher Taxonomic Classification: Echinodermata, Echinoidea, Spatangoida, Schizasteridae
Pacific Region Species Code (Hart): 6D4.
TSN: 158082.
AphiaID: 513143.
Synonyms: *Opissaster latifrons* (A. Agassiz, 1898)
Schizaster (Brisaster) latifrons A. Agassiz, 1898
Schizaster latifrons A. Agassiz, 1898
Common Name: Heart Urchin, Wide Heart Sea Urchin, oursin à front large.

Proposed General Status Ocean Rank: 4 = Secure
This species is widespread and abundant within BC waters.

Population Size: x = Unknown
Can form dense aggregations; off Oregon, mean densities from 0.2 to 3.8 individuals m^{-2} were estimated with the use of an anchor dredge (McCauley 1967). In upper Santa Barbara Basin, Thompson *et al*. (1987) recorded mean densities as high as 30 m^{-2} (Lambert and Austin 2007).

Distribution: C/D = Regional to Widespread
Known distribution is from the Aleutian Islands to southern California and the Gulf of California, in deeper water with soft sediments, 51-1,800 m (Lambert and Austin 2007). *Brisaster latifrons* is present coastwide in BC waters from inshore inlets and fjords, the Strait of Georgia, Queen Charlotte Sound and Hecate Strait and offshore on the slope from WCVI. They have been found at depths from 27 – 1,439 m with 69% of records collected between 100-200 m

Number of Occurrences: D = Widespread
There are 120 records of *B. latifrons* in BC representing 96 unique coordinate locations. All records are from museums, 104 of which are expert identified. There are 2,154 DFO survey and trawl fishery bycatch records for Superorder Atelostomata which in BC is represented primarily by *B. latifrons* (it also includes *Aeropsis fulva* but this species has not yet been found in BC).

Population Trend: x = Unknown
Not enough information to determine a trend.

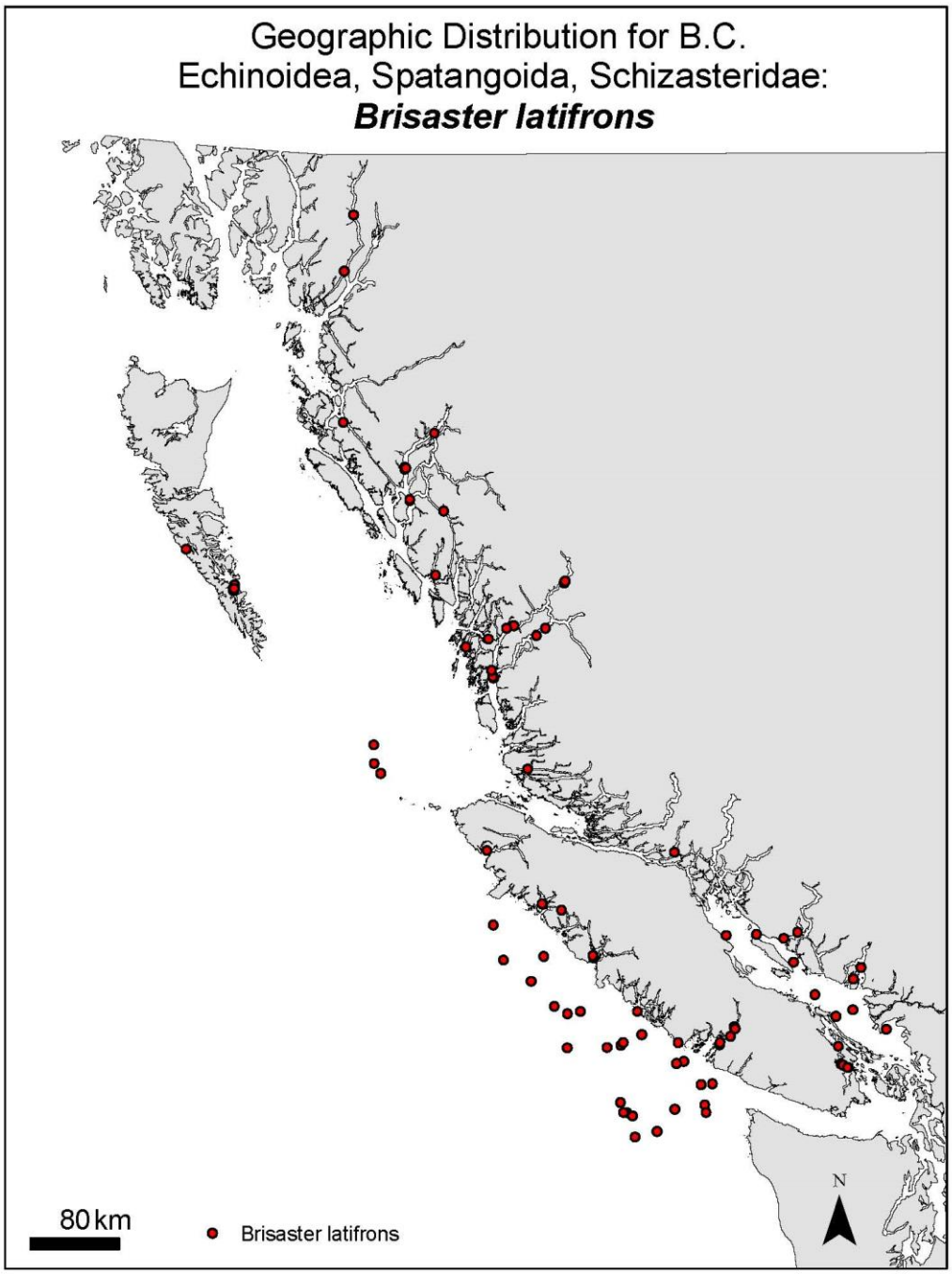
Distribution Trend: x = Unknown
Not enough information to determine a trend.

Threats to Population: x = Unknown
Due to lack of information on populations and threats in BC waters, threats to population are projected from literature pertaining to related species and habitat, rather than directly observed.

Anthropogenic Disturbances
Predation: Lambert and Austin (2007) state that "few predators have been documented. A related species, *Brisaster townsendi*, was reported to be eaten by a deep-sea star (*Rathbunaster californicus*) and another was found in the stomach of a Robust Clubhook Squid (*Moroteuthis robustus*).

Threats to Distribution: A= Extreme
Due to lack of information on populations and threats in BC waters, threats to distribution are projected from literature pertaining to related species and habitat, rather than directly observed.
Deep Sea Resource Exploration
Global climate change: *Brisaster latifrons* is found in inlets and fjords; with climate change increased surface warming may isolate the deeper parts of some enclosed water bodies where a thermocline forms behind a sill, leading to deoxygenation (Hiscock *et al*. 2004). During a low dissolved oxygen event in Howe Sound, BC in 1977 *B. latifrons* could not escape and died (Levings 1980).

Other Relevant Information: Heart Urchins are deposit feeders, ingesting mud as they move through it (Lambert and Austin 2007). Although they live infaunally, they obtain oxygen through large modified tube feet. During an ROV dive, Lambert observed a series of small holes in a soft mud surface; excavation revealed a *Brisaster latifrons* a few centimetres below the surface. He suggested it must have been moving slowly through the mud and creating successive respiratory chimneys (Lambert and Austin 2007). *Brisaster latifrons* spawns in March in the Salish Sea; echinopluteus larvae are planktivorous and settle 67-167 days after fertilization. If required, larvae can grow and settle without active feeding.


Geographic Distribution for B.C.
Echinoidea, Spatangoida, Schizasteridae:
Brisaster latifrons
80 km
Brisaster latifrons
N

DISCUSSION

Museum collections provided information on diverse species and experts ensure proper identification. Therefore, museum records are useful for determining what species are present in a geographic area. These data sets unfortunately do not usually have enough records or detail on one species to inform research on population abundance. This information is generally only collected through targeted studies.

DFO records provided information on commercially targeted species and some bycatch species. There was literature available covering biology and ecology of many marine invertebrate species but again, mainly common species were discussed and deep-water or hard to collect species were not available.

Twelve of 19 species of sea urchins are ranked as Undetermined through the GSR process. Six species are considered Secure and one is Sensitive. Secure species are generally considered to be widespread and abundant and includes commercially fished Red and Green Sea Urchin species. Undetermined species generally have no occurrence records within BC waters but are known from neighbouring waters. This includes one species (*Sperosoma giganteum*) that is considered Undetermined or misidentified; there are no records of this species in BC waters. It is included in this list because it has been found in Japan and in Oregon. However, the Oregon records are under question due to the smaller size of the organism collected. It could be a misidentification of the smaller *S. biseriatum* which is confirmed in BC waters, also at depth. *Cystocrepis setigera* was included because it is found at depths below those currently surveyed and was included in Lambert and Boutillier (2011) as hypothetically occurring in BC waters.

Strongylocentrotus purpuratus is the sea urchin species that is considered Sensitive. Purple Sea Urchins are long-lived (greater than 50 years), have patchy distribution, slow and variable growth, low and periodic recruitment, are sedentary and display density-dependent spawning success (Workman 1999). The above characteristics are indicative of a species susceptible to over-exploitation, which in turn dictates a very cautious approach to fisheries development. These life history characteristics, combined with the information that *S. purpuratus* appears less abundant than other urchin species in BC and the range extension of predatory Sea Otters along the west coast of Vancouver Island where *S. purpuratus* is primarily found are the reasons that this species be ranked Sensitive.

Echinoid Threats to Population are mostly Unknown (74%) but *Mesocentrotus franciscanus* is considered moderately threatened by Sea Otter predation. Predation by Sea Otters currently affects less than half of Red Sea Urchin populations coastwide, however this number is expected to exceed 50% based on current trends in Sea Otter population growth and expansions of distribution (D. Leus, C. Hand, pers. comm., 2010). Where otter populations are established on the west coast of Vancouver Island and Central Coast, it is likely that greater than 50% of Red Sea Urchin stocks have been consumed. An ecological balance has not yet been established.

CONCLUSIONS

The 2010 Pacific Region marine invertebrate GSR process included 362 species from 5 species groups. Forty-three percent of these species were ranked Undetermined due to lack of information available on populations, distributions and/or trends to provide an informed ranking. Thirty-four percent of species were ranked Secure where the species was known to be present, properly identified and qualitatively considered widespread and abundant.

Of the 19 species of echinoids assessed for the 2010 process, six were ranked as Secure, 12 Undetermined and one species considered Sensitive.

ACKNOWLEDGEMENTS

This work was funded by the Committee on the Status of Endangered Wildlife in Canada (through Environment Canada) and the SARA Monitoring Program of DFO. We thank Phil Lambert for reviewing the echinoid GSR. Thanks to Amy Ganton and Edith Krause who summarized literature and background information during the GSR process, and to Jessica Finney who helped create distribution maps. Thanks to Claudia Hand, Dan Leus, and Brenda Waddell for providing GSR information on commercially harvested species. We thank Moretta Frederick (Royal BC Museum) and Jean-Marc Gagnon (Canadian Museum of Nature) for help gathering information from the museum collections. Thanks also to Linda Ward (Smithsonian Institution: National Museum of Natural History), Christina Piotrowski (California Academy of Sciences), Maureen Zubowski (Royal Ontario Museum), Kelly Bartlett (Bamfield Marine Science Center), Kim Conway (Geological Survey of Canada), Pat Bartier (Parks Canada), Verena Tunnicliffe (University of Victoria) and Henry Reiswig (Royal BC Museum) for providing BC marine invertebrate occurrence data. We thank Sean MacConnachie, Janet Lochead and Dominique Bureau for their helpful reviews.

REFERENCES

Accord for the Protection of Species at Risk. 1996. (revised 1998). Available online: http://www.sararegistry.gc.ca/approach/strategy/accord_text_e.cfm

Agassiz, A. 1904. Reports on an exploration off the west coasts of Mexico, Central and South America, and off the Galapagos Islands, in charge of Alexander Agassiz, by the U. S. Fish Commission Steamer "Albatross" during 1891, Lieut.-Commander Z.L. Tanner, U.S.N., Commanding. XXXII. The Panamic deep sea Echini. Mus. Comp. Zool. (Harv. Univ.) Memoirs 31: 1-246.

Agassiz, A. and H.L. Clark. 1907. No. 5. Preliminary report on the Echini collected in 1906, from May to December, among the Aleutian Islands, in Bering Sea, and along the coasts of Kamchatka, Sakhalin, Korea and Japan, by the US Fisheries Commission Steamer "Albatross". Bull. Mus. Comp. Zool. (Harvard) 51: 109-139.

Austin, W.C. 1985. An annotated checklist of marine invertebrates in the cold temperate northeast Pacific. Vol. 1-3. Khoyatan Marine Laboratory, Cowichan Bay, BC 682 p.

Biermann, C.H. 1998. Population genetic structure and the evolution of reproductive isolation in strongylocentrotid sea urchins. *In*: R. Mooi and B. Telford [eds.]. Echinoderms: San Francisco – Proceedings of the Ninth International Echinoderm Conference, San Francisco, California, 5-9 August 1996.

Biermann, C.H., B.D. Kessing and S.R. Palumbi. 2003. Phylogeny and development of marine model species: strongylocentrotid sea urchins. Evol. Devel. 5: 360-371.

Birkeland, C. and F.S. Chia. 1971. Recruitment risk, growth, age and predation in two populations of sand dollars, *Dendraster excentricus* (Eschascholtz). J. Exp. Mar. Biol. Ecol. 6: 265-278.

Bluhm, B.A., D. Piepenbury and K. Juterzenka. 1998. Distribution, standing stock, growth, mortality and production of *Strongylocentrotus pallidus* (Echinodermata: Echinoidea) in northern Barents Sea. Polar Biol. 20: 325-334.

Breen, P.A., T.A. Carson, J.B. Foster and A.E. Stewart. 1982. Changes in subtidal community structure associated with British Columbia sea otter transplant. Mar. Ecol. Prog. Ser. 7: 13-20.

Burge, C.A., C.M. Eakin, C.S. Friedman, B. Froelich, P.K. Hershberger, E.E. Hofmann, L.E. Petesa, K.C. Prager, E. Weil, B.L. Willis, S.E. Ford and C.D. Harvell. 2014. Climate change influences on marine infectious diseases: implications for management and society. Ann. Rev. Mar. Sci. 6, 249-277.

Campbell, A. and R.M. Harbo. 1992. The sea urchin fisheries in British Columbia, Canada. p. 191-199. *In:* T. Yanagisawa, I. Yasumasu, C. Oguro, N. Suzuki and T. Motokawa [eds.]. Biology of Echinodermata. A.A. Balkema, Rotterdam.

Canadian Endangered Species Conservation Council (CESCC). 2001. Wild Species 2000: The General Status of Species in Canada. Ottawa: Minister of Public Works and Government Services Canada - (http://www.wildspecies.ca)

Canadian Endangered Species Conservation Council (CESCC). 2006. Wild Species 2005: The General Status of Species in Canada. Ottawa: Minister of Public Works and Government Services Canada - (http://www.wildspecies.ca)

Canadian Endangered Species Conservation Council (CESCC). 2011. Wild Species 2010: The General Status of Species in Canada. National General Status Working Group. 302 p. (http://www.registrelep-sararegistry.gc.ca/virtual_sara/files/reports/RptEspecesSauvagesWildSpecies-v00-2010-Eng.pdf)

Canadian Endangered Species Conservation Council (CESCC). 2016. Wild Species 2015: The General Status of Species in Canada. National General Status Working Group. 128 p. + data file. (http://www.registrelep-sararegistry.gc.ca/document/default_e.cfm?documentID=3174)

Chan, F., J. A. Barth, J. Lubchenko, A. Kirincich, H. Weeks, W.T. Peterson and B.A. Menge. 2008. Emergence of anoxia in the California Current Large Marine Ecosystem. Science 319(5865): 920.

Clark, H.L. 1913. Article VIII - Echinoderms from Lower California, with descriptions of new species. Bull. Amer. Mus. Nat. Hist. 32: 185-235.

Clarke, C.L. and G.S. Jamieson. 2006. Identification of ecologically and biologically significant areas in the Pacific North Coast Integrated Management Area: Phase II - Final Report. Can. Tech. Rep. Fish. Aquat. Sci. 2686: v + 25 p.

DFO. 2009. State of the Pacific Ocean 2008. DFO Can. Sci. Advis. Secr. Sci. Advis. Rep. 2009/030. 21 p.

DFO. 2015. Trends in the abundance and distribution of sea otters (*Enhydra lutris*) in British Columbia updated with 2013 survey results. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2015/043. 10 p.

DFO. 2016a. Pacific Region Integrated Fisheries Management Plan Red Sea Urchin. August 1, 2016 to July 31, 2017. 34 p. + app.

DFO. 2016b. Stock status update and harvest options for the Green Sea Urchin (*Strongylocentrotus droebachiensis*) fishery in British Columbia, 2016-2019. DFO Can. Sci. Advis. Secr. Sci. Resp. 2016/031. 19 p.

DFO. 2016c. Pacific Region Integrated Fisheries Management Plan Green Sea Urchin. September 1, 2016 to August 31, 2018. 27 p. + app.

DFO. 2017. Pacific Region Integrated Fisheries Management Plan Red Sea Urchin. August 1, 2017 to July 31, 2018. 37 p. + app.

D'yakonov, A.M. 1969. Fauna of Russia and adjacent countries - Echinoidea. Volume 1. Israel program for scientific translations, Jerusalem. 265 p.

Ebert, T. and J.R. Southon. 2003. Red Sea Urchin (*Strongylocentrotus franciscanus*) can live over 100 years: confirmation with A-bomb 14 carbon. Fish. Bull. (U.S.) 10(4): 915-922.

Ebert, T.A. 2008. Longevity and lack of senescence in the Red Sea Urchin *Strongylocentrotus franciscanus*. Exper. Geront. 43:734-738.

Estes, J. A. and D. O. Duggins. 1995. Sea Otters and kelp forests in Alaska: generality and variation in a community ecological paradigm. Ecological Monographs 65(1): 75-100.

Feehan, C.J. and R.E. Sheibling. 2014. Effects of sea urchin disease on coastal marine ecosystems. Mar. Biol. 161(7): 1467–1485.

Hand, C. 2010. Personal Communication. Research Biologist, DFO, Nanaimo, BC, Canada.

Harper, B., G. Court, S. Brechtel, A. Harcombe, B. Hall, R. Halladay and B. Andrews. 1996. Proposal for ranking species under the National Framework for endangered species conservation. Unpublished report presented to the National Endangered Species Workshop, June 10, 1996. BC Ministry of the Environment and Alberta Department of Environmental Protection.

Hewson I. , Button J. B. , Gudenkauf B. M. , Miner B. , Newton A. L. , Gaydos J. K. , Wynne J. , Groves C. L. , Hendler G. , Murray, M., Fradkin, S., Breitbart, M., Fahsbender, E., Lafferty, K., Kilpatrick, A.M., Miner, C.M., Raimondi, P., Lahner, L., Friedman, C.S., Daniels, S., Haulena, M., Marliave, J, Burge, C.A., Eisenlord, M.E. and Harvell, C.D. 2014. Densovirus associated with sea-star wasting disease and mass mortality. Proc Natl Acad Sci U S A 111, 17278–17283.

Hiscock, K., A. Southward, I. Tittley and S. Hawkins. 2004. Effects of changing temperature on benthic marine life in Britain and Ireland. Aquat. Conserv. Mar. Freshw. Ecosys. 14: 333-362.

Kober, K.M. and G. Bernardi. 2013. Phylogenomics of strongylocentrotid sea urchins. BMC Evol. Biol. 2013 13: 88. 14 p.

Kvitek, R.G, Shull, D., Canestro, D., Bowlby, E.C., and B. L. Troutman. 1989. Sea Otters and benthic prey communities in Washington State. Marine Mammal Science 5(3): 266-280.

Lamb, A. and B.P. Hanby. 2005. Marine life of the Pacific Northwest: A photographic encyclopedia of invertebrates, seaweeds and selected fishes. Harbour Publishing, Madeira Park. 398 p.

Lambert, P. 2007. Checklist of the Echinoderms of British Columbia. Curator Emeritus of Invertebrates, Royal British Columbia Museum, Victoria. 10 p. available online: http://ibis.geog.ubc.ca/biodiversity/efauna/documents/EchinodermsofBCChecklist.pdf.

Lambert, P. and W.C. Austin. 2007. Brittle stars, sea urchins and feather stars of British Columbia, Southeast Alaska and Puget Sound. Royal BC Museum Handbook. Royal BC Museum, Victoria BC. 150 p.

Lambert, P. and J. Boutillier. 2011. Deep sea Echinodermata of British Columbia, Canada. Can. Tech. Rep. Fish. Aquat. Sci. 2929. viii + 143 p.

Leus, Dan. 2010. Personal Communication, Red Sea Urchin Biologist, DFO, Nanaimo, BC, Canada.

Leus, D., A. Campbell, E. Merner, W.C. Hajas and L.L. Barton. 2014. Framework for estimating quota options for the Red Sea Urchin (*Strongylocentrotus franciscanus*) fishery in British Columbia using shoreline length and linear density estimates. DFO Can. Sci. Advis. Sec. Res. Doc. 2013/094.: vi + 68 p.

Levings, C.D. 1980. Demersal and benthic communities in Howe Sound basin and their responses to dissolved oxygen. Can. Tech. Rep. Fish. Aquat. Sci. 951. iv + 27 p.

Lochead, J. 2018. Personal Communication. Assessment Biologist, DFO, Nanaimo, BC, Canada.

Pearse. J.S. and A.H. Hines. 1987. Long-term population dynamics of sea urchins in a central California kelp forest: rare recruitment and rapid decline. Mar. Ecol. Prog. Ser. 39: 275-283.

McClintock, J.B. 1994. Trophic biology of Antarctic shallow-water echinoderms. Mar. Ecol. Prog. Ser. 111: 191-202.

Mironov, A.N. 1973. New deep-sea species of sea urchins of the genus *Echinocrepis* and the distribution of the family Pourtalesiidae (Echinoidea, Meridosternina). Tr. Inst. Okeanol. Akad. Nauk SSSR 91: 240-247.

Mironov, A.N. 1976. Deep-sea urchins of the northern Pacific. Tr. Inst. Okeanol. Akad. Nauk SSSR 99: 140-164.

Mironov, A.N., K.V. Minin and A.B. Dilman. 2015. Abyssal echinoid and asteroid fauna of the North Pacific. Deep Sea Res. Pt. II: Topical Stud. Oceanogr. 111: 357-375.

Mooi, R. and B. David. 1996. Phylogenetic analysis of extreme morphologies: deep-sea holasteroid echinoids. J. Natur. Hist. 30: 913-953.

Mortensen, T. 1950. A monograph of Echinoidea. V. 1 Spatangoida. I.Protosternata, Meridosternata, Amphisternata I. Palaeopneustidae, Palaeostomatidae, Aeropsidae, Toxasteridae, Micrasteridae, Hemiasteridae. Volume 1. C.A. Reitzel, Copenhagen. 432 p.

Munk, J.E. 1992. Reproduction and growth of green urchins *Strongylocentrotus droebachiensis* (Muller) near Kodiak, Alaska. J. Shellf. Res. 11(2): 245-254.

National General Status Working Group (NGSWG). 2003. Guidelines for Assessing the General Status of Wild Species in Canada. Version 2.0. Unpublished Report. 19 p.

Nichol, L.M., J.C. Watson, R. Abernethy, E. Rechsteiner and J. Towers. 2015. DFO Can. Sci. Advis. Sec. Res. Doc. 2015/039. vii + 31 p.

Rodrigues, N., R. Sharma and B.N. Nath. 2001. Impact of benthic disturbance on megafauna in Central Indian Basin. Deep-Sea Res. II. 48: 3411-3426.

Ruhl, H.A. 2008. Community change in the variable resource habitat of the abyssal northeast Pac. Ecol. 89(4): 991-1000.

Ruhl, H.A., 2007. Abundance and size distribution dynamics of abyssal epibenthic megafauna in the northeast Pacific. Ecology 88(5): 1250-1262.

Schultz, J.A., Cloutier, R.N. and I.M. Côté. 2016. Evidence for a trophic cascade on rocky reefs following sea star mass mortality in British Columbia. PeerJ 4:e1980; DOI 10.7717/peerj.1980

Tatarenko, D.E. and A.B. Poltaraus. 1993. Affiliation of sea urchin *Pseudocentrotus depressus* to the family Strongylocentrotidae and description of a new genus *Mesocentrotus* belonging to the group based on DNA-DNA hybridization and comparative morphological data. Zoologicheskii Zhurnal 72(2): 61-72.

Vardaro, M.F., H.A. Ruhl and K.L. Smith Jr., 2009. Climate variation, carbon flux, and bioturbation in the abyssal North Pacific. Limnol. Oceanogr., 54(6): 2081-2088.

Waddell, Brenda. 2010. Personal Communication. Assessment Technician, DFO, Nanaimo, BC, Canada.

Waddell, B.J. 2017. Survey results of Green Sea Urchin (*Strongylocentrotus droebachiensis*) populations in Haro Strait, British Columbia, March 2008 and 2009, August 2009, and March 2010. Can. Tech. Rep. Fish. Aquat. Sci. 3208. viii + 69 p.

Waddell, B.J. and I.R. Perry. 2012. Survey results of Green Sea Urchin (*Strongylocentrotus droebachiensis*) populations in Queen Charlotte Strait, British

Columbia, October 2008 and November 2010. Can. Tech. Rep. Fish. Aquat. Sci. 3000. ix + 73 p.

Waddell, B., Z. Zhang and R.I. Perry. 2010. Stock assessment and quota options for the Green Sea Urchin, *Strongylocentrotus droebachiensis*, fishery in British Columbia, 2010-2013. DFO Can. Sci. Advis. Secr. Res. Doc. 2010/027. vi + 36 p.

Watson, J. and J.A. Estes. 2011. Stability, resilience, and phase shifts in rocky subtidal communities along the west coast of Vancouver Island, Canada. Ecol. Monog. 81(2): 215-239.

Williams, G.C. 2010. Personal Communication. Curator and Chair, Department of Invertebrate Zoology and Geology, California Academy of Sciences, San Francisco, CA.

Workman, G., 1999. A review of the biology and fisheries for Purple Sea Urchin (*Strongylocentrotus purpuratus* Stimpson, 1857) and discussion of the assessment needs for a proposed fishery. DFO Can. Sci. Advis. Secr. Res. Doc. 99/163. 58 p.

WoRMS Editorial Board. 2018. World Register of Marine Species. Available from http://www.marinespecies.org at VLIZ. doi:10.14284/170