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Living Marine Legacy of Gwaii Haanas. I:
Marine Plant Baseline to 1999 and Plant-related Management Issues

N. A. Sloan and P. M. Bartier

March 2000
Report 027

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Report # 27

Living Marine Legacy of Gwaii Haanas I: Marine Plant Baseline to 1999 and Plant-related Management Issues

by

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ABSTRACT

This is the first report in a series of baseline marine biological inventories for the Haida Gwaii (Queen Charlotte Islands) archipelago including Gwaii Haanas National Park Reserve/Haida Heritage Site. We list the seaweed and seagrass species and map their distributions known to the end of 1999. Our geographic information system contains records of 348 seaweed and four seagrass species from 456 localities in the archipelago. We include a preliminary marine lichen flora of 88 species. The importance of plant communities to the coastal ecosystem integrity of Gwaii Haanas is great. Kelp (large seaweed) forests and seagrass meadows comprise ecosystems that shelter many species of juvenile and adult fishes and invertebrates. Kelp is critical to traditional and commercial Pacific herring spawn-on-kelp fisheries. Further, marine plants are important to indigenous Haida culture.

RESUMÈ

Il s’agit du premier d’une série de rapports de base sur l’inventaire des espèces marines de l’archipel Haida Gwaii (îles de la Reine-Charlotte), qui comprend la réserve de parc national/le site du patrimoine haïda Gwaii Haanas. Nous y énumérons les diverses espèces d’algues et de graminées marines et y cartographions leurs aires de distribution connues jusqu’à la fin de 1999. Notre système d’information géographique contient une liste de 348 espèces d’algues et de 4 espèces de graminées marines peuplant 456 localités de l’archipel. Le rapport renferme également une liste préliminaire de 88 espèces de lichens marins. Les communautés végétales contribuent grandement à l’intégrité de l’écosystème côtier de Gwaii Haanas. Les forêts de varech (grandes algues) et les prés de graminées marines forment des écosystèmes qui servent d’habitat à de nombreuses espèces de poissons et d’invertébrés juvéniles et adultes. Le varech joue aussi un rôle essentiel dans la récolte traditionnelle et la pêche commerciale des œufs de hareng du Pacifique. Enfin, les plantes marines revêtent de l’importance dans la culture indigène des Haïdas.

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PREFACE

My first exposure to the marine flora of British Columbia was in 1946 as an undergraduate at the University of British Columbia (UBC). In the late 1940s and early 1950s I studied and collected marine plants at many sites between the southern end of Vancouver Island and Langara Island in Haida Gwaii (Queen Charlotte Islands). I visited the extensive kelp forests sheltered in Cumshewa Inlet on the east coast of Moresby Island and saw the rugged and exposed coast at Tasu Sound off the west coast of Moresby Island and Hippa Island off the west coast of Graham Island looking (unsuccessfully) for *Postelsia palmeaformis.* I also visited areas along the north shore of Graham Island between the Mazarredo Islands and Chanal Reef off Langara Island. My most memorable Haida Gwaii experience was on the north coast of Graham Island, where I first observed the extent of the tidal amplitude and the great richness of the intertidal flora. By myself in a 3-m dinghy, observing, photographing and collecting marine algae in Hazardous Cove on Langara Island was an especially exciting and rewarding experience. These early visits, together with those of my graduate students and postdoctoral fellows after I joined UBC in 1952, provided opportunities to collect marine algae for UBC's Phycological Herbarium. Except for the somewhat questionable (as to locale) records for a few marine algae (including *Egregia menziesii*, which may have been collected somewhere in Haida Gwaii) recorded by Archibald Menzies in 1787-1788, our collections in the 1940s, 1950s and 1960s provided the first significant records of the benthic marine algae of Haida Gwaii. The UBC Phycological Herbarium, which has grown from a handful of specimens in 1946 to over 84,000 in 1999, has provided a rich resource of phycological data for this report.

The special value of this publication is that it brings together for the first time for the area a detailed inventory of the marine flora based on published literature as well as on available herbarium specimens. Much more needs to be done to obtain a more comprehensive inventory of the biota of the area. A great diversity of habitats exists in Haida Gwaii and many more sites need to be examined intertidally as well as subtidally – especially where diving has been little exploited.

Marine plants can be useful indicators of the physio-chemical characteristics of the environment in which they occur. Haida Gwaii occupies a unique and important geographic position as it presents a transition from the southern region to the northern region and contributes significantly to an understanding of the distribution patterns of benthic marine plants on the Pacific Coast of North America. With increasing need for conservation and concern for the marine habitat, it is especially important that we have analyses such as presented in this publication, so that, over time, it will be possible to detect changes in marine biota, assess the impact of man's use and exploitation of the marine habitat, and attempt to conserve the biodiversity of this phycologically rich area.

Robert F. Scagel
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University of British Columbia

EXECUTIVE SUMMARY

"Gosh, there's an awful lot of work to make even the most cursory survey of this sort."
Ed Ricketts on marine biological surveys; Masset Inlet, June 1946 (Hedgpeth 1978)

This is the first report in a series providing baseline marine biological inventories for the Haida Gwaii (Queen Charlotte Islands) archipelago including Gwaii Haanas National Park Reserve/Haida Heritage Site. An assessment of biodiversity is central when addressing Parks Canada's mandate to protect and conserve representative samples of Canada's marine areas by maintaining ecosystem structure and function.

We list the seaweed and seagrass species and map their distributions known to the end of 1999. Our geographic information system (GIS) database contains 6031 records, comprising 348 seaweed and four seagrass species recorded from 456 localities among the islands. Haida Gwaii is of marine biogeographical interest as it represents the southern extreme of the northern seaweed flora. The closest area whose flora is reasonably well known is Bamfield on the southwestern coast of Vancouver Island. A preliminary marine lichen flora of 88 species is also included.

The importance of plant-structured communities to the nearshore ecosystems of Gwaii Haanas cannot be overstressed. Besides being of academic service to marine botanists and biodiversity specialists, this Haida Gwaii marine plant survey has practical implications for Parks Canada's long-term stewardship of Gwaii Haanas in particular.

Kelp forests and seagrass meadows comprise vital nearshore marine ecosystems here. They provide detritus into coastal food webs, shelter many species as nurseries for juveniles and habitat for adults. Kelp is fundamental to traditional and commercial herring spawn-on-kelp fisheries. Further, marine plants are important to Haida culture.

Issues relating to Parks Canada's marine ecosystem mandate in Gwaii Haanas include:

- understanding the role of plants in structuring nearshore marine communities;
- environmental monitoring of threats to, and well-being of, ecosystems;
- assessing impacts of repatriated sea otters on nearshore kelp forest ecosystems;
- evaluating the role of red sea urchin grazing (herbivory) on kelp forest ecosystems;
- rehabilitation of depleted kelp-associated northern abalone stocks;
- maintaining healthy kelp resources in support of herring spawn-on-kelp harvest;
- appreciating the role of seagrass meadows in the land-sea linkages in estuaries; and
- backcountry monitoring of visitor impacts to intertidal habitats.

Marine plant-associated management issues are discussed and recommendations made concerning maintaining nearshore ecosystem structure and function of Gwaii Haanas. We hope that this report will serve regional marine botany and help focus attention on marine ecosystem management issues of Gwaii Haanas.

INTRODUCTION

Parks Canada is mandated to protect and conserve representative samples of marine regions that includes maintaining ecosystem structure and function while permitting multiple uses within proposed Marine Conservation Areas. An important step in assessing biodiversity is creating taxonomically and systematically (i.e., named and ordered) up-to-date inventories. This is the first report in a series providing baseline marine inventories of Haida Gwaii (Queen Charlotte Islands) and particularly the living marine legacy of Gwaii Haanas. Further, this follows up on our Marine Plant Biodiversity Plan (Druehl 1999 a).

This marine plant report addresses Gwaii Haanas' management objectives for two main reasons:

- to advise management on the knowledge of current marine plant species and plant-associated ecosystem management issues; and

- to establish the marine plant historic baseline in the form of a reliable species listing for specialists to augment and compare with other North Pacific regions.

Gwaii Haanas comprises the southern end of Moresby Island and associated islands in southern Haida Gwaii archipelago off the northern British Columbia mainland coast (Figure 1). Gwaii Haanas incorporates ~1,470 km^2 of land, ~3,400 km^2 of proposed sea space and ~1,700 km of shoreline.

Gwaii Haanas represents the National Marine Conservation Area Natural Regions of Queen Charlotte Islands Shelf to the west, Hecate Strait to the east and borders the Queen Charlotte Sound region to the south (Mercier and Mondor 1995). Gwaii Haanas' west coast is highly exposed to the open Northeast Pacific and has a narrow shelf and continental slope descending rapidly to >2000 m depth within 20 km offshore. The east coast faces Hecate Strait, which extends ~70 km to the northern British Columbia mainland, and is mostly shallower than 150 m.

The environment of Gwaii Haanas marine area is temperate coniferous forests on mountainous terrain along an extremely complex, mostly rocky (~75%) shoreline, much of which is exposed to high winds and heavy rains in the winter storm season. Less than 10% of the shoreline is sandy, of which estuarine flats account for ~6% of the total shoreline. The entire shoreline has received preliminary biophysical classification (Harper *et al.* 1994) and is on a geographic information system (GIS) platform for our marine knowledge.

This marine plant inventory provides a model for subsequent GIS-based marine inventories proposed for Gwaii Haanas. These inventories, together with the complete science bibliography of Haida Gwaii under preparation, will provide a starting point of natural science support for future ecosystem-based management of Gwaii Haanas.

A sound inventory is an important step towards understanding the ecosystem role of marine plants in nearshore Gwaii Haanas habitats. At present, this role is virtually unknown and, arguably, would remain unknowable if such basic biodiversity information is not made available.

This report focuses on seaweeds, seagrasses and marine lichens only. Beach grasses, herbs and sedges rooted in sandy

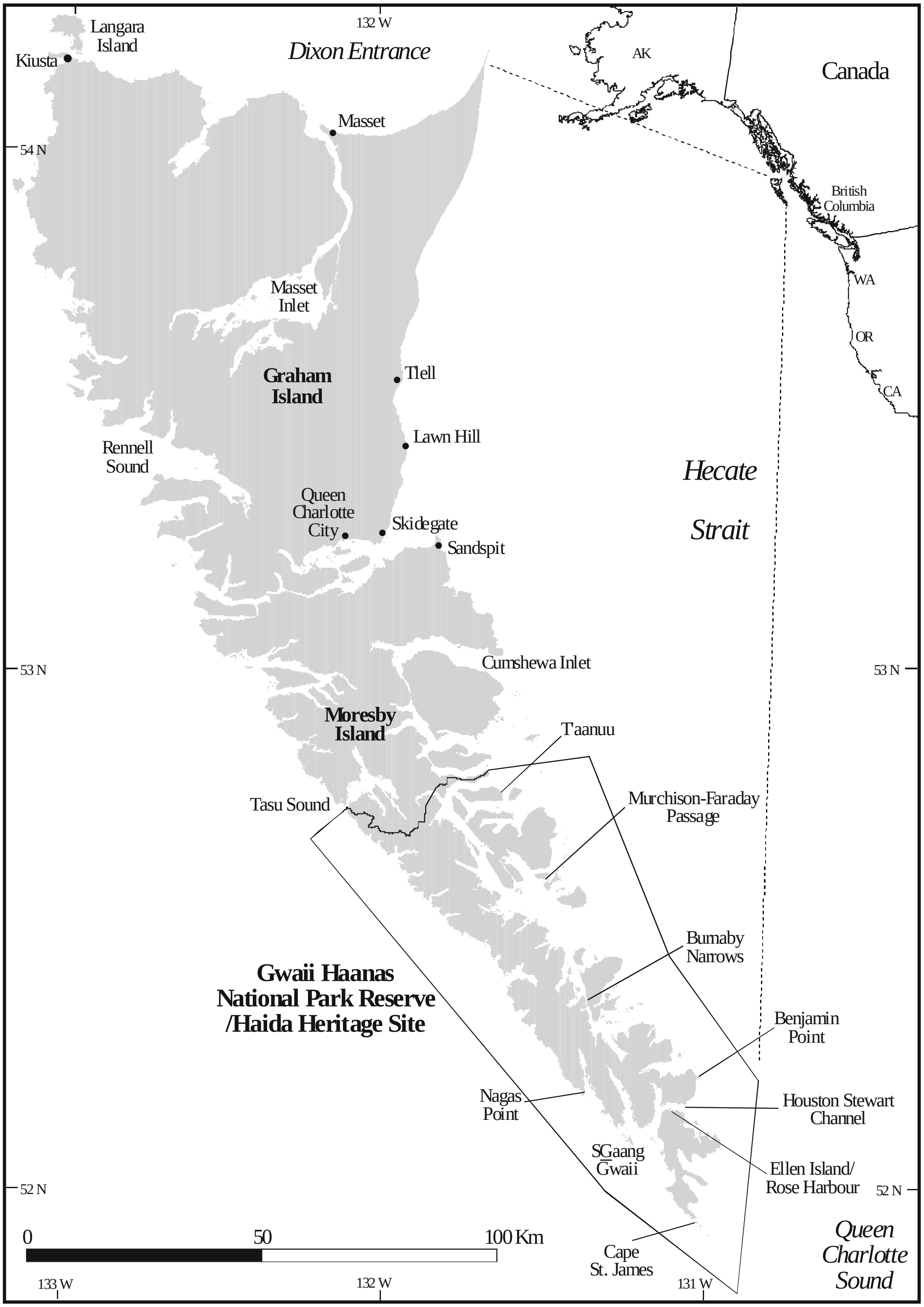

Figure 1. Location of Gwaii Haanas within Haida Gwaii (Queen Charlotte Islands) including place names mentioned in the text.

backshores, estuarine wetlands flora and phytoplankton are not included, but must eventually be covered for a complete Gwaii Haanas marine plant baseline. Surveys of beach and wetland plant communities are available in specific Haida Gwaii reports such as Calder and Taylor (1968; Maritime Communities section, p. 55-71) and Ogilvie (1994); as well as general B.C. coastal floral summaries (Klinka *et al.* 1989; Pojar and MacKinnon 1994; Turner 1995).

Highest quality, standardised listings acceptable to international convention are vital to the long-term utility of any species survey. Our commitment to conventions and protocols concerning nomenclature and systematics are described in the Methods section.

The importance of plant-structured communities to the nearshore ecosystem integrity of Gwaii Haanas is fundamental. Kelp (large brown seaweed) forests and seagrass meadows comprise vital nearshore marine ecosystems. Besides being of academic service to marine botanists and biodiversity specialists, this report has practical implications for our long-term stewardship of Gwaii Haanas. Further, marine plants are important to indigenous (Haida) culture.

This is the first comprehensive marine plant survey of this type for a national park in North America. In a survey of 252 National Parks and National Monuments under U.S. National Park Service management, Stohlgren *et al.* (1994) reported that few parks had complete inventories of organisms. Further, they concluded that invertebrate and non-vascular plant inventories were "*poor or non-existent*".

SEAWEEDS

"Seaweeds" in this report are algae; plants that have always lived in water. They have no vascular system, roots, flowers or seeds. All species are characterized by alternating life history phases which can be isomorphic or heteromorphic. Seaweeds occur wherever there is stable attachment surface (including other organisms) from the immediate spray zone just above the upper intertidal of rocky shores down to ~35 m below the zero tide line in the Northeast Pacific. The lower limits of seaweeds are often dictated by suitable substrate rather than amount of available light. There are three main types of seaweed: green, red and brown.

British Columbia's general seaweed handbook is Scagel (1971) and for Southeast Alaska is O'Clair and Lindstrom (2000) . Hawkes at al. (1978) is the only broad northern British Columbia seaweed synopsis. There are only a few additions to the peer-reviewed Haida Gwaii literature, such as the Langara Island survey of Garbary *et al.* (1980). Historical inventories of commercial British Columbia seaweeds have focused on south coast kelp (Cameron 1916; Scagel 1947). The only published commercial survey in Haida Gwaii was restricted to the north and west coasts of Graham Island (Coon *et al.* 1979).

Kelp is ubiquitous in the archipelago. The Haida have harvested **k'aaw,** Pacific herring (*Clupea harengus pallasi*) spawn-on-kelp in season, likely for millennia, particularly along the east and north coasts of Haida Gwaii. In the signing of the *South Moresby Agreement* between Canada and the Province of British Columbia in July 1988, the intent to transfer the stewardship of all provincial marine resources in Gwaii Haanas to Parks Canada was declared. The transfer will occur after passage of the proposed *Marine Conservation Areas Act* expected in 2000. Resources covered in the transfer will include licensing giant kelp (*Macrocytsis integrifolia*) harvest in support of the commercial **J**-licence, spawn-on-kelp (SOK) fishery that currently has 46 licences Province-wide.

SEAGRASSES

Seagrasses originate from land plants and they flower, pollinate, produce fruit and disperse seeds as do aquatic land grasses. They are not closely related to land grasses such as those seen on sand/gravel beach backshores. Unlike seaweeds, seagrasses have true roots, leaves and an internal tubular transport (vascular) system for nutrients and gasses. In tide pools, lower intertidal and shallow subtidal sandy to muddy shores they can form productive meadows that provide vital animal habitat and organic detritus primarily into inshore food webs. Seagrasses spread vegetatively by horizontal underground stems (rhizomes) which, with the roots, form dense mats in the substrate. Broad-scale dispersal occurs by sexual reproduction involving seed-release from pollinated flowers.

Seagrasses root in moderately to very sheltered sediment shores, although some species prefer sediments in crevices of exposed rocky shores. Seagrasses occur in the lower intertidal, down to a maximum in Gwaii Haanas waters of ~10 m depth. The upper limit of seagrasses, which is in the lower intertidal, is imposed by exposure to desiccation and wave energy. Their lower (subtidal) limit is imposed by the penetration of sufficient light to allow photosynthesis to exceed respiration.

Seagrass meadows are found along the wave-exposed rocky British Columbia (and Gwaii Haanas) coasts to sheltered, depositional areas such as bays and deltas at the heads of inlets. Although sedimentary habitats are relatively small overall compared to rocky habitats, they are considered very important for juvenile fish such as salmon, many invertebrates and marine birds.

MARINE LICHENS

Lichens are a symbiotic partnership between a fungus and a green alga or, less commonly, a cyanobacterium (previously termed "blue-green" algae). A brown algal symbiot in the marine lichen, *Verrucaria tavaerisae*, was recently reported from California and red algal-fungal obligate associations called mycophycobioses are also known (M. Hawkes, *personal communication*). The fungus supplies the structural support in lichens and the alga is the photosynthetic component; usually sandwiched as a distinct layer within fungal layers. Marine species grow mostly in two of the three main growth forms; crustose and foliose (O'Clair *et al.* 1996).

According to O'Clair *et al.* (1996), marine lichens in the Northeast Pacific are hardy, salt-tolerant and usually slow-growing species which firmly attach to hard substrates such as rock, driftwood and tree bark from the upper intertidal to the forest edge. There are a number of zonation schemes for shore lichens and these must be tempered by local conditions (Ryan 1988, Figure 1). For example, local freshwater seepage can obscure marine-controlled zonation patterns (Ryan 1988). The zones from Southeast Alaska are defined by O'Clair *et al.* (1996) as follows:

• "*salt spray*" zone - areas experiencing only seawater spray;

• "*splash*" zone - areas covered by only the highest annual tides and/or wetted by intermittent wave splash; and

• "*high intertidal*" zone - areas regularly covered by seawater during high tides.

The first zone comprises the general maritime flora with the splash zone separating the maritime from the true marine (most salt tolerant) flora. Knowledge of marine lichens in Haida Gwaii comes almost entirely from Dr. I.M. Brodo of the Canadian Museum of Nature (e.g., Brodo 1995; Brodo and Santesson 1997). Appropriate zonation of marine lichens in Gwaii Haanas awaits field verification by Dr. Brodo scheduled for summer, 2000.

HAIDA MARINE PLANT USE

The importance of marine plants to Haida culture is clear when you consider that the name of T'aanuu village means eelgrass – referring to eelgrass meadows growing nearby.

The Haida Fisheries Program has gathered (and partially mapped) giant kelp (*M. integrifolia*) data from the east and north coasts of Haida Gwaii in support of the traditional spawn-on-kelp fishery (Russ Jones, *personal communication*). As well, the Haida Fisheries Program has also collected kelp information under contract to the commercial **J**-Licence Pacific herring spawn-on-kelp fishers.

Listed in Table 1 are marine plant species matched with Haida names currently in the scientific literature. This would likely be

Table 1. Haida names for some marine plants from Haida Gwaii.

Haida Name	Common Name	Scientific Name
Ihkyaa'maa[1]	Bull kelp	*Nereocystis luetkeana*
Ngaal[2]	Giant kelp	*Macrocystis integrifolia*
T'al	Rockweed / Sea wrack	*Fucus gardneri*
Sgyuu	Red laver / Nori	*Porphyra perforata*
Sgyuu	Black laver / Black seaweed	*Porphyra abbottae*[3]
Sgiiwaay	"Winter seaweed"[4]	*Porphyra lanceolata* *Porphyra torta*
Ga7aan	Ribbon kelp / Wing kelp	*Alaria marginata*
Sgii'naaw	Sea lettuce / Sea hair	*Ulva lactuca* *Enteromorpha intestinalis*
Chaagaan-xiilaay	Coralline and some other red algae	*Corallina* spp. *Constantinea* spp.
T'aask'aat'uugaa	Dead man's fingers	*Halosaccion glandiforme*
T'aanuu	Eelgrass / Seagrass	*Zostera marina*
T'aanuu	Surfgrass / Seagrass	*Phyllospadix* spp.

[1] the bull kelp stipe is called **tle'gaay** ("fishing line") (Turner 1974)

[2] other "kelps" in this general taxonomic category include species of *Laminaria, Pleurophycus, Costaria, Egregia, Alaria* and *Agarum* as well as *Nereocystis* blades, but **ngaal** is itself giant kelp (Turner 1974)

[3] the *Porphyra* species most commonly used (Turner 1995)

[4] the seaweeds gathered in early spring travels from winter villages in search of greens and sea vegetables or "winter" seaweeds (Barb Wilson, *personal communication*)

expanded considerably with a focused traditional knowledge survey. Among the plants, the most important food species are giant kelp, black laver and winter seaweed. Seaweed (**sgyuu**) and spawn-on-kelp (**k'aaw**) [using giant kelp **ngaal**], besides being important foods to be consumed fresh, were dried and traded to the Nass River Tsimshian every spring for eulachon grease (Turner 1974). Dawson (1880), likely referred to **sgyuu,** as follows: "*A sea-weed resembling dulse, but which I have only seen in dried cakes, is found, especially in the southern islands, preserved by drying and boiled into a sort of tea or soup.*"

The Haida word for foliose lichens is **ihk'inxaa-kwii7aawaay** ["forest-cumulus-cloud"], but relatively few Haida names have been recorded for lichens and fungi (Turner 1974).

METHODS

"*Many regions of conservation concern are increasingly threatened by environmental degradation, and conservation biologists often require copious quantities of data concerning the distribution of species in order to establish conservation priorities.*" Snow and Keating (1999)

For the species lists we will eventually adopt the nomenclature and systematics of the Integrated Taxonomic Information System (ITIS). The ITIS is a dynamic biological checklist supported by government agencies of Canada, the U.S. and Mexico and maintained by a network of over 1000 taxonomists. It is accessible through the World Wide Web (in Canada: http://res.agr.ca/itis and in the U.S.: http://www.itis.usda.gov/plantproj/itis/index.html).

The ITIS conforms with the *International Codes of Botanical and Zoological Nomenclature*. Its purpose is to provide accurate, scientifically credible and current taxonomic data standards for the comparison of biodiversity datasets. Having stated that, ITIS can be expected to lag behind the most recent literature. The ITIS assigns a unique code ("Taxonomic Serial Number") to each taxon and all attendant systematic levels up to Kingdom. The ITIS also includes, for all systematic levels, taxon authorities, synonyms and data quality indicators. Central to the data quality process is peer review prior to incorporation into ITIS, and periodical review thereafter. The ITIS, therefore, facilitates international sharing, transfer and comparison of information. This is important for national agencies such as Parks Canada when cooperating with international programs and global issues of information sharing in support of biodiversity knowledge.

The ITIS is a work-in-progress and is not yet complete for some groups such as algae. Currently, the ITIS contains algae and lichens only from the U.S. Department of Commerce, National Oceanic and Atmospheric Administration's National Oceanographic Data Center and these data are not yet fully quality-controlled. Therefore, the algae in this report follow the most recent version of the University of British Columbia (UBC) Phycological Herbarium master list as will be reflected in Gabrielson *et al.* (in press). This list is the regional benchmark and is likely to be adopted by ITIS, as is Qian and Klinka (1998). For lichens, the nomenclature follows Qian and Klinka (1998) whenever possible. The ITIS is used for lichen systematics and for taxa not listed in Qian and Klinka (1998). Vascular plants (seagrasses) listed here are based on the

ITIS. When available, we will retrofit our species lists with fully quality-controlled ITIS codes.

Four major Pacific regional marine herbaria and the Canadian Museum of Nature (CMN) were contacted to establish the extent of their material from Haida Gwaii (Appendix A). The two institutions with material from Haida Gwaii were the University of British Columbia (2758 records) and the CMN (9 records).

Our intent was to capture all possible sources and enter data into our GIS. The starting point was the Biophysical Inventory of Coastal Resources (Harper *et al.* 1994) with its 107 shore observation stations in Gwaii Haanas illustrated in Figure 2. We then looked back in time to marine biological expeditions by universities and government agencies for all of Haida Gwaii. Figures 3 to 5 contain the sample sites from other noteworthy marine surveys. Figure 3 contains sample sites in Gwaii Haanas from two surveys commissioned by Environment Canada-Parks before the establishment of Gwaii Haanas. The marine botanical expeditions to Haida Gwaii were the University of British Columbia (UBC), Department of Botany synoptic surveys of 1963 and 1976 supported by Professor Robert F. Scagel, with the latter published by Hawkes *et al.* (1978). Sample sites from these surveys comprise the majority of sites in the UBC herbarium records illustrated in Figure 4. The sample locations from other selected surveys of Haida Gwaii are provided in Figure 5. Reports such as Adkins (1977) that have general regional

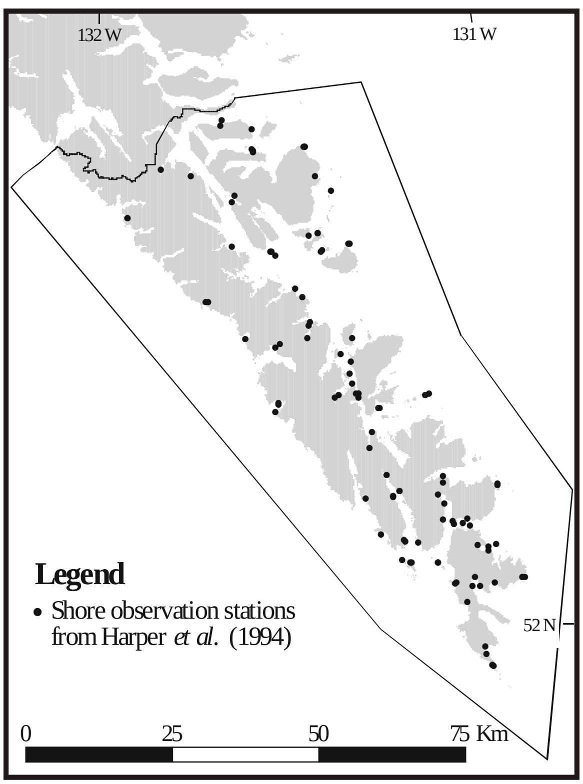

Figure 2. The 107 shore observation locations from which marine plant data were recorded in the coastal biophysical inventory of Gwaii Haanas by Harper *et al.* (1994).

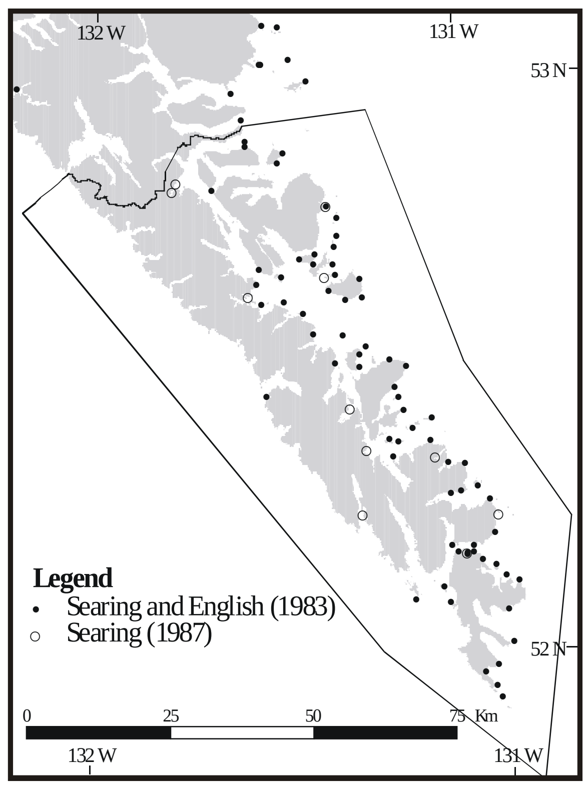

Figure 3. Sample locations from surveys of Gwaii Haanas commissioned by Environment Canada - Parks.

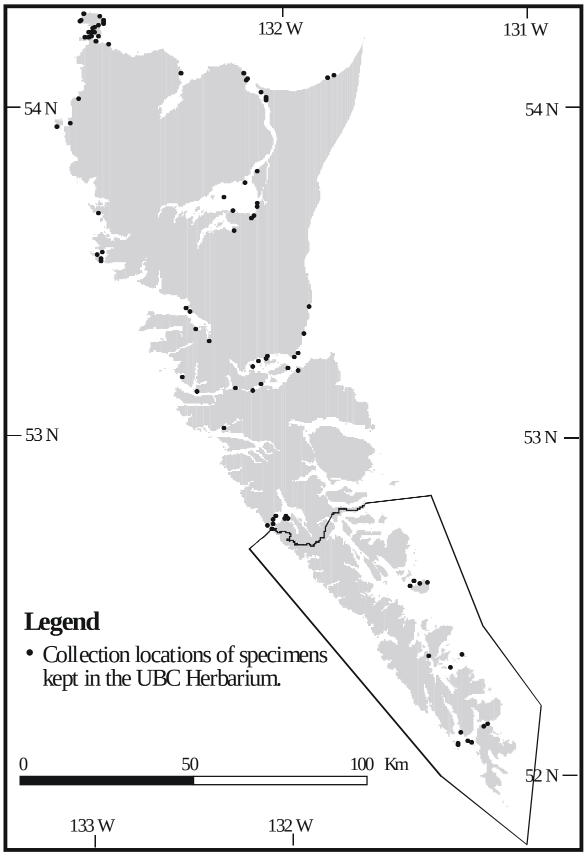

Figure 4. Sample locations in Haida Gwaii from which marine plant specimens are retained at the University of British Columbia Phycological Herbarium.

species lists, but with no specific locality data, were not included.

Marine plant species data quality can be ranked as follows:

1. species for which there are herbarium specimens;

2. species mentioned in internationally peer-reviewed publications; and

3. species mentioned in "grey" literature reports and unpublished surveys.

Within the grey literature, the expertise of investigators determines data quality. If taxonomic specialists were engaged, this increases the report's reliability.

RESULTS AND DISCUSSION

SPECIES LISTS

"*The difficulty in defining biodiversity is in proving the absence of a species. Absence of proof is not proof of absence*." Druehl (1999 a)

With very few exceptions, the historical species listings were made without protocols specifically establishing the *absence* of species. Lists of seaweeds and seagrasses and marine lichens in the Gwaii Haanas database are provided in Appendix B. Included are the number of sites at which all marine plant taxa have been reported from Haida Gwaii (Queen Charlotte Islands) and Gwaii Haanas National Park Reserve. Also included are the number of vouchered specimens for each species at the UBC or CMN herbaria and the map number for the distribution of that species illustrated in Appendix C. Part 1 of Appendix B covers marine algae and seagrasses and Part 2 covers marine lichens, all of which are vouchered CMN specimens.

<u>Algae</u>

Algal species names in Appendix B are based on *Keys to the benthic marine algae and seagrasses of British Columbia, Southeast Alaska, Washington and Oregon* [Revised Edition] (Gabrielson *et al.* in press) that reflect the most complete and current update of the Scagel *et al.* (1993) Synopsis. The important exception is the exclusion of 10 new species combinations that will be issued first in print by Gabrielson *et al.* (in press). Their names (to be replaced) are tagged in Appendix B to alert readers to the imminent change.

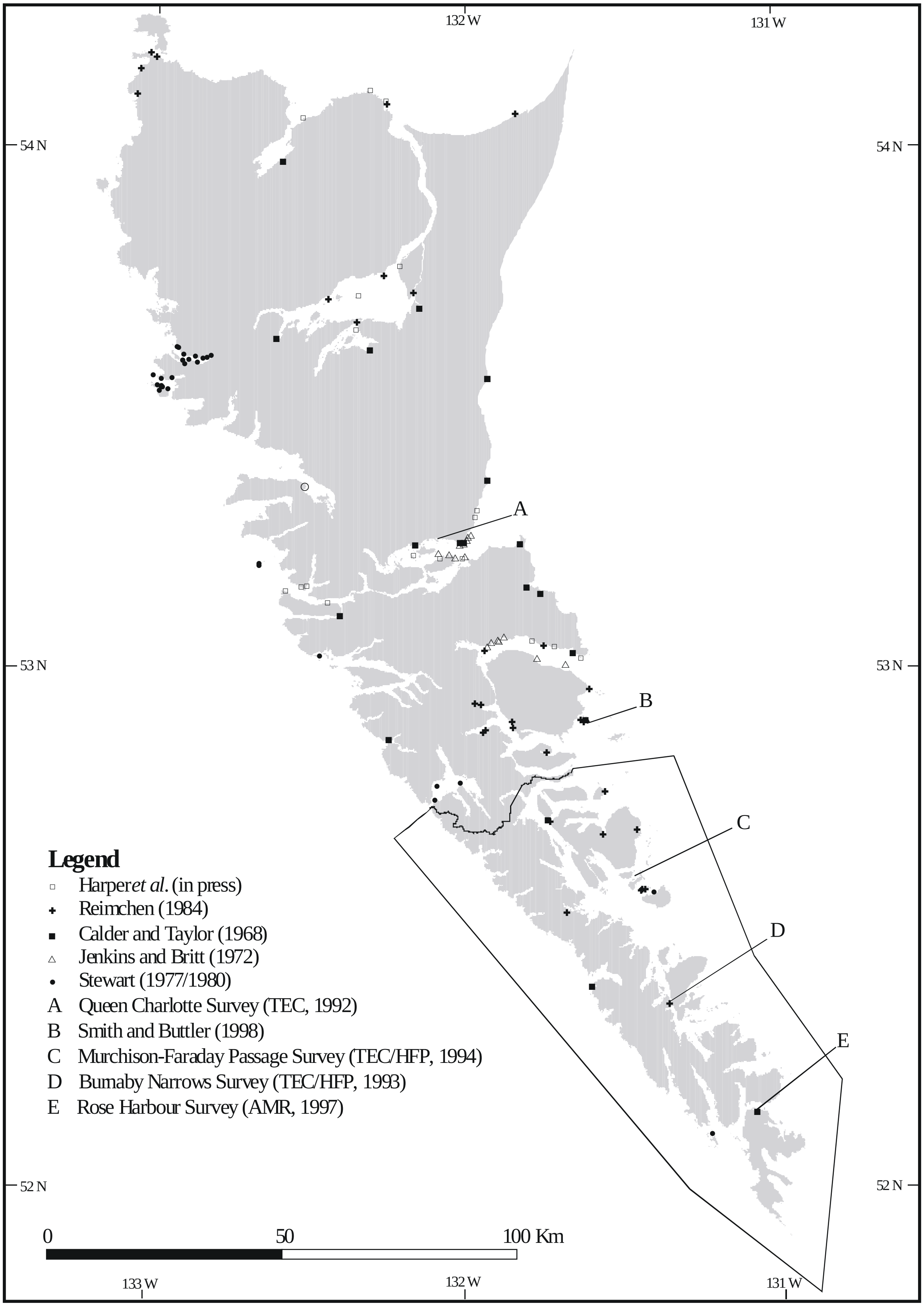

Figure 5. Sample locations of various marine surveys in Haida Gwaii from which marine plants were dentified.

Concerning range extensions since Scagel *et al.* (1993), excluding name changes, the only two extensions are for *Cirrulicarpus sp. nov*. and *Myriogramme repens*, both of which require checking with original material (M. Hawkes, *personal communication*). We underscore that there remain significant seaweed taxonomic and systematic problems whose resolutions will change the region's marine flora appreciably in the future.

Table 2 lists the nine marine algal specimens at the Canadian Museum of Nature. All species are listed in Appendix B, but only the two, those from Rennell Sound, are mapped in Appendix C, described below.

Table 2. Herbarium marine specimens from Haida Gwaii in the Canadian Museum of Nature, Ottawa.

Species (current name) [National Herbarium No.]	Location*	Collector (Year)
Spongomorpha coalita (*Acrosiphonia coalita*) [4618]	QCI	Spreadborough (1911)
Ulva lactuca latissima (*Ulva fenestrata*) [4347]	QCI	Spreadborough (1911)
Ralfsia verrucosa (*Ralfsia pacifica*) [4614]	QCI	Dawson (1878)
Ceramium rubrum [4620]	QCI	Spreadborough (1911)
Rhodomela lycopodioides [4485]	QCI	Spreadborough (1911)
Bossiella sp. [5189]	Rennell Snd.	W.v.V. (1966)
Corallina sp. [5188]	Rennell Snd.	W.v.V. (1966)
Cryptosiphonia woodii [4617]	QCI	Spreadborough (1911)
Rhodymenia pertusa (*Sparlingia pertusa*) [4585]	QCI	Spreadborough (1911)

* no Latitude or Longitude recorded

Haida Gwaii is of inherent marine biogeographical interest as it represents the southern extreme of the northern seaweed flora (Druehl 1981, 1999 a). Haida Gwaii had 32 species not reported from northern British Columbia mainland coasts (Hawkes *et al.* 1978). Garbary *et al.* (1980) added another 16 to this count, but also mentioned that over 50 taxa known from Alaska and southern British Columbia were not recorded from northern British Columbia. Garbary *et al.* (1980) commented that such findings could be due to insufficient collecting from northern British Columbia coastal areas. The four floristic categories of Hawkes *et al.* (1978): *northern species* (found north of 59° N), *southern species* (found south of Washington State), *local species* (occurring between 59° N and Washington State only) and *cosmopolitan species* (occurring north and south along the entire coast), occurred in equal proportions for the northern mainland and Haida Gwaii coasts. Within Southeast Alaska (Icy Bay [~60° N] to Dixon Entrance) alone, O'Clair *et al.* (1996) identified three seaweed areas. They found that "*outer coast*" (warmer, higher salinity), "*northern inside waters*" (colder, lower salinity) and "*southern inside waters*" (warmer, lower salinity) shared many species, but each also had distinct species. Perhaps Haida Gwaii compares most closely with the "*outer coast*" type area. Clearly, much more collecting needs to be done in the northern British Columbia-Southeast Alaska region.

With focused marine botanical effort, the seaweed species diversity recorded within Gwaii Haanas will likely increase as current knowledge represents ~49% of regional seaweed biodiversity. Table 3 lists the number of taxa recorded from Gwaii Haanas and Haida Gwaii as a whole. The seaweed taxa of Haida Gwaii in Appendix B exclude the "unidentified" specimens in the database. In Table 3 we did include lone genera for which no species were assigned. The Oregon to Southeast Alaska region listings are based on Scagel *et al.* (1993), Hawkes (1992, 1994 a), Tunnicliffe (1993) and Gabrielson *et al.* (in press).

Table 3. Seaweed and seagrass taxa of Haida Gwaii and the Oregon to Southeast Alaska region.

Algae / Seagrass Type	Gwaii Haanas	Haida Gwaii	Whole Region: Genera	Whole Region: Species/ Subspecies
Red (Rhodophyta)	151	225	161	373
Brown (Phaeophyta)	46	73	66	143
Green (Chlorophyta)	22	45	51	171
Golden (Chrysophyta)	1	1	3	6
Seagrass (Anthophyta)	3	4	3	6
Totals	223	348	284	645*

* 34 species are known only from B.C. Waters

Seagrasses

The following three seagrass species are confirmed to occur in Haida Gwaii waters:

- "eelgrass" (*Zostera marina*) found along sheltered sediment shores; and

- two "surfgrasses" (*Phyllospadix scouleri* and *P. torreyi*) growing from bedrock crevices and among boulders and cobbles of exposed rocky shores.

There was a consultant's report originating from an assessment for the new harbour in Sandspit recording a thin-bladed species as the introduced species *Zostera japonica*, which is now common in the southern Strait of Georgia. Those specimens, plus some from Queen Charlotte City collected in 1999 by us, were confirmed by Dr. Paul G. Harrison of UBC to be *Z. marina* (P.G. Harrison, *personal communication*).

There is an anomaly in the form of *Ruppia maritima* which is illustrated in Pojar and MacKinnon (1994) as occurring throughout Haida Gwaii. There are herbarium specimens as documented in Calder and Taylor (1968), but there are no records from the marine herbaria we contacted. Pojar and MacKinnon's (1994) map is likely based on Calder and Taylor's (1968, p. 70) generalizations on the occurrence of *R. maritima* (along with *Z. marina* further to seaward) in Haida Gwaii estuarine salt marshes. The species is not discussed further here. Regional seagrass specialists tend not to view *R. maritima* as a seagrass, but as a brackish water grass (Wyllie-Echeverria and Thom 1994), although the species is also assigned to the upper intertidal (Gabrielson *et al.* 1990).

Although three species of seagrasses occur in Gwaii Haanas, they likely have a disproportionately important impact on biodiversity in shallow marine areas because of the communities of organisms associated with them. The federal-provincial Marine Protected Areas strategy for the Pacific identified the limited amount of eelgrass habitat as areas of "*primary concern*" for protection (Anonymous 1998, p. 9).

Marine Lichens

The 88 marine lichen species listed in Appendix B (Part 2) all represent vouchered specimens held in the Canadian Museum of Nature. The substrate type and shore zone(s) occupied by all species are included.

The zonation designations are preliminary.

GEOGRAPHIC DISTRIBUTION

Appendix C comprises individual maps illustrating the distribution of every species of alga and seagrass listed in Appendix B (Part 1). The species are illustrated in the same order that they are listed in Appendix B. The map number from Appendix C is cross-referenced with each species in Appendix B (Part 1).

Algae

As a first approximation of kelp forest distribution, Figure 6 shows the occurrence of kelp symbols from Canadian Hydrographic Service charts (3807, 3808, 3809, 3825, 3827, 3894) of the Moresby Island area, including much of Gwaii Haanas. The kelp species illustrated are most likely to be those forming conspicuous forest, such as giant kelp (*M. integrifolia*) and bull kelp (*Nereocystis luetkeana*), which are visible as floating kelp forest canopy along rocky shores. Note that the west coast of Gwaii Haanas north from Nagas Point to Tasu Sound is uncharted; hence no kelp symbols. Kelp is likely ubiquitous in Gwaii Haanas and could be expected to occur along all rocky shores.

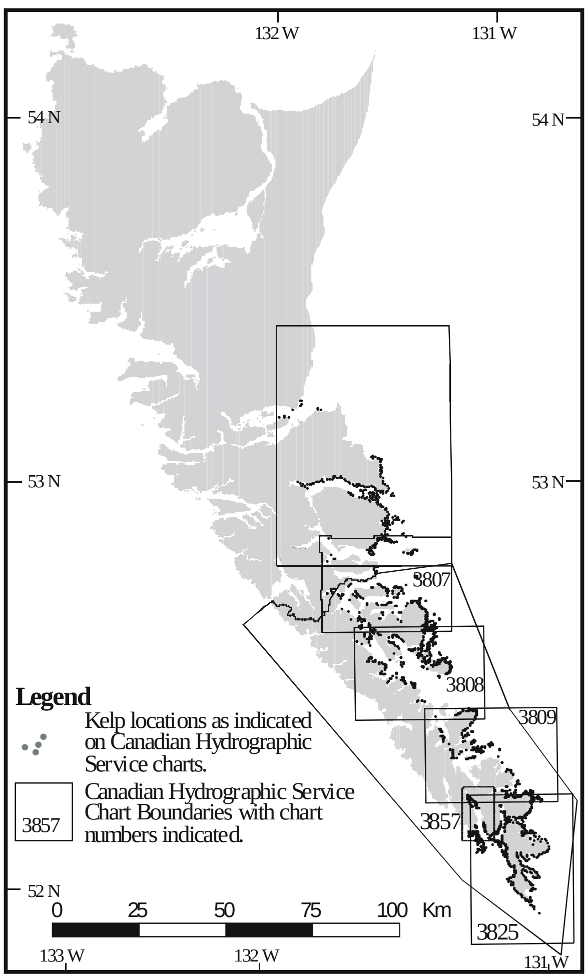

Figure 6. The distribution of kelp symbols (likely representing mostly *Macrocystis integrifolia* and *Nereocystis luetkeana*) on six Canadian Hydrographic Service nautical charts of the Moresby Island area.

Illustrated in Figure 7 is the inferred distribution of kelp in Gwaii Haanas from the Biophysical Inventory (Harper *et al.* 1994) aerial videotaping. Kelp distribution was derived largely from the videotapes; with some verification from the 107 shore observation stations illustrated in Figure 2.

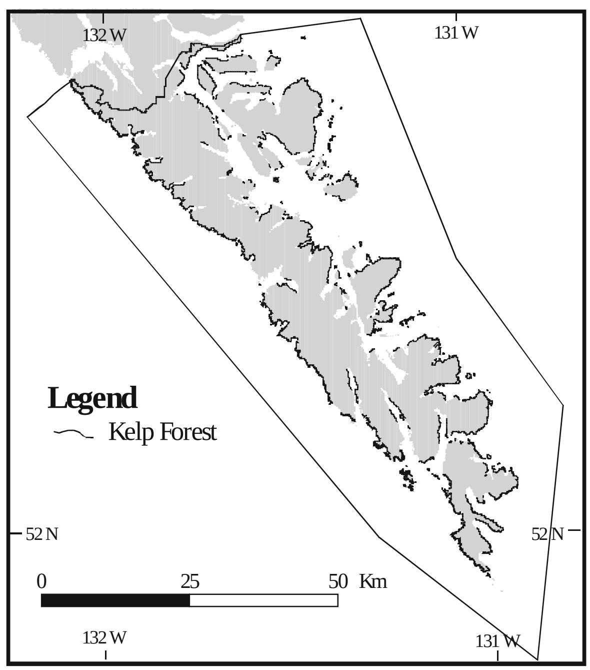

Figure 7. Inferred distribution of kelp (likely dominated by *Macrocystis integrifolia* and *Nereocystis luetkeana*) from the coastal biophysical inventory of Harper *et al.* (1994).

The largest kelp forest in southern Haida Gwaii is on Fairburn Shoals, Cumshewa Inlet mapped by Haegele and Hamey (1981) for herring spawning area surveys. Other extensive kelp forests are located along the north shore of Graham Island (Coon *et al.* 1979).

Seaweeds and seagrasses are useful indicators for assessing wave exposure criteria of rocky shores. Table 4 lists occurrence of selected plant species used to discriminate community types according to exposure, substrate and tidal zone in Gwaii Haanas by Harper *et al.*(1994). This was refined by Druehl and Hopkins (1999) in their survey of SGaang Gwaii shown in Table 5 and illustrated in Figure 8, in which both have the Harper *et al.* (1994) exposure classifications. The presence of *Mazzaella cornucopiae* and *Zostera marina* in Table 5 bracket the full exposure range within which there are at least four core species per exposure class. Some of the exposure classification differences in Figure 8, such as sites P and R, are large and likely attributable to transcription errors in the 1994 biophysical inventory. This is not surprising, given the large scale of that project. Other differences are refinements due to better information on the presence of indicator species. Druehl and Hopkins (1999) speculated that, unlike the mainland, rapid seawater mixing and less freshwater runoff from the limited land mass means that substrate, wave exposure and temperature determine kelp distribution with little impacts from salinity. This could extend the range of wave exposures at which some species may be found in Haida Gwaii as species do not experience as much salinity fluctuation.

In 1999, a preliminary seaweed survey was done in the Ellen Island region. The six permanent intertidal seaweed monitoring transect sites and the reference and aberrant *Macrocystis* sp. sites are shown in Figure 9. There is no transect site No. 3. The transects were established based, in part, on a protocol developed for Pacific Rim National Park Reserve by Druehl and Elliott (1996). The objective of the protocol was to identify communities based on kelp assemblage-shore physical attribute correlations. Monitoring the rich kelp assemblages from different shore exposure types of Gwaii Haanas over time has benefits as discussed below.

Besides the aberrant giant kelp being a noteworthy botanical anomaly, its presence is an issue of potential interest to the herring spawn-on-kelp fishery as discussed below. The northern giant kelp (*M. integrifolia*) occurs from Sitka, AK to Monterey, CA (Foster and Schiel 1985). Until recently, the southern giant kelp (*M. pyrifera*) was reported from Monterey, CA to Baja California, Mexico (Foster and Schiel 1985), but O'Clair and Lindstrom (2000) have reported it from Alaska waters based on an old Setchell and Gardiner report. The species' preference for moderate wave exposure is well known (Druehl 1978). In Gwaii Haanas, giant kelp normally occurs on more sheltered shores than bull kelp (*N. luetkeana*) and is found shoreward of bull kelp where the two coexist (e.g., at the "reference" sites in Figure 9). South of Benjamin Point on Moresby Island, however, giant kelp was found seaward of bull kelp along exposed shores (e.g., "aberrant" sites in Figure 9). The identity of this giant kelp type cannot be resolved until holdfasts, diagnostic features of *Macrocystis* spp., can be retrieved for examination. The southern giant kelp is larger (to ~45 m) and grows at deeper sites than the northern giant kelp (to ~10 m).

Table 4. Intertidal algae, seagrass and lichens, used with exposure, substrate and tidal zone, to discriminate community types from aerial photographs (from Harper *et al*. 1994).

	Bedrock/Boulder			**Bedrock/Boulder and Sand/Gravel**		**Estuary Sand/Mud**
Tidal Zone	Very Exposed (VE)	Exposed (E)	Semi-exposed (SE)	Semi-protected (SP)	Protected (P)	(SP) and (P)
Upper	*Verrucaria* spp.	*Verrucaria* spp.	*Verrucaria* spp. *Fucus gardneri*	*Verrucaria* spp. *Fucus gardneri*	*Verrucaria* spp. *Fucus gardneri*	*Fucus gardneri*
Middle	-	-	-	***Ulva/Ulvaria* spp.**	***Ulva/Ulvaria* spp.**	*Ulva/Ulvaria* spp.
Mid/Low	*Alaria nana*	Alaria nana	*Halosaccion glandiforme* ***Hedophyllum sessile*** *Codium fragile* ***Phyllospadix scouleri***	*Halosaccion glandiforme* *Codium fragile*	*Halosaccion glandiforme*	-
Lower	***Lessionopsis littoralis*** *Laminaria setchelii* *Lithothamnion* spp. (foliose coralline algal turf)	***Lessionopsis littoralis*** *Laminaria setchelii* *Lithothamnion* spp.	***Egregia menziesii*** *Laminaria setchellii* *Laminaria bongardiana* *Alaria marginata* *Lithothamnion* spp.	*Laminaria bongardiana* ***Laminaria saccharina*** *Alaria marginata* *Lithothamnion* spp.	***Laminaria saccharina***	-
Subtidal	*Nereocystis luetkeana*	*Nereocystis luetkeana*	*Nereocystis luetkeana* ***Macrocystis integrifolia*** *Agarum* spp.	*Nereocystis luetkeana* *Macrocystis integrifolia* *Agarum* spp. ***Zostera marina***	*Macrocystis integrifolia* *Agarum* spp. ***Zostera marina***	***Zostera marina***

Notes:
- bolding indicates diagnostic species used to distinguish between communities
- sand and sand/gravel (exposure classes VE to SE) excluded as they had no visible flora
- "-" means no plant used

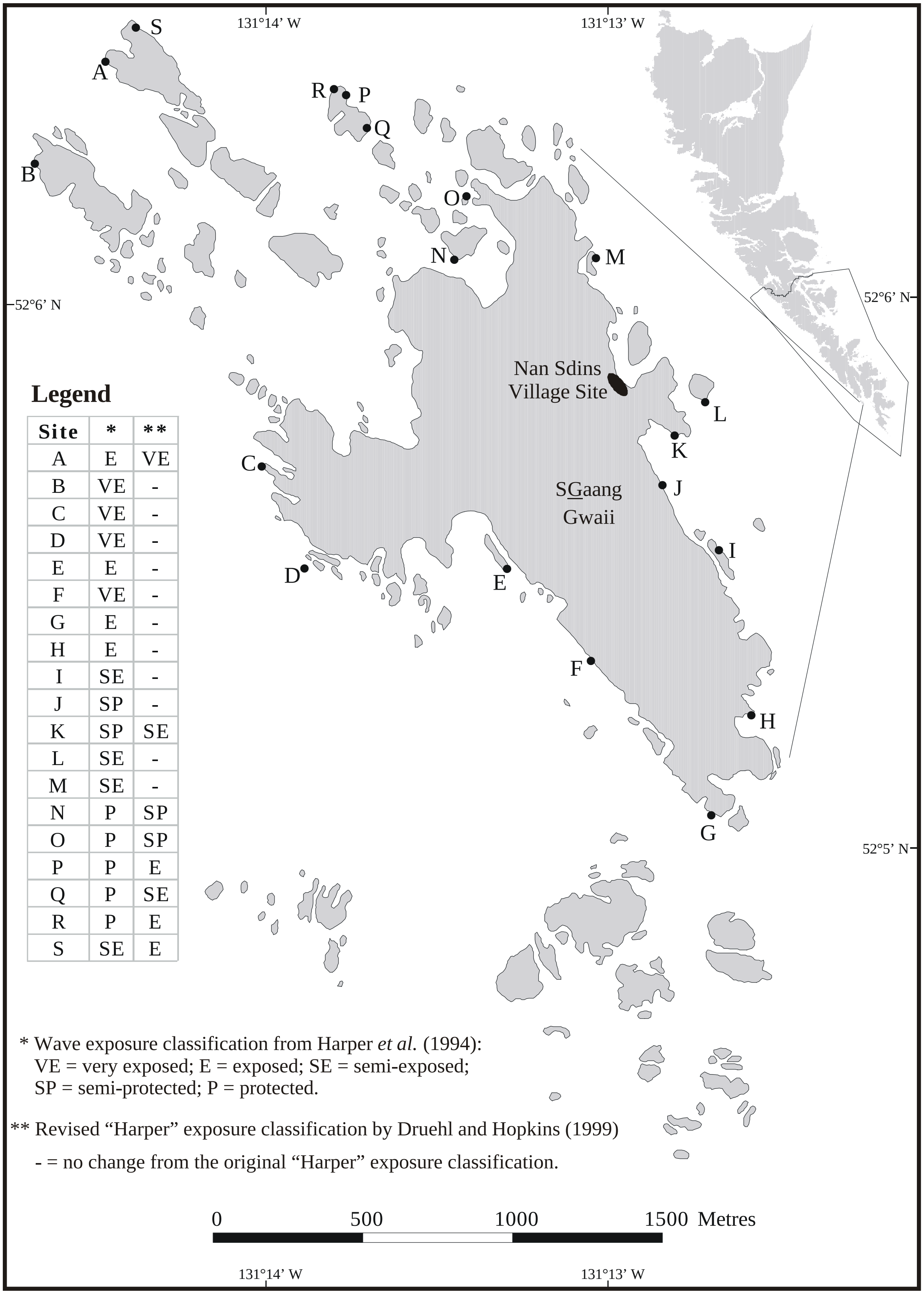

Figure 8. Locations of the 19 wave exposure assessment sites in the SGaang Gwaii archipelago surveyed in July, 1999 by Druehl and Hopkins (1999).

Table 5. The expected presence/absence of marine plant species indicating wave exposure on SGaang Gwaii.

Exposure Class*	*Mazzaella cornucopiae*	*Alaria nana*	*Lessoniopsis littoralis*	*Laminaria setchellii*	*Nereocystis luetkeana*	*Laminaria bongardiana*	*Macrocystis integrifolia*	*Fucus gardneri*	*Zostera marina*
VE	+	+	+	+	+	-	-	-	-
E	-	+	+	+	+	-	-	+/-	-
SE	-	-	+	+	+	+/-	-	+	-
SP	-	-	-	+/-	+/-	+/-	+	+	-
P	-	-	-	-	-	+/-	+/-	+	+

* Exposure classes according to Harper *et al.* (1994):
VE = very exposed / E = exposed / SE = semi-exposed / SP = semi-protected / P = protected
\+ = expected present / - = expected absent

The only invasive seaweed recorded so far in Haida Gwaii is *Sargassum muticum*. It is speculated to have been introduced into the Strait of Georgia and Puget Sound, WA in the 1930s from imported Japanese oysters. The species now ranges in the Northeast Pacific from Baja California, Mexico north to southern Southeast Alaska (O'Clair *et al.* 1996). Figure 10 illustrates the distribution of *S. muticum* in Haida Gwaii. Included are observations made on the south side of Ellen Island in July, 1999 (Druehl and Hopkins 1999) and just south of Lawn Hill (Ms. M. Stronge, Gwaii Haanas, *personal communication*).

Seagrasses

Figure 11 illustrates the distribution of eelgrass (*Z. marina*) which prefers sheltered, sedimentary shores and surfgrasses (*Phyllospadix* spp.) which tend to grow on exposed, rocky shores. Overall, there is a tendency for surfgrasses to be recorded from more exposed sites. There are anomalies that require verification such as surfgrass (not eelgrass) reported from Masset Inlet.

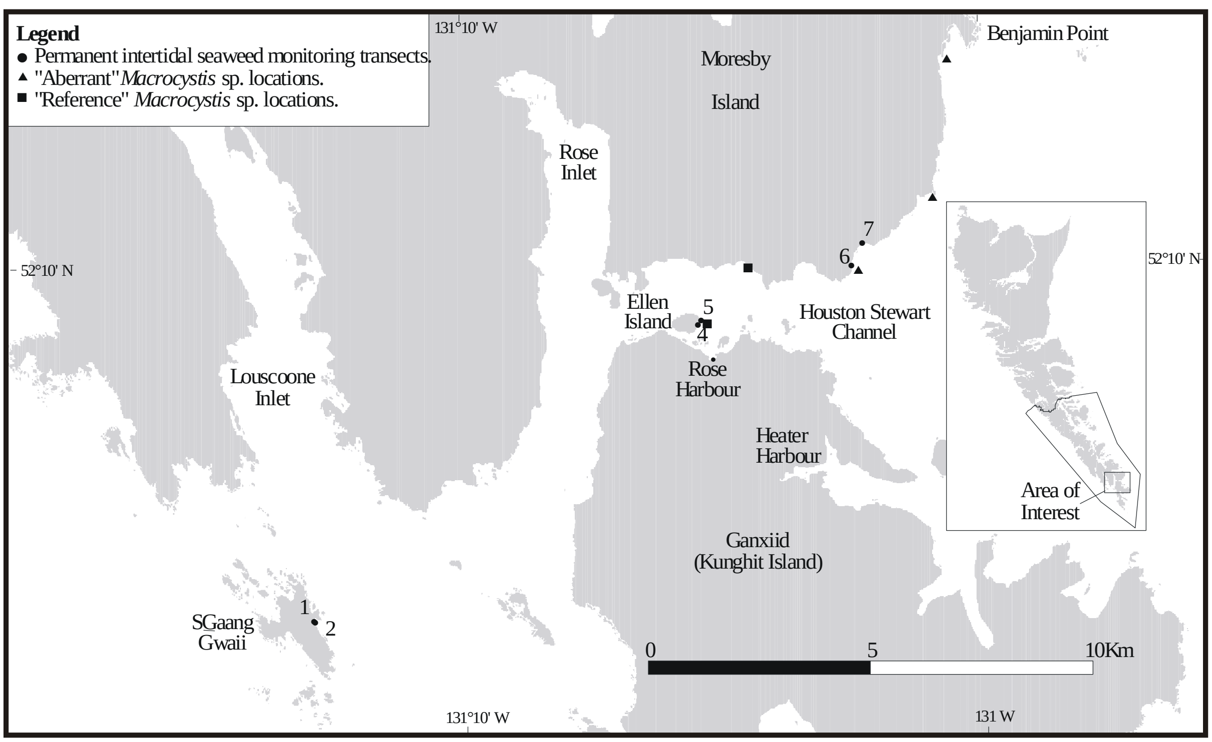

Figure 9. Locations of the six permanent intertidal seaweed monitoring transects and *Macrocystis* sp. observations made in July, 1999 by Druehl and Hopkins (1999).

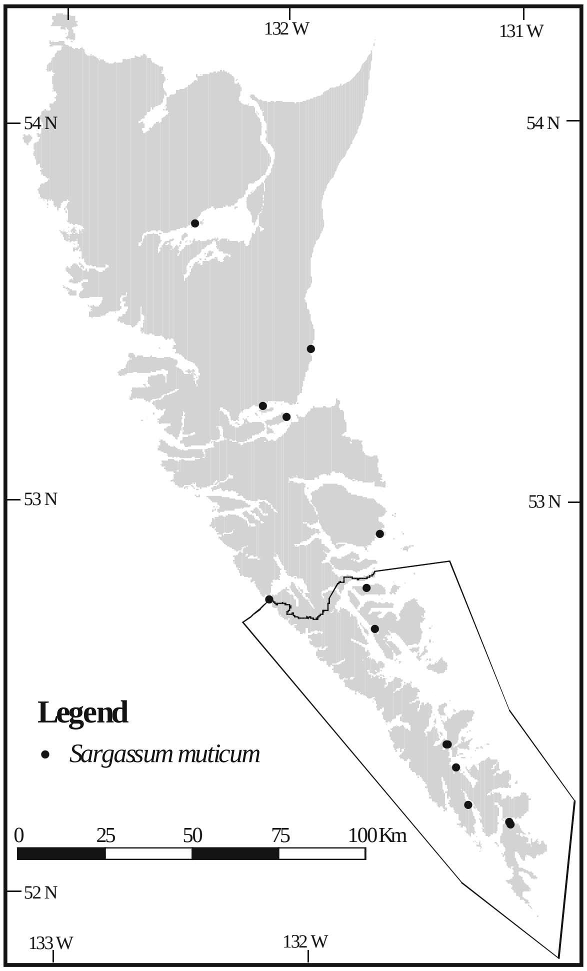

Figure 10. Distribution of *Sargassum muticum* from various marine surveys in Haida Gwaii.

Within Gwaii Haanas, 254 sites from various surveys were ordered according to their shore exposure category as defined in the biophysical inventory (Harper *et al.* 1994). Listed in Table 6 is an examination of these exposure categories of the sites at which eelgrass and surfgrass occurred. The sample size for the "very exposed" sites is small, but the "exposed" and "semi-exposed" sites show particularly well the concurrence of the shore exposure rating with the expected differing exposure preferences of each species. This reveals that the current state of the Gwaii Haanas database, with its commitment to the shore exposure classification system, reasonably reflects habitat preferences of some species.

In 1999, Gwaii Haanas' Warden Services began an intermittent task of mapping the eelgrass meadows which straddle the lower intertidal to the shallow subtidal. Illustrated in Figure 12 is the first output from this long-term project. It is likely that *Z. marina* is ubiquitous along sheltered sedimentary shores of Gwaii Haanas. On-site mapping could also provide ground-truthing for possible future remote sensing of Gwaii Haanas' nearshore resources.

Distribution maps are viewed as important for establishing seagrass baselines (Wyllie-Echeverria and Thom 1994). This is doubly important for Gwaii Haanas as eelgrass are associated with sheltered sedimentary shores

Table 6. The number (and percent) of sites at which seagrasses occurred according to exposure category at 254 sites in Gwaii Haanas.

	Shore Exposure Categories				
	Very Exposed	**Exposed**	**Semi-Exposed**	**Semi-Protected**	**Protected**
Total Sites	20	54	73	61	65
Zostera marina	2 (10%)	0 (0%)	6 (8%)	10 (16%)	26 (40%)
Phyllospadix spp.	6 (30%)	25 (46%)	31 (42%)	19 (31%)	8 (12%)

Notes:
The number of sites by exposure category according to Harper *et al.* (1994) is based on a spatial proximity analysis that tallies samples if they are within 100 m of a given coastline class. Using this methodology, it is possible for a sample to be tallied more than once because it can be within 100 m of more than one coastline class. For this reason, the 273 total for the top row is greater than the actual number of 254.

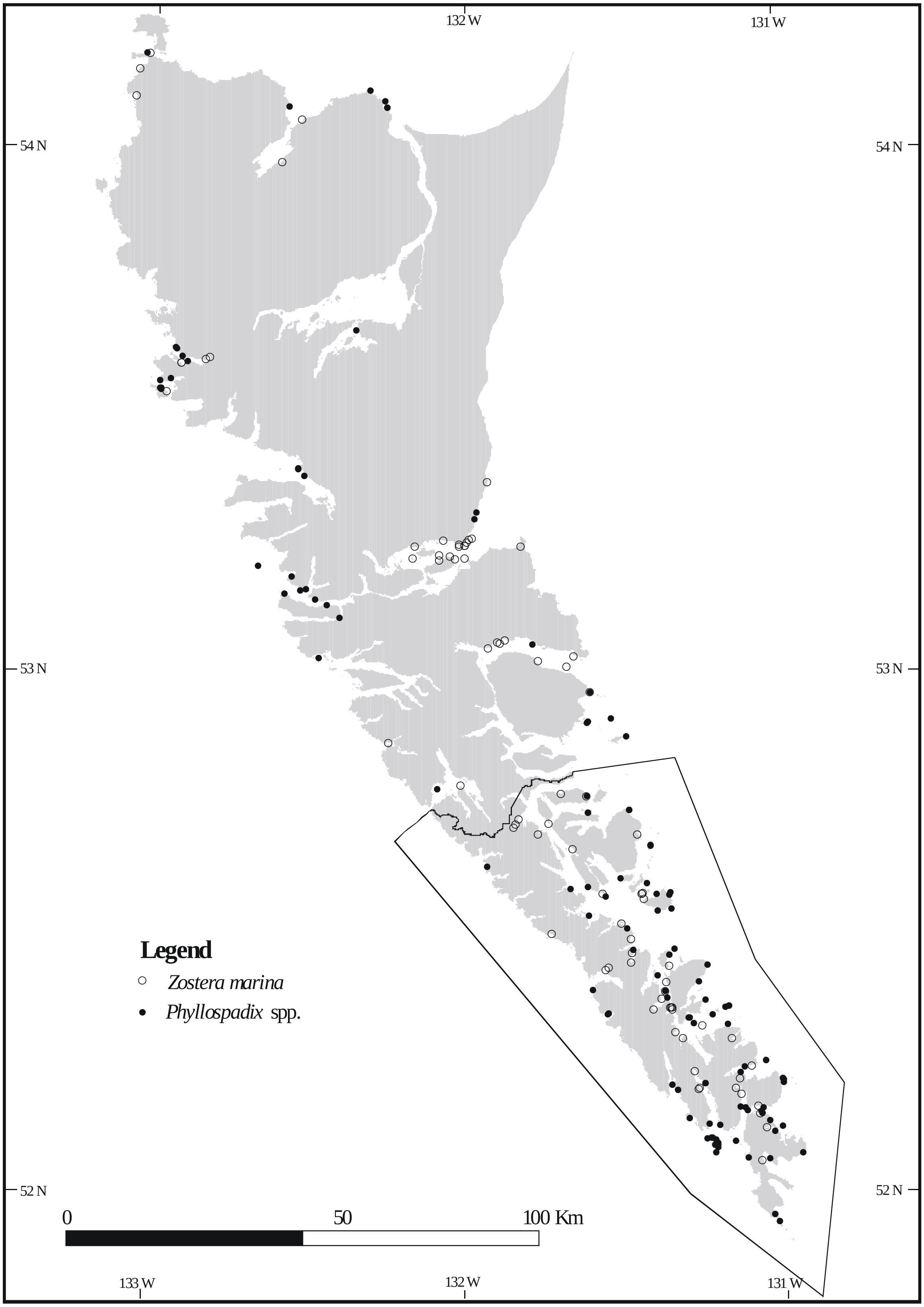

Figure 11. Distribution of eelgrass (*Zostera marina*) and surfgrasses (*Phyllospadix* spp.) from various surveys in Haida Gwaii.

which, in the case of estuaries, represent only ~6% of Gwaii Haanas' shoreline (Harper *et al*. 1994). Yet, estuaries are undoubtedly important to the juvenile salmonid production of Gwaii Haanas as well as being nurseries for other inshore fish and invertebrates.

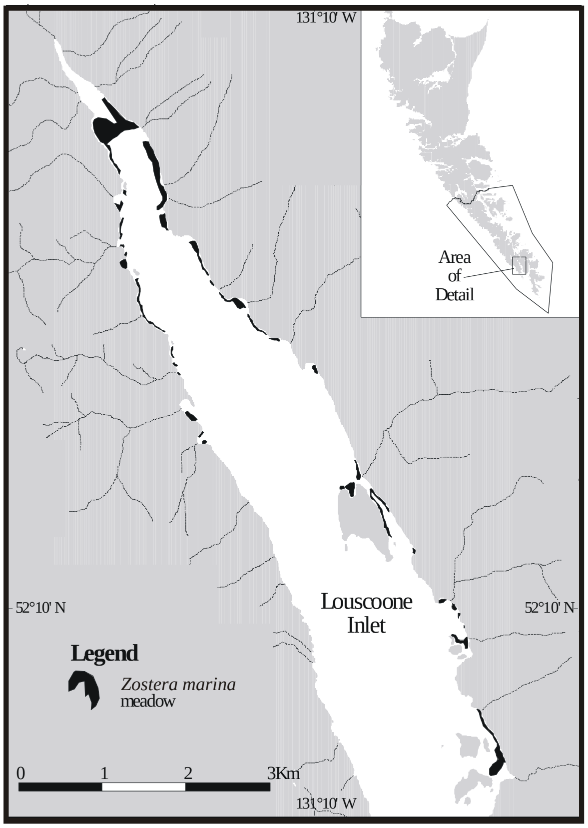

Figure 12. An example of eelgrass (*Zostera marina*) mapping in Louscoone Inlet, summer, 1999.

MARINE PLANT ISSUES IN GWAII HAANAS MANAGEMENT

"…. *the most critical part of maintaining biodiversity is maintaining the dynamic set of interactions that define what that ecosystem is and how it functions.*" (Suchanek 1994)

"*The protection of natural, self-regulating marine ecosystems is important for the maintenance of biological diversity*" Preamble: *Marine Conservation Areas Act*

Marine plants and their associated communities are immensely important to the nearshore ecosystem structure and function in Gwaii Haanas. Inventory, in isolation, is of limited interest to managers unless it is placed in a broader context. Inventory is the acknowledged first step in taking responsibility for an area's marine biodiversity (Hawkes 1992; Suchanek 1994). Maintaining biodiversity is a cornerstone of ecosystem structure and function - the general goal of ecosystem-based management (Grumbine 1994). The most stringent conservation norm has been suggested by Callicott *et al.* (1999) as being biological integrity, defined as; "… *native species populations in their historic variety and numbers naturally interacting in naturally structured biotic communities*." This includes retaining biological elements (i.e., biodiversity) and processes. Marine inventories are, therefore, linked to ecosystem-based stewardship as articulated in the proposed *Marine Conservation Areas Act*.

Kelp forests and seagrass meadows provide the following ecosystem functions:

- inputs detritus into coastal food webs (Phillips 1984; Duggins *et al.* 1989);

- yields a "*trophic subsidy*" of plant biomass from the subtidal to intertidal grazers (Bustamante *et al.* 1995);

- provides energy from beached drift algal and seagrass wrack (Polis and Hurd 1996);

- moderates nearshore water movement (Phillips 1984; Lobban and Harrison 1997);

• forms a biogenic nearshore habitat architecture of nurseries of juvenile fish and invertebrates (Phillips 1984; Foster and Schiel 1985);

• creates biogenic habitat for adults of many species, including those of commercial and cultural value such as northern abalone (*Haliotis kamtschatkana*) (Sloan and Breen 1989) and rockfish (*Sebastes* spp.)(Carr 1994); and

• underpins the basis for traditional and commercial Pacific herring spawn-on-kelp fisheries.

Concerning marine stewardship, the importance of marine plants is manifested in the following nearshore Gwaii Haanas marine ecosystem issues that include:

• understanding the role of plants in ecosystem structure and function, such as the role of seagrass meadows in the land-sea linkages in our estuaries;

• monitoring environmental threats to, and well-being of, ecosystems;

• assessing impacts of repatriated sea otters (*Enhydra lutris*) on nearshore kelp forest ecosystems;

• evaluating the role of red sea urchin (*Strongylocentrotus franciscanus*) grazing (herbivory) on kelp forest ecosystems;

• cooperating in the Department of Fisheries and Oceans' northern abalone stock rebuilding;

• maintaining healthy kelp resources in aid of Pacific herring SOK harvest; and

• assisting with backcountry monitoring of visitor impacts to intertidal habitats.

<u>Nearshore Marine Environmental Monitoring</u>

"*Without reliable data about rates of change within any habitat, there is no possibility that we can predict the sorts of changes that are likely to be associated with human interferences and developments.*" (Underwood and Kennelly 1990)

"*Long-term ecological monitoring is the first step in learning how to assess ecosystem health.*" (Davis 1993)

Monitoring is becoming a fundamental component of Parks Canada's mandate of sustainable management and use without compromising the structure and function of ecosystems (Woodley 1993). Davis (1993) summarized the utility of the U.S. National Park Service's marine monitoring commitment as follows:

• indicating ecosystem health;

• defining limits of normal variation;

• identifying abnormal environmental conditions; and

• verifying agents of abnormal change.

The process of monitoring development should be experimental, begin with a conceptual model of the ecosystem and be focused on the population dynamics of selected species relative to physio-chemical environmental variables (Davis 1993).

At a workshop assessing ecological status hosted by Pacific Rim National Park Reserve, both kelp and seagrass were selected as potential marine environmental indicators of merit on the British Columbia coast (Rowe *et al.* 1999). Marine plants are effective sentinels for monitoring the well-being of inshore marine ecosystems and reflecting ocean climate changes. Monitoring can be done using both intertidal species and shallow subtidal species within the photic zone (~35 m depth limit of light penetration). Seaweed in the upper intertidal, kelp and seagrass in the lower intertidal and shallow subtidal, and water surface kelp forest canopy in the subtidal are all possible targets. Monitoring suites of plant species with known environmental tolerances can permit establishing potential consequences of environmental change (Druehl 1999 b). Both kelp forests and seagrass meadows in intertidal and shallow subtidal waters are amenable to surveillance by remote sensing (Deysher 1993; Guillaumont *et al.* 1993; Israel and Fyfe 1996).

Without seasonal and interannual data on distribution and abundance of algae, no comparison between locations is possible (Underwood and Kennelly 1990). These authors proposed the following two stages towards understanding intertidal and subtidal rocky shore plant communities:

- quantitative studies to describe the patterns of distribution and abundance of algae with appropriate spatial and temporal replication to estimate variances among and within shores and among years and seasons; and

- experimental analyses of the processes causing the observed patterns.

The latter is the evolutionary end-point of such work and has not yet been achieved anywhere in temperate coastal systems worldwide.

The positive attributes of seaweed for monitoring are defined by Druehl (1999 b) from the Pacific Rim National Park Reserve workshop as follows:

- stationary plants must integrate environmental effects or perish;

- have variable age structures (ephemeral to perennial) spanning duration of changes;

- occupy diverse nearshore habitats (intertidal/subtidal) and wave exposure regimes;

- possess variable physiological tolerances;

- convenient – abundant, large size, species rich, easy to locate and identify; and

- high degree of morphological plasticity reflecting environment conditions such as wave exposure.

Intertidal Seaweed and Subtidal Kelp Forest

"*…. an extensive monitoring program for inshore macroalgal habitats is a valuable tool for evaluating effects of environmental change*." (Milligan *et al.* 1999)

" *…. analyzing community patterns for marine algae via groupings based on functional aspects of their morphology and anatomy provides substantial insight into community structure*." (Steneck and Dethier 1994)

" *…. no matter how well one understands kelp populations, any current program will fail to discern the ghosts of missing animals.*" (Dayton *et al.* 1998)

The National Park Service in California has been the leader in long-term intertidal monitoring in Northeast Pacific National Parks. Monitoring for general intertidal ecosystem status began in Channel Islands National Park in 1982 (Richards and Davis 1988) and the first long-term visitor impact assessment was at Cabrillo National Monument in 1990 (Engle and Davis 1996).

A summary of plant components of some intertidal marine monitoring initiatives from Alaska to California is provided in Table 7. Plants clearly play a prominent role in intertidal monitoring. Note how recent these initiatives are. This is a time of growth and widespread acceptance of the need for long-term intertidal monitoring in National Parks.

Intertidal monitoring is usually focused on discrete bands characterized by dominant species, among which bands of vegetation are prominent. For example, Richards and Davis (1988) monitored their upper to mid intertidal rocky shores including vegetated bands described in Table 7. In British Columbia, "bio-band" codes based, in part, on conspicuous bands of certain plant types are used in zonation mapping schemes for marine shores (Searing and Frith 1995) and estuaries (Howes *et al.* 1999). A detailed review of rocky intertidal marine monitoring is in draft form for the California Sea Grant Program (Murray *et al. in press*).

In Barkley Sound, off the west coast of Vancouver Island, Milligan *et al.* (1999) used intertidal kelp populations of *Hedophyllum sessile* to document effects of the 1997-1998 El Niño. They drew upon the area's only long-term (1991-1998) kelp data to evaluate the negative (poor growth due to depressed nutrient levels) impacts of that warm-water event. Among the variables measured were percent cover, adult-juvenile density, plant reproductive status, biomass and cover of understory species.

Of all rocky nearshore subtidal habitats in the Northeast Pacific, kelp forests dominate ecosystem architecture and are the most investigated. There are sufficient time series data from which some ecosystem generalizations can be made. Kelp forest aerial surveillance began off the southern California coast in the 1930s with regular surveys by the commercial kelp harvest sector since the 1950s (Deysher 1993). Regular aerial scientific broad-scale surveys began in 1967 (North *et al.* 1993) and quarterly *in situ* surveys by divers at Point Loma, near San Diego began in 1983 (Tegner *et al.* 1997). Kelp forest monitoring has also been undertaken at Channel Islands National Park annually since 1981 (Davis 1988; Davis *et al.* 1994; Davis *et al.* 1996; Davis *et al.* 1997). Also in the area, SPOT High Resolution Visible (HRV) digital multispectral (XS) satellite images were evaluated for their use in mapping and quantifying giant kelp forest (Augenstein *et al.* 1991). The authors concluded that SPOT HRV-XS digital data yielded kelp survey maps sufficient for resource mapping and monitoring and that imagery closely corresponded to distributions derived from colour infrared aerial photographs. No other region of the Northeast Pacific has a comparable long-term kelp monitoring history as southern California.

Detecting kelp ecosystem trends depends upon two things (Dayton *et al.* 1998):

- a good description of the benchmark (i.e., a sound baseline/inventory); and
- an ability to establish distinctions between natural and human changes.

There is doubt, however, as to what kelp

Table 7. Summary of selected intertidal monitoring attributes involving marine plants in National Parks and Monuments from Alaska to California.

Park (Proponent)	Start Date	Frequency* (mo/season)	Notes on the protocols and plant species	Reference
Glacier Bay National Park and Preserve (NPS/USGS[1])	1997	Annual (June)	Uses 200 m long shore segments for coarse-grained transect/quadrat surveys and a subset of these for fine-grained transect/quadrat surveys; lichen *Verrucaria* spp. used to demarcate landward side of segments and *Fucus gardneri* the only plant sampled (% cover, frond length and reproductive status) but mentioned seven other genera as potential monitoring candidates	Irvine (1998)
Pacific Rim National Park Reserve (Parks Canada)	1997	Annual (June)	Modified the protocols of the DFO[2] *Shorekeepers' Manual*; 1 m^2 mid intertidal quadrats are used in different rocky habitats (tidepool/ bench/surge channel/vertical face) examined for all conspicuous plant and animal species, number and % cover by volunteer participants	Holmes (1999)
Olympic National Park (U.S. National Park Service)	1988	Biannually[3] (summer)	Method revised in 1997 after sampling experiments in 1996; quadrats (20X20 cm) sampled along 20 m transects within 3 recommended shore levels down to the mid rocky intertidal; plants represent ~50% of "good " taxa for monitoring at all levels	Dethier (1997)
Channel Islands National Park (U.S. National Park Service)	1982[4]	Annual (January)	Permanent photoquadrats (50X75 cm) recording % cover: within an uppermost band of red turf algae (*Endocladia muricata*), a band of fucoid rockweed (*Pelvetia fastidata*) and *Hesperophycus harveyanus*, then a band of red algae (*Gigartina* sp. and *Gelidium* sp.) just landward of mussels	Richards & Davis (1988) Davis *et al.* (1994)
Cabrillo National Monument (U.S. National Park Service)	1990	Semi-annual[5] (spring/fall)	Permanent photoquadrats (50X75 cm) recording % cover; fucoid rockweed (*Pelvetia fastidata*) / 10 m transect counts; *Egregia menziesii*, *Sargassum muticum*, *Phyllospadix* spp., *Corallina* spp.	Engle & Davis (1996)

***** actual or recommended

1 Two U.S. Department of Interior agencies (National Park Service and U.S. Geological Survey's Alaska Biological Science Center), developed this method for a total of three parks, including also: Katmai National Park and Preserve and Wrangell-St. Elias National Park and Preserve

2 Department of Fisheries and Oceans developed its *Shorekeepers' Manual* (Jamieson *et al.* 1999)

3 After 1993 there was even-year and odd-year sampling divided among the 22 rocky shore locations

4 Anacapa Is. in 1982, expanded to 15 locations among the islands by 1988

5 Three sites at one location

forest monitoring can achieve given the poor historical baseline from undisturbed kelp forests and the inadequate understanding of human (e.g., harvest and pollution) impacts on kelp forest ecosystems (Dayton *et al.* 1998). From 25 years of kelp forest observations in southern California, Dayton *et al.* (1998) concluded that the definition of a meaningful benchmark was "*impossible*" because:

• many large kelp forest predators have been locally extirpated for decades;

• kelp are very susceptible to irregular, large-scale, low-frequency oceanographic phenomena such as warm water, low-nutrient El Niño events (Tegner *et al.* 1997) and episodic severe storms (North *et al.* 1993); and

• fisheries still have major, but poorly understood, impacts on kelp forest ecosystems.

In the wilderness area comprising Gwaii Haanas, fishing impacts on kelp forests are likely to be much less than those in southern California. With the significant exception of sea otters, the suite of large kelp-associated predators in Gwaii Haanas is relatively intact. Nonetheless, we cannot differentiate between natural and human impacts on local kelp forest ecosystems. We know nothing about how ocean climate affects local kelp forests, nor do we know about indirect commercial harvesting impacts.

On the one hand, kelp are useful for monitoring physiochemical attributes of ocean climate such as temperature and nutrients (Tegner *et al.* 1997; Druehl 1999 a,b). Moreover, examining algae yields insight into environmental conditions because, when observed at the functional group level, they are temporally stable and predictable (Steneck and Dethier 1994). This is especially applicable compared to studying algae at the species level. On the other hand, the generalization by Ward *et al.* (1999) that marine plant assemblages are poor surrogates for overall species richness (i.e., biodiversity) may apply to kelp forests as an assemblage - but perhaps not as a habitat. Firstly, because of the patchiness of kelp forests that includes species richness of non-vegetated habitats. Secondly, because of the suggestion by Dayton *et al.* (1998) that kelp forest communities can be loosely integrated with weak mutual dependencies, e.g., large predatory fish can be removed with little effect to the rest of the ecosystem. Perhaps the solution is functional group (total kelp forest) focus on both canopy and understory floras and attendant faunas as changing environmental conditions favor different kelp forest components.

In summary, we do not yet know enough about overall kelp forest status to reflect nearshore ecosystem structure and function in Gwaii Haanas. Kelp forests have attributes worth investigating, but a long-term commitment would be needed to understand natural impacts such as those induced by ocean climate (temperature, nutrients and waves) and a better knowledge of human impacts dominated by commercial fishing.

Reports are just now emerging on responses of seaweed populations in "no-take" reserves. Edgar and Barrett (1999) recounted from temperate Tasmanian reefs that seaweed species richness increased and individual species dominance changed in protected versus reference areas.

Seagrass Meadows

Seagrass monitoring straddles the mid intertidal through to the shallow subtidal. Seagrass meadows are amenable to remote surveillance (aerial and satellite) and to ground-truthing by various forms of *in situ* diver-related techniques (Kirkman 1990). A conservation strategy suggested for seagrass meadows stressed protection of discrete meadows within a larger area (McNeill and Fairweather 1993). The greater range of habitat types, locations and aspects associated with different small meadows sheltered more biodiversity than a single large meadow. As with kelp forests, connections among habitats and knowledge of recruitment processes should be well understood before protected site selection and boundary delimitation.

In British Columbia, there is no regular seagrass monitoring (Colin Levings, *personal communication*). There is one research series of aerial infra red and colour photography of seagrass meadows nearby Roberts Bank port on the Fraser River delta system (Tarbotton and Harrison 1996). Elsewhere in the northwest U.S. there are no long-term seagrass monitoring sites (Ron Thom, *personal communication*). Remote sensing of seagrass meadows in Puget Sound was abandoned by the Washington State Department of Natural Resources because poor water clarity obscured their deeper, seaward portions (Ron Thom, *personal communication*). Washington and Oregon are collaborating in the Pacific Northwest Coastal Ecosystem Research Study (PNCERS) to monitor, among other things, seagrass meadows for up to four years in Willapa Bay (WA) and Coos Bay (OR) starting in 1998.

Remote sensing using, for example, multispectral SPOT XS imagery to monitor well-being and distribution of seagrasses is well known (Kirkman 1990; Israel and Fyfe 1996). A variety of intertidal and shallow subtidal cover types can be differentiated. Remote sensing coupled with GIS is particularly efficient for data collection and analysis, and provides good potential for monitoring applications. The water clarity around Gwaii Haanas is amenable to remote sensing but the weather is often overcast. The database being developed by the Warden Services could provide a baseline for comparison with remote imagery.

Global threats to seagrasses come from human modification of watersheds decreasing downstream coastal water quality, other coastal pollution and coastal development (Fong *et al.* 1997). For Gwaii Haanas, the undisturbed watersheds and undeveloped wilderness shoreline mean that seagrasses are little threatened by human activities. Local seagrass meadows represent, therefore, relatively undisturbed ecosystems.

Marine Lichens

Outside of California, no marine lichen species has been used for environmental monitoring in the Northeast Pacific. Lichens are, however, well established as air pollution monitors.

Coastal marine lichens have been used as environmental air pollution monitors of marine aerosols. In southern California, *Ramalina menziesii*, which also occurs on coastal trees in Haida Gwaii (I. Brodo, *personal communication*), accumulates metals (Boonpragob and Nash 1990). Marine lichens (*Ramalina* spp.) have also been used in monitoring marine aerosol pollution in Europe (Roux et Sigoillot 1987).

In the context of Gwaii Haanas' wilderness setting, lichens could be sentinels of distant, Pacific Rim atmospheric pollution. Once the marine lichen flora of Gwaii Haanas is better known, perhaps candidate species could be selected for monitoring regional pollution of marine aerosols.

Kelp Forest Ecosystem Issues

Sea Otters and Haida Gwaii History

The extirpated sea otter casts a broad shadow over Haida Gwaii – biologically and culturally. In 1778, Captain Cook took sea otter pelts from Nootka Sound and the next year traded them in Canton at ~1800% profit (Gibson 1992). This precipitated a scramble for sea otter pelts that was strongly felt in the early post-contact times of the 1790s in Haida Gwaii. For example, British traders acquired thousands of sea otter pelts for the China trade from Chief Cuneah of Kiusta village on the northwest tip of Graham Island (Robinson 1996). Desire for sea otter fur intensified early European contact, brought great material wealth (e.g., iron tools) and social change to the Haida. Contact from trade eventually brought devastating diseases as well, such as the smallpox that ravaged the Haida in the 1860s. The sea otter trade rapidly lost vigor and by 1825 potatoes became the major commodity for the depressed Haida trading economy (Acheson 1995). Despite the decline in the sea otter trade, European trading presence for other commodities remained entrenched coast-wide.

The sea otter and its prey the red sea urchin are on the family crest of Gwaii Haanas. The relationships between these species and their kelp forest habitat are vital socio-cultural and scientific issues for Gwaii Haanas. Human reintroduction of sea otters to establish nearshore ecosystems reflecting pre-contact status and subsequent impacts to resident red sea urchin and northern abalone populations will be important among the many long-term stewardship issues to be resolved for Gwaii Haanas.

Kelp Deforestation, Sea Otter and Red Sea Urchin

"Local extinction of sea otters has cascading effects of broad influence in kelp forest ecosystems." (Estes *et al.* 1989)

"The concept's (of keystone species) *potential significance to conservation biologists is that it designates species that exert influences on the associated assemblage, often including numerous indirect effects, out of proportion to the keystone's abundance or biomass."* (Paine 1995)

Among kelp forests along rocky, nearshore British Columbia and Alaskan coasts, sea otters have a keystone community role (Breen *et al.* 1982; Estes *et al.* 1989; Watson 1993; Estes and Duggins 1995). There is some disagreement, however, on their keystone status. In California, Foster (1990) suggested that sea otter importance was overrated because, outside of sea otter range, red sea urchins and kelp abundances were highly variable with ~20% of rocky coast deforested. Estes and Duggins (1995) agree with this area estimation, but counter that such deforested habitat patchiness is typical throughout the Northeast Pacific where sea otters are a regional "keystone" predator.

The extirpation of sea otters from Haida Gwaii at some time before 1929 (Watson *et al.* 1997) likely led to an explosion of their herbivorous red sea urchin prey and attendant heavy grazing on kelp often causing kelp deforestation and the formation of sea urchin-dominated “barrens”. Hawkes (1994 b) speculated that lower seaweed biomass and diversity has occurred coast-wide in British Columbia due to sea otter extirpation from their historical range. The factors that determine red sea urchin abundance in Haida Gwaii are complex. For example, in the absence of sea otters off the northern Graham Island coast, densities of red sea urchins and kelp vary widely and red sea urchins do not dominate the presence of kelp at all localities (Jamieson and Campbell 1995). Jamieson and Campbell suggested that depth and shelter from wave action are also important factors in these species' distributions.

Sea urchin barrens occur as a light-coloured band (due to encrusting coralline algae on rocks denuded of fleshy algae) seaward of the linear fringe of kelp forests along much of Gwaii Haanas' rocky shores. Whereas ~20% of Northeast Pacific kelp forest areas not occupied by sea otters are denuded of kelp, the amount of such habitat is appreciably greater in Gwaii Haanas. Approximately 50% of rocky coastline of Gwaii Haanas is characterized by the presence of kelp forest (Figures 6 and 7), half of that also has urchin barrens immediately to seaward (Harper *et al.* 1994). Therefore, the return of sea otters could be expected to have a significant effect on the expansion of kelp forest as the red sea urchin grazers are consumed by sea otters. This would be rapid as sea otters expand at a rate of ~20% annually when reoccupying new areas within their historical range (Watson *et al.* 1997; Woodby *et al.* 2000). The ecological effects of greatly expanded kelp forests in Haida Gwaii would mean much more structured nearshore adult and nursery habitat with attendant population increases, more detritus into nearshore food webs and more drift algal wrack on the beaches.

Another potentially important species to kelp forest ecosystems in the North Pacific worthy of mention is Steller's sea cow (*Hydrodamalis gigas*). Approximately 20,000 years ago, this large (~10 m body length) highly specialized, non-diving kelp grazer lived in herds throughout the North Pacific (Domning 1972). The species was discovered in its last refuge, the Commander (Komandorskiye) Islands in the Northwest Pacific, and was extinct by 1768. The speculation is that maritime aboriginal hunters extirpated Steller's sea cow from most of its range by the time it was scientifically described from Bering's Russian expedition in 1741 (Estes *et al.* 1989).

There is much speculation concerning the ecological relationships between kelp forests, sea otters and Steller's sea cow. Estes and Steinberg (1988) suggested that kelp evolved in a North Pacific environment in which kelp herbivory was at low intensity due to sea otter predation on sea urchins. Domning (1989) disagreed, suggesting that sea cow herds likely placed intense grazing pressure on kelp. Pitcher (1998) speculated on a potential keystone role of Steller's sea cow in nearshore North Pacific habitats within the last few millennia. Anderson (1995) theorized that sea cows may have been *“precariously balanced on sea otter carnivory”* by evolving as specialized surface-feeders of preferred kelp species maintained by sea otter predation on sea urchins.

One could speculate that kelp forests of Haida Gwaii may have developed through the influences of two important mammal species, sea otters and Steller's sea cow. The reintroduction of sea otters may not, therefore, yield a complete kelp forest ecosystem for the archipelago if sea cows were extirpated some millennia previously.

Estes *et al.* (1998) have shown that adding an apex predator (the killer whale *Orcinus orca*) to a kelp forest ecosystem under top-down control from sea otters in the central Aleutian archipelago had predictable effects on plant populations of intense herbivory by red sea urchins released from predation. Effects of commercial fishing and climate change likely decreased offshore forage fish resources that, in turn, decreased offshore pinniped prey populations of killer whales. This caused switching by killer whales to predate on inshore sea otters and attendant inshore ecosystem changes in keeping with the sea otters' keystone role. This is a reminder of ecosystem linkages by which offshore events can induce significant inshore changes.

Kelp Forest-associated Fisheries

"*Unfortunately, although populations of numerous potentially important species have been recently reduced in kelp forest communities, usually little or nothing is known of the ecological consequences of these reductions*." (Estes *et al.* 1989)

Important commercial kelp-associated species or groups in Gwaii Haanas include sea urchins, abalone and rockfish. The issue of indirect fisheries impacts on kelp forest ecosystems continues to vex managers. Knowledge of changing species interactions and succession patterns under various harvest regimes in kelp forests is poor (Dewees and Davies 1992). Relevant to Gwaii Haanas, for example, is how does red sea urchin harvest effect kelp and northern abalone recruitment?

The close association of kelp forests to red sea urchins and northern abalone introduces another significant future management question - harvest refugia. Both red sea urchins and northern abalone are broadcast spawners for whom fertilization efficiency declines with adult densities. Distribution into clumps of appropriate size and density is critical to the design of the protection regime for sea urchins and abalone (Quinn *et al.* 1993; Shepherd and Brown 1993). The idea is that abalone stocks, for example, are composed of local populations linked by larval dispersal into metapopulations (Shepherd and Brown 1993). Sizes of refugia depend on the dispersal ability of target species. Which areas are "*sources*" [contribute disproportionately large numbers of recruits] and which are "*sinks*" [receive recruits but contribute little] of recruits becomes critical marine conservation management information (Roberts 1998). Knowledge of the association of these species with Gwaii Haanas' kelp forests will be an important long-term management issue.

Kelp forest-associated species also comprise important political and cultural values. For example, northern abalone (this region's only abalone species) has been closed to all forms of harvest since 1990 with no relief in sight due to chronically low stocks (Campbell 2000). This has had attendant negative impacts to Haida culture (Richardson and Green 1989) and has, along with the SOK industry, created political momentum to address kelp-associated resources. Further, in April, 1999 the northern abalone became the first Canadian marine invertebrate to be designated by COSEWIC (Committee on the Status of Endangered Wildlife in Canada) as "**threatened**" [i.e., "*likely to become endangered if limiting factors are not* *reversed*"]. When Environment Canada's proposed endangered species legislation becomes law, this could intensify emphasis on abalone conservation Province-wide.

The removal of sea otters has similar effects as commercial harvest of red sea urchins; the well known "trophic cascade" of kelp reforestation after release from sea urchin grazing pressure (Sala *et al.* 1998). The intense predation effects of sea otters on species of commercial invertebrates in the Northeast Pacific including British Columbia are well known (Watson and Smith 1996). Watson and Smith speculated that the extirpation of sea otters may have allowed invertebrate stocks to accumulate at unnaturally high levels. However, multispecies relationships within kelp forest ecosystems remain poorly understood (Estes *et al.* 1989; Dewees and Davies 1992).

In Gwaii Haanas, one could reasonably expect from sea otter reestablishment dramatic decreases in red sea urchin and red sea cucumber (*Parastichopus californicus*) populations and reduction of northern abalone to low numbers of cryptic, crevice-dwellers (Sloan and Breen 1989). In the north and east Graham Island areas, there could be declines in Dungeness crab (*Cancer magister*) stocks as well. The issue of sea otter-commercial invertebrate species interactions and attendant economic impacts warrant careful consideration as sea otters are likely to return to Gwaii Haanas naturally (passively) within decades or sooner if repatriated by humans.

Active repatriation of sea otters could be a future sociopolitical issue of importance for Gwaii Haanas. Allowance for marine ecosystem restoration is established in Parks Canada policy. In the marine component of the guiding principles and operational policies under section 3.1 *Ecosystem Management* (Parks Canada 1994), the following two subsections are relevant:

- subsection 3.1.2 – "*Where marine ecosystems or components thereof have been seriously degraded, Parks Canada will initiate restoration programs in cooperation with others*"; and

- subsection 3.1.4 – "*Extirpated species that are native to the marine conservation area may be reintroduced after research has shown that reintroduction is likely to succeed and that its probable effects are acceptable within the conservation area and the surrounding region*."

Pacific Herring Spawn-on-Kelp (SOK) Fisheries and Kelp Mariculture

In part because kelp from the southeast coast of Haida Gwaii is considered to be of superior quality, this is where the first commercial (by experimental permit) SOK fishery was initiated in 1971, with a second experimental permit issued in 1974 (Shields *et al.* 1985). Full commercial production began in 1975 (13 licences) with rapid expansion, including 11 licences from Haida Gwaii, by 1978. Southeast Haida Gwaii was also a location of early development of methods for estimating egg deposition as the basis for herring stock assessment (Haegele and Schweigert 1985). When available, giant kelp was the herrings' substrate of choice as revealed from SCUBA surveys.

The fishery is based on kelp being deployed in impoundments for deposition of eggs from gravid herring that have been seined, transported to the impoundment and which will later be released after spawning. Mainland harvesters remove kelp mostly during February-March from Haida Gwaii.

This is done along with the current nine **J**-licence holders (five of them Haida) permitted to impound herring in Haida Gwaii. There were applications to harvest 39 wet tonnes from Haida Gwaii (just north of Skidegate [Lawn Hill] to Cape St. James) in support of the 1999 SOK fishery (Druehl 1999 a). Access to the high quality local kelp forests by off-island **J**-licence holders is a contentious issue.

From Gwaii Hannas' view, the major issue is understanding the nearshore ecosystem impacts of the sanctioned kelp harvest. Although the scale of harvesting is limited, as a matter of management principle, such understanding is warranted for the long-term well-being of Gwaii Haanas. Moreover, the return of sea otters would likely be accompanied by appreciable kelp forest expansion as kelp are released from grazing pressure due to sea otter predation on the herbivorous red sea urchins discussed in the above section. Such expansion could be followed by SOK industry requests to increase kelp harvest for their impoundments.

An issue requiring verification is the possible discovery of aberrant giant kelp (perhaps *Macrocystis pyrifera*) in small patches along the southeast coast of Moresby Island south of Benjamin Point (Druehl and Hopkins 1999). The presence of *M. pyrifera* in Gwaii Haanas could have implications for the SOK industry and is a most interesting biogeographic question in its own right.

The proposed *Marine Conservation Areas Act* allows for the possibility of mariculture in Marine Conservation Areas. Given that Gwaii Haanas is a prime collection area of wild kelp and the need for quality giant kelp for the SOK industry, there clearly is a potential demand for a more reliable source of kelp through local culture (Druehl 1999 a). Kelp culture is more environment-friendly compared, for example, to salmonid culture. There are no concerns about escapement, disease introduction, organic enrichment from feed and feces or introduced chemicals (e.g., antibiotics). Kelp farms require simple floating frames and would appear very similar in size and shape to the **k'aaw** pens that currently exist in Gwaii Haanas. Peak farm activities would be in March and April – well before the main visitor season starting in June. Key issues would likely be safety to navigation, visual impact of farms on wilderness settings and shading effects of farms on the underlying communities.

<u>Visitor Impacts – Trampling Intertidal Seaweeds</u>

This is the field of "*recreation ecology*" *sensu* Liddle (1991), that began with studies of trampling of terrestrial plants in parks (e.g., Cole and Bayfield 1993) and has since expanded to marine studies on corals and intertidal rocky shores.

Gwaii Haanas had ~ 1,600 visitors comprising ~10,000-12,000 visitor-day/nights in 1999, which is among the largest "*backcountry*" (wilderness) visitations in the Parks Canada system. Virtually all visitor impacts on Gwaii Haanas are coastal due to small boat access such as kayaks in the intertidal and the immediate back-beach for camping.

The first Parks Canada initiative on monitoring visitor impacts on the rocky intertidal was from Pacific Rim National Park Reserve (H. Holmes in Rowe *et al.* 1999). The monitoring protocol, based on the Department of Fisheries and Oceans'

"*Shorekeeper's Manual*" (Jamieson *et al.* 1999), was initiated in 1997 (Table 7). Data include marine plant observations made in tide pool, horizontal bench, crevice and vertical rock face substrates. The intertidal kelp monitoring protocol developed for Pacific Rim by Druehl and Elliott (1996), that was not focused necessarily on visitor impact, has not yet been adopted into standard operations.

There is now a rocky intertidal trampling literature in which protected seashore areas in Australia (Keough and Quinn 1998), South Africa (Bally and Griffiths 1993) and the U.S. (Brosnan 1993; Brosnan and Crumrine 1994) have been the sites of visitor impact surveys. The intertidal flora features importantly in these studies. For example, the rocky intertidal of Cabrillo National Monument, near San Diego, CA has been monitored by the National Park Service semi-annually since 1990 in which at least four algae and a seagrass are among the target species (Engle and Davis 1996). Generally, foliose algae such as *Ulva* spp., *Iridaea* spp. and fucoid rockweeds are susceptible to trampling whereas turf-forming species are more resistant. Shifts have been observed in community composition in favor of low-profile turf over foliose species. However, Keough and Quinn (1998) caution on the use of intertidal algae for visitor impact monitors until the natural variation and patchiness of intertidal species are better understood and more discernable from variation caused by human impacts.

Visitor focal points of Gwaii Haanas such as Burnaby Narrows at low tide experience appreciable visitor traffic including trampling the intertidal biota, as articulated in the Backcountry Management Plan (Gajda 1999). This impact is unquantified but, given the adoption of the *Precautionary Principle* in the proposed *Marine Protected Areas Act*, it could be within Parks Canada's mandate to implement area closure based on trampling concerns until the science behind such intertidal impacts is better understood. The current management recommendation is to promote visitor-vessel float-through rather than intertidal walking. In fact, the Burnaby Narrows area is closed under the *National Parks Act* (i.e., all areas of Gwaii Haanas landward of the high tide line), for various non-marine reasons (Gajda 1999). In the longer-term, it would be best to investigate trampling in intertidal areas in order to scientifically back up any long-term area closure based on marine ecosystem concerns.

CONCLUSIONS AND RECOMMENDATIONS

This report provides a baseline marine flora and discusses attendant plant-associated management issues upon which conservation enthusiasts, marine biologists and protected area managers can improve the marine floristic legacy and its contribution to nearshore ecosystem structure and function in Haida Gwaii.

GWAII HAANAS MARINE FLORA KNOWLEDGE

We hope that this report will attract marine botanists and encourage collection of voucher specimens to help complete the regional flora including verifying the absence of noteworthy species. Appreciable data gaps occur in all the algal groups found in Gwaii Haanas, which account for ~49% of regional marine flora biodiversity at this time. This is all the more important as Haida Gwaii is at the periphery (southern extreme) of the northern seaweed flora. A wide range of botanical opportunities are available to investigators including and beyond the kelp “charismatic megaflora”.

The following recommendations are made based on this report and the literature:

1) Synoptic surveys for all marine algal phyla should be conducted as knowledge of local flora is incomplete for total species biodiversity and for local species assemblages.

2) Future surveys should encourage protocols for establishing species’ absences.

3) Interesting species distributions, such as the apparent northern limit of the sea palm *Postelsia palmaeformis* at Hope Island off northern Vancouver Island, require further investigation – is distribution related to habitat, sea temperature or limits of propagule transport (currents) and viability?

4) The genetic distinctiveness of the Haida Gwaii marine flora needs to be assessed and compared with the region’s mainland flora to establish the degree of relatedness.

5) Traditional Haida marine ethnobotanical knowledge requires further study as it has been relatively little researched beyond plant naming. Gwaii Haanas is a cooperative management partnership between the Haida Nation and Canada (Hawkes 1996) in which both scientific and traditional Haida knowledge must be seen to contribute to long-term management.

6) The aberrant *Macrocystis* species issue warrants resolution through the simple retrieval of the (diagnostic) holdfast of the unusually located plants.

7) Parks Canada should establish an electronic repository providing all interested parties with access the Gwaii Haanas biodiversity data sets.

8) The lack of seasonal algal collections from any location in Haida Gwaii should be attended to.

GWAII HAANAS ECOSYSTEM MANAGEMENT

The vital role of plants to nearshore Gwaii Hanaas ecosystem structure and function and in long-term stewardship initiatives yield the following recommendations:

1) Marine plants such as seaweeds and seagrasses should be used for long-term monitoring based on physical environment-plant assemblage correlations.

2) Kelp forest monitoring must occur before natural (or human) repatriation of sea otters to enable assessment of post-introduction changes to these ecosystems.

3) The full geographic extent and an index of abundance of the invasive species, *S. muticum*, in Haida Gwaii should be established.

4) The relationship of prominent kelp forest-associated species such as sea otters, red sea urchins and northern abalone should be researched as they impinge on culture, nearshore ecosystem structure and function, and local fisheries.

5) Marine plant values must be included among other criteria when implementing zonation, as defined in the proposed *Marine Conservation Areas Act*.

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Appendix A

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Appendix B Part 1

Number of sites at which all marine algae and seagrass have been reported from Haida Gwaii and Gwaii Haanas National Park Reserve.

Notes.
1. '-' indicates either that the taxa has not been reported for Gwaii Haanas, or that no herbarium specimen(s) for this taxa are known from Haida Gwaii or Gwaii Haanas.
2. Multiple herbarium specimens of the same species were sometimes collected from individual sites.
3. UBC = University of British Columbia Phycological Herbarium (2556 specimens).
4. CMN = Canadian Museum of Nature herbarium (9 specimens).
5. spp. is used where the observations may represent more than one species within a genera.
6. These names will be changed according to *comb. nov.'s* to be published in Gabrielson *et al.* (in press).

	Haida Gwaii	Gwaii[1] Haanas	Herbarium Specimens[1,2] UBC[3] | CMN[4]	Map No. in Appendix C
Phylum Chrysophyta (golden algae)				
Class Sarcinochrysidophyceae				
Order Sarcinochrysidales				
Family Phaeosacciaceae				
Phaeosaccion collinsii	2	1	2	1
Phylum Chlorophyta (green algae)				
Class Ulvophyceae				
Order Cladophorales				
Family Cladophoraceae				
Chaetomorpha aerea	2	-	2	2
Chaetomorpha cannabina	2	-	2	3
Cladophora columbiana	8	2	8	4
Cladophora hutchinsiae	3	1	3	5
Cladophora microcladioides	1	-	1	6
Cladophora sericea	2	1	2	7
Cladophora spp.[5]	52	42	3	8
Cladophora stimpsonii	2	-	3	9
Lola lubrica	1	-	1	10
Rhizoclonium riparium	8	-	10	11
Rhizoclonium spp.	2	2	-	12
Rhizoclonium tortuosum	3	1	3	13
Order Codiales				
Family Bryopsidaceae				
Bryopsia plumosa	3	-	4	14
Derbesia marina	18	5	17	15
Family Codiaceae				
Codium fragile	113	71	34	16
Codium setchellii	57	37	28	17
Codium spp.	4	4	-	18
Order Prasiolales				
Family Prasiolaceae				
Prasiola meridionalis	5	2	5	19

	Haida Gwaii	Gwaii[1] Haanas	Herbarium Specimens[1,2] UBC[3] | CMN[4]	Map No. in Appendix C
Prasiola spp.[*]	4	1	1	20
Rosenvingiella constricta	1	-	1	21
Order Ulotrichales				
Family Acrosiphoniaceae				
Acrosiphonia arcta	3	-	2	22
Acrosiphonia coalita	13	-	15 | 1	23
Acrosiphonia mertensii	12	2	16	24
Acrosiphonia saxitilis	5	2	6	25
Acrosiphonia spinescens	10	3	14	26
Acrosiphonia spp.	30	21	-	27
Urospora penicilliformis	2	-	2	28
Family Capsosiphonaceae				
Capsosiphon fulvescens	4	-	2	29
Family Collinsiellaceae				
Collinsiella tuberculata	6	1	6	30
Family Gayraliaceae				
Gayralia oxysperma	4	-	6	31
Family Kornmanniaceae				
Blidingia marginata	3	1	3	32
Blidingia minima	2	-	3	33
Blidingia sp.	1	1	1	34
Blidingia subsalsa	3	1	3	35
Kornmannia leptoderma	5	1	6	36
Family Monostromataceae				
Monostroma grevillei	7	-	6	37
Monostroma spp.	3	-	4	38
Family Ulotrichaceae				
Eugomontia sacculata	2	-	3	39
Ulothrix flacca	1	-	2	40
Ulothrix spp.	5	1	5	41
Family Ulvaceae				
Enteromorpha clathrata	4	-	4	42
Enteromorpha flexuosa	1	-	1	43
Enteromorpha intestinalis	20	3	11	44
Enteromorpha linza	19	3	15	45
Enteromorpha prolifera	4	1	4	46
Enteromorpha spp.	47	37	6	47
Percursaria percursa	1	-	1	48
Ulva crenulata	1[**]	-	-	49
Ulva fenestrata	31	8	39 | 1	50
Ulva spp.	118	91	2	51
Ulva taeniata	4	4	-	52
Ulvaria obscura var. *blyttii*	8	1	12	53
Ulva/Ulvaria spp.	12	0	-	54
Family Ulvellaceae				
Bolbocoleon piliferum	1	-	1	55
Ulvella setchellii	1	-	1	56

[*] Includes "*Schizogonium murale*", a life history stage of *Prasiola* (Michael Hawkes, *personal communication*).

[**] Requires confirmation because this species has not been recorded elsewhere on the B.C. coast (M.Hawkes, *personal communication*).

	Haida Gwaii	Gwaii Haanas[1]	Herbarium Specimens[1,2] UBC[3] | CMN[4]	Map No. in Appendix C
Phylum Phaeophyta (brown algae)				
Class Phaeophyceae				
Order Ectocarpales				
Family Acrotrichaceae				
Acrothrix sp.	1	-	1	57
Family Chordariaceae				
Eudesme virescens	5	-	6	58
Haplogloia andersonii	8	-	8	59
Saundersella simplex	10	1	14	60
Family Coilodesmaceae				
Coilodesme bulligera	3	-	3	61
Coilodesme californica	2	-	4	62
Phaeostrophion irregulare	2	-	2	63
Family Dictyosiphonaceae				
Dictyosiphon foeniculaceus	2	-	2	64
Family Ectocarpaceae				
Ectocarpus parvus	11	2	12	65
Ectocarpus siliculosus	7	3	7	66
Ectocarpus spp.	2	1	2	67
Feldmannia irregularis	1	-	1	68
Feldmannia paradoxa var. *cylindrica*	2	-	2	69
Feldmannia sp.	1	-	1	70
Hincksia ovata	1	-	1	71
Hincksia sandriana	3	-	3	72
Hincksia spp.	2	-	2	73
Pilayella littoralis	14	2	15	74
Pilayella tenella	3	1	1	75
Spongonema tomentosum	3	-	4	76
Family Elachistaceae				
Elachista fucicola	9	3	10	77
Family Heterochordariaceae				
Analipus japonicus	27	15	12	78
Family Leathesiaceae				
Leathesia difformis	95	58	41	79
Family Myrionemataceae				
Hecatonema streblonematoides	1	-	1	80
Myrionema globosum	1	-	1	81
Myrionema strangulans	3	-	3	82
Family Punctariaceae				
Melanosiphon intestinalis	7	1	7	83
Punctaria expansa	2	-	2	84
Punctaria hesperia	2	-	2	85
Soranthera ulvoidea	23	2	30	86
Family Ralfsiaceae				
Ralfsia confusa	1	-	1	87
Ralfsia fungiformis	4	-	7	88
Ralfsia pacifica	5	-	3 | 1	89
Ralfsia spp.	14	14	-	90
Family Scytosiphonaceae				
Colpomenia peregrina	14	6	16	91
Colpomenia spp.	12	10	-	92
Petalonia fascia	8	-	5	93
Scytosiphon simplicissimus	38	16	27	94

	Haida Gwaii	Gwaii Haanas[1]	Herbarium Specimens[1,2] UBC[3] | CMN[4]	Map No. in Appendix C
Scytosiphon spp.	10	1	-	95
Family Striariaceae				
Stictyosiphon tortilis	2	-	2	96
Order Sphacelariales				
Family Sphacelariaceae				
Sphacelaria norrisii	1	1	1	97
Sphacelaria racemosa	5	1	5	98
Order Dictyotales				
Family Dictyotaceae				
Dictyota binghamiae	19	6	21	99
Order Syringodermatales				
Family Syringodermataceae				
Syringoderma abyssicola	6	1	6	100
Order Desmarestiales				
Family Desmarestiaceae				
Desmarestia aculeata	24	8	10	101
Desmarestia foliacea	1	1	-	102
Desmarestia ligulata	32	12	18	103
Desmarestia munda	30	23	5	104
Desmarestia viridis	13	4	13	105
Order Laminariales				
Family Alariaceae				
Alaria crispa	6	1	7	106
Alaria marginata	67	52	11	107
Alaria nana	53	41	9	108
Alaria praelonga	13	11	3	109
Alaria spp.	29	13	7	110
Alaria taeniata	1	-	-	111
Alaria tenuifolia	4	2	3	112
Lessoniopsis littoralis	67	50	17	113
Pterygophora californica	21	16	3	114
Family Laminariaceae				
Agarum clathratum	8	1	8	115
Agarum fimbriatum	22	12	2	116
Agarum spp.	18	13	2	117
Costaria costata	89	58	26	118
Cymathere triplicata	45	33	11	119
Hedophyllum sessile	116	79	36	120
Laminaria bongardiana	106	62	48	121
Laminaria complanata	3	-	2	122
Laminaria dentigera	8	2	14	123
Laminaria ephemera	1	-	1	124
Laminaria saccharina	80	45	12	125
Laminaria setchellii	114	85	23	126
Laminaria spp.	27	2	-	127
Laminaria yezoensis	8	-	12	128
Pleurophycus gardneri	42	22	22	129
Family Lessoniaceae				
Egregia menziesii	135	100	33	130
Eisenia arborea	3	-	4	131
Macrocystis integrifolia	124	84	13	132
Nereocystis luetkeana	154	119	24	133
Order Fucales				

	Haida Gwaii	Gwaii[1] Haanas	Herbarium Specimens[1,2] UBC[3] | CMN[4]	Map No. in Appendix C
Family Cystoseiraceae				
Cystoseira geminata	7	-	11	134
Family Fucaceae				
Fucus gardneri	115	54	49	135
Fucus spiralis	4	1	2	136
Fucus spp.	94	77	-	137
Pelvetiopsis limitata	1	1	-	138
Family Sargassaceae				
Sargassum muticum	14	9	3	139

Phylum Rhodophyta (red algae)

Class Rhodophyceae				
Subclass Bangiophycidae				
Order Porphyridiales				
Family Porphyridiaceae				
Stylonema alsidii	1	-	1	140
Order Compsopogonales				
Family Erythropeltidaceae				
Erythrocladia irregularis	3	2	-	141
Erythrotrichia carnea	5	1	5	142
Erythrotrichia pulvinata	3	1	4	143
Porphyropsis coccinea	5	1	5	144
Smithora naiadum	15	1	16	145
Order Bangiales				
Family Bangiaceae				
Bangia atropurpurea	11	1	8	146
Porphyra abbottae	5	-	6	147
Porphyra cuneiformis	3	1	2	148
Porphyra fallax	1	-	1	149
Porphyra fucicola	3	1	3	150
Porphyra gardneri	8	2	9	151
Porphyra kanakaensis	1	-	1	152
Porphyra lanceolata	1	-	-	153
Porphyra nereocystis	10	1	8	154
Porphyra papenfussii	1	-	1	155
Porphyra perforata	24	4	22	156
Porphyra pseudolanceolata	3	1	4	157
Porphyra schizophylla	5	1	5	158
Porphyra smithii	6	1	6	159
Porphyra spp.	76	47	29	160
Porphyra thuretii	1	-	1	161
Porphyra torta	9	3	18	162
Porphyra variegeta	1	-	1	163
Subclass Florideophycidae				
Order Hildenbrandiales				
Family Hildenbrandiaceae				
Hildenbrandia occidentalis	6	5	1	164
Hildenbrandia rubra	2	-	2	165
Hildenbrandia spp.	6	6	-	166
Order Ahnfeltiales				
Family Ahnfeltiaceae				
Ahnfeltia fastigiata	13	3	11	167

	Haida Gwaii	Gwaii[1] Haanas	Herbarium Specimens[1,2] UBC[3] | CMN[4]	Map No. in Appendix C
Order Corallinales				
Family Corallinaceae				
Bossiella californica ssp. *schmittii*	15	5	12	168
Bossiella chiloensis	6	2	7	169
Bossiella cretacea	1	-	1	170
Bossiella orbigniana	16	7	12	171
Bossiella orbigniana ssp. *dichotoma*	7	1	8	172
Bossiella plumosa	9	1	7	173
Bossiella spp.	25	15	-|1	174
Calliarthron spp.	9	5	-	175
Calliarthron tuberculosum	21	5	21	176
Clathromorphum circumscriptum	1	-	1	177
Clathromorphum parcum	2	2	2	178
Clathromorphum reclinatum	17	4	15	179
Clathromorphum sp.	1	-	1	180
Corallina frondescens	6	-	6	181
Corallina officinalis var. *chilensis*	31	5	31	182
Corallina pilulifera	3	2	1	183
Corallina spp.	32	12	- | 1	184
Corallina vancouveriensis	81	44	25	185
Lithophyllum spp.	7	1	9	186
Lithothamnion adeyi[6]	1	1	1	187
Lithothamnion phymatodeum	11	4	5	188
Lithothamnion spp.	88	64	-	189
Lithothrix aspergillum	1	-	1	190
Melobesia mediocris	2	-	1	191
Melobesia spp.	2	-	-	192
Mesophyllum conchatum	2	1	2	193
Mesophyllum lamellatum	11	4	8	194
Mesophyllum spp.	6	1	6	195
Pneophyllum zostericolum	7	-	8	196
Pseudolithophyllum muricatum	18	7	14	197
Pseudolithophyllum neofarlowii	5	2	3	198
Serraticardia macmillanii	15	4	16	199
Yamadaia americana	7	2	3	200
Order Acrochaetiales				
Family Acrochaetiaceae				
Acrochaetium arcuatum	2	1	-	201
Acrochaetium densum	2	-	2	202
Acrochaetium microscopicum	4	-	4	203
Acrochaetium porphyrae	1	-	1	204
Audouinella amphiroae[6]	2	1	2	205
Audouinella concrescens[6]	1	-	1	206
Audouinella membranacea	2	-	2	207
Audouinella plumosa	1	-	1	208
Audouinella plumosa var. *variabile*[6]	1	-	1	209
Audouinella rhizoidea[6]	4	-	4	210
Audouinella simplex	5	2	-	211
Audouinella spp.	4	1	4	212
Audouinella thuretii[6]	2	1	2	213
Calaconema daviesii	4	2	4	214
Rhodochorton purpureum	5	1	5	215
Order Nemaliales				
Family Galaxauraceae				
Scinaia confusa	12	-	12	216

	Haida Gwaii	Gwaii[1] Haanas	Herbarium Specimens[1,2] UBC[3] | CMN[4]	Map No. in Appendix C
Family Liagoraceae				
Cumagloia andersonii	3	2	-	217
Nemalion helminthoides	2	2	-	218
Order Palmariales				
Family Palmariaceae				
Halosaccion glandiforme	129	87	36	219
Palmaria callophylloides	9	-	12	220
Palmaria hecatensis	11	-	16	221
Palmaria mollis	22	4	26	222
Palmaria spp.	4	-	-	223
Family Rhodophysemataceae				
Meiodiscus spetsbergensis	3	1	2	224
Rhodophysema elegans	1	-	1	225
Rhodophysema georgii	1	1	1	226
Order Ceramiales				
Family Ceramiaceae				
Antithamnion defectum	18	6	12	227
Antithamnion spp.	15	5	-	228
Antithamnionella pacifica	2	-	2	229
Antithamnionella spirographidis	5	-	3	230
Callithamnion acutum	6	-	6	231
Callithamnion biseriatum	4	2	3	232
Callithamnion pikeanum	42	23	22	233
Callithamnion spp.	5	2	4	234
Ceramium californicum	4	-	4	235
Ceramium codicola	5	2	5	236
Ceramium eatonianum	1	-	1	237
Ceramium gardneri	4	1	4	238
Ceramium pacificum	9	-	7	239
Ceramium rubrum	3	1	1 | 1	240
Ceramium spp.	16	9	-	241
Ceramium strictum	9	1	10	242
Ceramium washingtoniense	4	2	4	243
Griffithsia pacifica	5	1	6	244
Hollenbergia nigricans	2	-	2	245
Hollenbergia subulata	6	-	5	246
Microcladia borealis	40	22	25	247
Microcladia coulteri	4	4	-	248
Microcladia spp.	9	2	-	249
Neoptilota asplenioides	4	-	7	250
Neoptilota californica	5	-	1	251
Neoptilota hypnoides	9	6	6	252
Pleonosporium vancouverianum	2	1	1	253
Pterothamnion pectinatum	4	1	4	254
Pterothamnion villosum	7	2	-	255
Ptilota filicina	32	6	39	256
Ptilota serrata	3	-	-	257
Ptilota spp.	14	13	-	258
Ptilothamnionopsis lejolisea	7	3	9	259
Scagelia occidentale	3	-	2	260
Tiffaniella snyderae	4	-	4	261
Family Dasyaceae				
Heterosiphonia densiuscula	15	6	7	262
Rhodoptilum plumosum	4	-	4	263
Family Delesseriaceae				

	Haida Gwaii	Gwaii Haanas[1]	Herbarium Specimens[1,2] UBC[3] | CMN[4]	Map No. in Appendix C
Branchioglossum bipinnatifidum	3	1	1	264
Cryptopleura lobulifera	1	1	1	265
Cryptopleura ruprechtiana	26	11	17	266
Cryptopleura sp.	1	-	-	267
Delesseria decipiens	15	5	6	268
Haraldiophyllum mirabile	2	1	1	269
Haraldiophyllum nottii	1	1	1	270
Hymenena flabelligera	9	-	8	271
Hymenena kylinii	2	-	1	272
Hymenena multiloba	6	1	7	273
Hymenena setchellii	3	-	-	274
Hymenena spp.	7	3	1	275
Membranoptera dimorpha	6	-	6	276
Membranoptera platyphylla	11	4	14	277
Myriogramme repens	1	-	1	278
Nienburgia andersoniana	2	-	2	279
Nitophyllum cincinnatum	12	6	18	280
Nitophyllum hollenbergii	1	-	1	281
Phycodrys isabellae	1	-	1	282
Phycodrys riggii	1	-	1	283
Phycodrys setchellii	1	1	1	284
Polyneura latissima	39	13	31	285
Tokidadendron kurilensis	2	-	3	286
Family Rhodomelaceae				
Amplisiphonia pacifica	3	-	2	287
Herposiphonia plumula	14	1	14	288
Neorhodomela larix	104	47	36 | 1	289
Neorhodomela oregona	1	-	2	290
Odonthalia floccosa	61	6	61	291
Odonthalia kamtschatica	3	-	3	292
Odonthalia lyallii	5	-	3	293
Odonthalia spp.	56	43	3	294
Odonthalia washingtoniensis	9	1	6	295
Osmundea spectabilis	11	5	6	296
Polysiphonia hendryi var. *deliquescens*	2	1	2	297
Polysiphonia hendryi var. *gardneri*	13	3	16	298
Polysiphonia hendryi var. *hendryi*	12	6	2	299
Polysiphonia pacifica	17	5	18	300
Polysiphonia pacifica var. *disticha*	2	-	2	301
Polysiphonia pacifica var. *gracilis*	1	-	1	302
Polysiphonia pacifica var. *pacifica*	3	1	3	303
Polysiphonia paniculata	9	2	7	304
Polysiphonia spp.	36	24	-	305
Polysiphonia tongatensis	4	-	4	306
Polysiphonia urceolata	6	2	5	307
Pterochondria woodii	9	5	5	308
Pterosiphonia bipinnata	23	3	30	309
Pterosiphonia dendroidea	22	6	25	310
Pterosiphonia gracilis	5	-	3	311
Pterosiphonia hamata	11	3	17	312
Pterosiphonia sp.	1	-	-	313
Rhodomela lycopodioides	4	-	5	314

	Haida Gwaii	Gwaii Haanas[1]	Herbarium Specimens[1,2] UBC[3] | CMN[4]	Map No. in Appendix C
Rhodomela spp.[*]	3	-	1	315
Schizochlaenion rhodotrichum	1	-	1	316
Order Bonnemaisoniales				
Family Bonnemaisoniaceae				
Bonnemaisonia geniculata	2	1	3	317
Bonnemaisonia nootkana	7	3	4	318
Bonnemaisonia sp.	1	1	-	319
Order Gelidiales				
Family Gelidiaceae				
Gelidium coulteri	1	1	-	320
Gelidium purpurescens	5	2	4	321
Gelidium pusillum	1	-	1	322
Gelidium spp.	2	-	-	323
Order Gigartinales				
Family Choreocolacaceae				
Harveyella mirabilis	1	1	-	324
Leachiella pacifica	2	-	2	325
Family Dumontiaceae				
Constantinea simplex	10	4	8	326
Constantinea subulifera	4	1	3	327
Cryptosiphonia woodii	70	34	18 | 1	328
Dilsea californica	4	3	1	329
Farlowia mollis	8	1	13	330
Neodilsea borealis	2	1	2	331
Neodilsea sp.	1	-	2	332
Pikea californica	6	2	3	333
Family Endocladiaceae				
Endocladia muricata	88	45	41	334
Gloiopeltis furcata	61	37	20	335
Family Furcellariaceae				
Opuntiella californica	26	11	21	336
Turnerella mertensiana	1	-	-	337
Family Gigartinaceae				
Chondracanthus corymbiferus	24	18	9	338
Chondracanthus exasperatus	18	15	-	339
Chondracanthus spp.	35	14	1	340
Mazzaella affinis	9	8	1	341
Mazzaella californica	5	2	4	342
Mazzaella cornucopiae	50	41	7	343
Mazzaella heterocarpa	17	6	11	344
Mazzaella lineare	11	8	5	345
Mazzaella rosea	9	1	10	346
Mazzaella splendens	48	26	32	347
Mazzaella spp.	22	4	-	348
Family Gloiosiphoniaceae				
Gloiosiphonia capillaris	1	-	1	349
Family Kallymeniaceae				
Callophyllis crenulata	11	2	9	350
Callophyllis edentata	1	1	-	351
Callophyllis firma	12	3	6	352

[*] These may be *Rhodomela lycopoides* or *Neorhodomela larix* (Michael Hawkes, *personal communication*).

	Haida Gwaii	Gwaii[1] Haanas	Herbarium Specimens[1,2] UBC[3] | CMN[4]	Map No. in Appendix C
Callophyllis flabellulata	16	3	10	353
Callophyllis heanophylla	3	1	2	354
Callophyllis pinnata	3	1	3	355
Callophyllis spp.	15	3	-	356
Callophyllis thompsonii	1	-	-	357
Callophyllis violacea	7	2	5	358
Cirrulicarpus n. sp.	1	-	1	359
Erythrophyllum delesserioides	12	5	7	360
Euthora cristata	3	1	2	361
Kallymeniopsis spp.	2	-	2	362
Pugetia fragilissima	11	2	13	363
Family Petrocelidaceae				
Mastocarpus jardinii	13	3	17	364
Mastocarpus papillatus	157	99	47	365
Family Peysonneliaceae				
Peyssonnelia meridionalis	6*	6	-	366
Peyssonnelia pacifica	5	2	5	367
Family Phyllophoraceae				
Ahnfeltiopsis gigartinoides	1	-	-	368
Ahnfeltiopsis leptophyllus	8	6	2	369
Ahnfeltiopsis linearis	4	4	-	370
Ahnfeltiopsis spp.	4	3	-	371
Stenogramma interrupta	1	-	1	372
Family Schizymeniaceae				
Schizymenia pacifica	8	1	5	373
Family Solieriaceae				
Sarcodiotheca furcata	3	-	3	374
Sarcodiotheca gaudichaudii	9	3	6	375
Order Halymeniales				
Family Halymeniaceae				
Cryptonemia obovata	1	-	-	376
Cryptonemia spp.	3	1	2	377
Grateloupia postelsii	2	-	3	378
Grateloupia setchellii	1	-	1	379
Halymenia californica	2	-	2	380
Halymenia spp.	4	-	6	381
Prionitis filiformis	5	2	6	382
Prionitis lanceolata	37	23	16	383
Prionitis linearis	1	-	1	384
Prionitis lyallii	4	2	1	385
Prionitis spp.	6	1	2	386
Order Rhodymeniales				
Family Champiaceae				
Gastroclonium subarticulatum	21	10	8	387
Family Faucheaceae				
Fauchea laciniata	15	4	22	388
Fauchea spp.	3	-	1	389
Family Rhodymeniaceae				

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* Requires confirmation because this species has not been recorded North of Oregon (M.Hawkes, *Personal Communication*).

	Haida Gwaii	Gwaii[1] Haanas	Herbarium Specimens[1,2] UBC[3] | CMN[4]	Map No. in Appendix C
Botryocladia pseudodichotoma	4	2	3	390
Fryeella gardneri	6	4	5	391
Rhodymenia californica	5	2	4	392
Rhodymenia pacifica	1	-	-	393
Sparlingia pertusa	24	1	14 | 1	394
Order Gracilariales				
Family Gracilariaceae				
Gracilaria pacifica	9	2	4	395
Gracilaria spp.	5	3	-	396
Gracilariopsis lemaneiformis	8	-	8	397
Order Plocamiales				
Family Plocamiaceae				
Plocamium cartilagineum	16	15	1	398
Plocamium spp.	9	5	-	399
Plocamium violaceum	27	12	19	400

Phylum Anthophyta (flowering plants)

Class Liliopsida

Order Zosterales

	Haida Gwaii	Gwaii Haanas	Herbarium Specimens UBC | CMN	Map No. in Appendix C
Family Potogometonaceae*				
Ruppia maritima	9	1	-	401
Family Zosteraceae				
Phyllospadix scouleri	72	44	9	402
Phyllospadix spp.	41	34	-	403
Phyllospadix torreyi	4	-	4	404
Zostera marina	82	45	1	405

* Family Ruppiaceae is used in place of Potomogetonaceae in *The plants of B.C.* (Qian and Klinka 1998).

Appendix B Part 2

Numbers of specimens of marine lichens according to shore zones and substrates in Haida Gwaii.

Notes.
[1] R=rock/W=drift wood/B=bark of living trees
[2] preliminary shore zonation categories according to O'Clair et al.(1996)

		Shore Zone[2]		
Species	**Sub-strate[1]**	**high intertidal**	**splash**	**salt spray**
Amandinea coniops (Wahlenb. in Ach.) M. Choisy ex Scheid. & H. Mayrh.	R	1	1	2
Arthonia phaeobaea (Norman) Norman	R		6	6
Aspicilia caesiocinerea (Nyl. ex Malbr.) Arn.	R		1	10
Aspicilia supertegens Arn.	R	1	5	9
Bacidia alaskensis (Nyl.) Zahlbr.	R			18
Bacidina inundata (Fr.) Vezda	R			2
Buellia griseovirens (Turner & Borrer ex Sm.) Almb. (= B. hassei Imsh., ined.)	W			2
Caloplaca chlorina (Flotow) H. Olivier	R			1
Caloplaca citrina (Hoffm.) Th. Fr.	R & W	1		5
Caloplaca flavogranulosa Arup	R	3	2	11
Caloplaca inconspecta Arup	R	4		
Caloplaca litoricola Brodo	R		8	22
Caloplaca rosei Hasse	R			3
Caloplaca verruculifera (Vainio) Zahlbr.	R	1	5	4
Catillaria chalybeia (Borrer) Massal.	R	1	1	3
Catillaria sp. no.2 (corticolous, lge spores)	B			1
Cliostomum griffithii (Sm.) Coppins	B & W			22
Coccotrema maritimum Brodo	R	1		25
Collema fecundum Degel.	R	1	2	16
Collema flaccidum (Ach.) Ach.	R			1
Collema furfuraceum (Arn.) Du Rietz var. furfuraceum	R			9
Diplotomma chlorophaeum (Hepp ex Leighton) Szat.	R			2
Ephebe lanata (L.) Vainio	R		1	16
Fuscidea intercincta (Nyl.) Poelt in Poelt & Buschart	R			2
Fuscidea mollis (Wahlenb.) V. Wirth & Vezda	R			3
Fuscidea thomsonii Brodo & V. Wirth	R			9
Hafellia tlellensis Brodo & Sheard	W		1	
Kohlmeyera complicatula (Nyl.) Schatz	R		1	
Lecanora albescens (Hoffm.) Branth & Rostrup (??; see Lecanora sp. no.1)	R	1		1
Lecanora expallens Ach.	W		1	21
Lecanora grantii H. Magn.	W		1	11
Lecanora muralis (Schreber) Rabenh.	R			11
Lecanora orae-frigidae R. Sant.	W			2
Lecanora poliophaea (Wahlenb.in Ach.) Ach. s. lat. ("subsp. nobleae Brodo, ssp. nov.")	R		2	4
Lecanora straminea Wahlenb. ex Ach.	R			5
Lecanora tenera (Nyl.) Cromb.	R			1
Lecanora zosterae (Ach.) Nyl.	W			5
Lecanora sp. no.1 (xanthone-containing, maritime, white, saxicolous; cfr. L. albescens)	R		2	
Lecanora sp. no.5 (xanthone-containing, maritime, saxicolous; cfr. L. contractula)	R		1	
Lecidella effugiens (B. Nilson) Knoph & Hertel in Knoph	W			1
Lecidella elaeochroma (Ach.) M. Choisy	B			11
Lecidella scabra (Taylor) Hertel & Leuckert	R		2	1
Lecidella stigmatea (Ach.) Hertel & Leuckert f. stigmatea	R		1	20

Species	Sub-strate[1]	Shore Zone[2] high intertidal	splash	salt spray
Ochrolechia subplicans (Nyl.) Brodo subsp. hultenii (Erichs.) Brodo	R			2
Ochrolechia subplicans (Nyl.) Brodo subsp. subplicans	R			2
Pannaria laceratula Hue	B			9
Pannaria leucostictoides Ohlsson	B			7
Pannaria maritima P.M. Joerg.	R			14
Pertusaria glaucomela (Tuck.) Nyl.	B			30
Pertusaria glomerata (Ach.) Schaerer	B			1
Pertusaria suboculata Brodo & Dibben	B			16
Physcia caesia (Hoffm.) Füürnr.	R		3	30
Physcia tenella (Scop.) DC. in Lam. & DC.	B			3
Polychidium contortum Henssen	B			10
Polychidium muscicola (Sw.) S.F. Gray	R			9
Porina pacifica Brodo & R.C. Harris, ined. (n. sp.)	R			16
Porpidia carlottiana Gowan	R			28
Punctelia stictica (Duby) Krog	R			3
Pyrenocollema sublitorale (Leighton) R.C. Harris ex Fletcher in Coppins, P. James & D. Hawksw.	barnacles	5		
Pyrrhospora quernea (Dickson) Köörber	W			2
Ramalina dilacerata (Hoffm.) Hoffm.	B			3
Ramalina menziesii Taylor	B			10
Ramalina roesleri (Hochst. ex Schaerer) Hue	B			12
Rhizocarpon geminatum Köörber	R		2	21
Rhizocarpon hensseniae Brodo	R			14
Rhizocarpon hochstetteri (Köörber) Vainio (large spored morph)	R	1		30
Rhizocarpon hochstetteri (Köörber) Vainio (small-spored morph; = "Rhizocarpon sp. no.1")	R			1
Rinodina conradii Köörber	W			8
Rinodina disjuncta Sheard & Tonsberg (Syn. R. columbiensis Sheard, ined.)	B			1
Rinodina gennarii Bagl.	R		2	2
Spilonema revertens Nyl.	R	1	2	14
Tephromela atra (Hudson) Hafellner in Kalb	R			3
Topelia microspora Brodo, ined. (n. sp.)	R			1
Tylothallia biformigera P. James & R. Kilias in R. Kilias	R			3
Verrucaria amphibia Clemente	R		1	
Verrucaria degelii R. Sant.	R			2
Verrucaria epimaura Brodo	R	2	16	1
Verrucaria erichsenii Zsch.	R	2	1	
Verrucaria halizoa Leighton	R		2	
Verrucaria maura Wahlenb. in Ach.	R		40	40
Verrucaria mucosa Wahlenb. in Ach.	R		1	
Verrucaria schofieldii Brodo	R		4	8
Verrucaria silicicola Fink	R			6
Verrucaria sp. no.2 (dry rock at edge of beach)	R			3
Xanthoria candelaria (L.) Th. Fr.	R & B		2	31
Xylographa hians Tuck.	W			13
Xylographa opegraphella Nyl. in Rothr.	W			3
Xylographa vitiligo (Ach.) J.R. Laundon	W			7

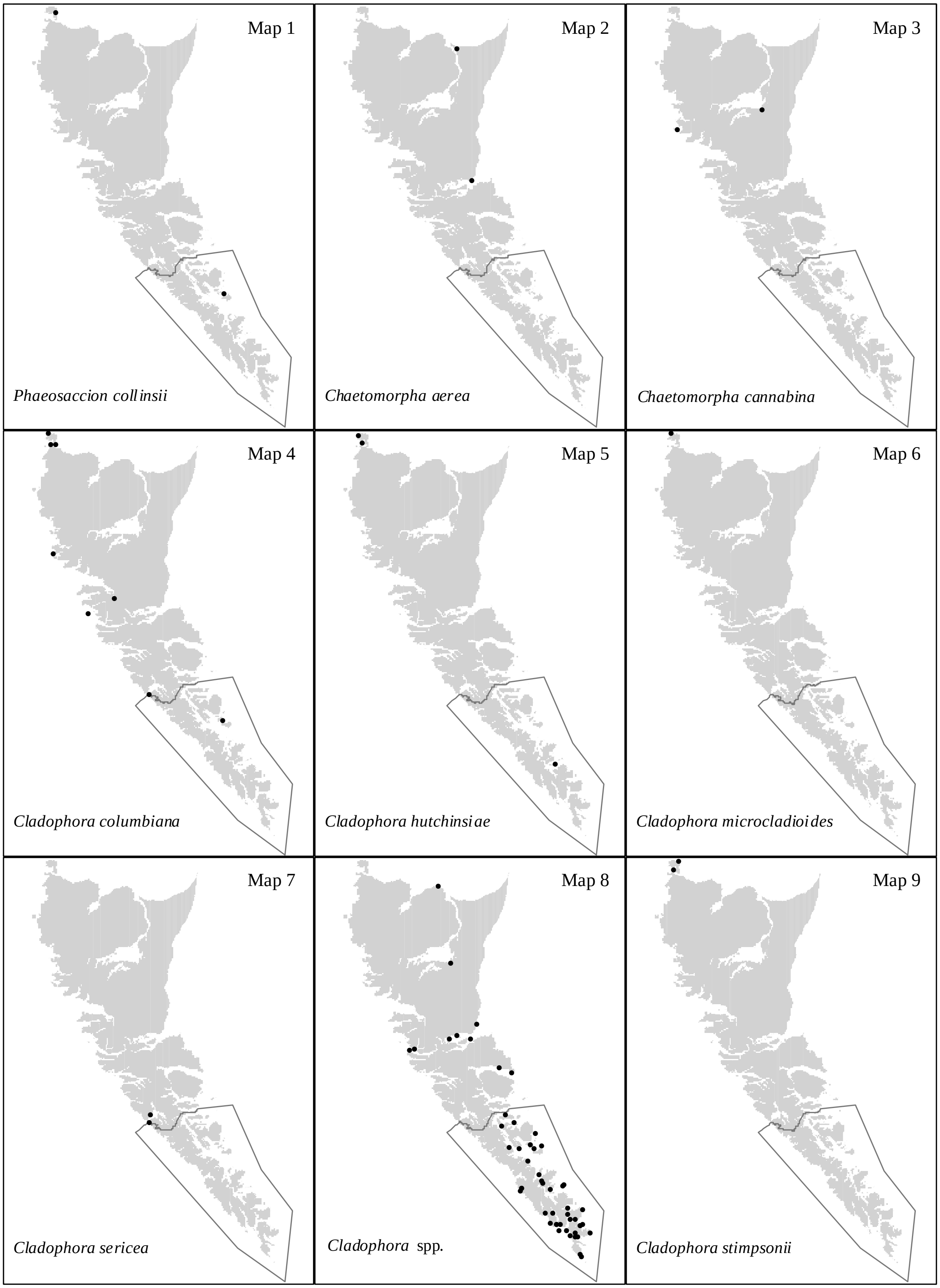
Appendix C

Distribution maps of individual algal and seagrass taxa in Haida Gwaii

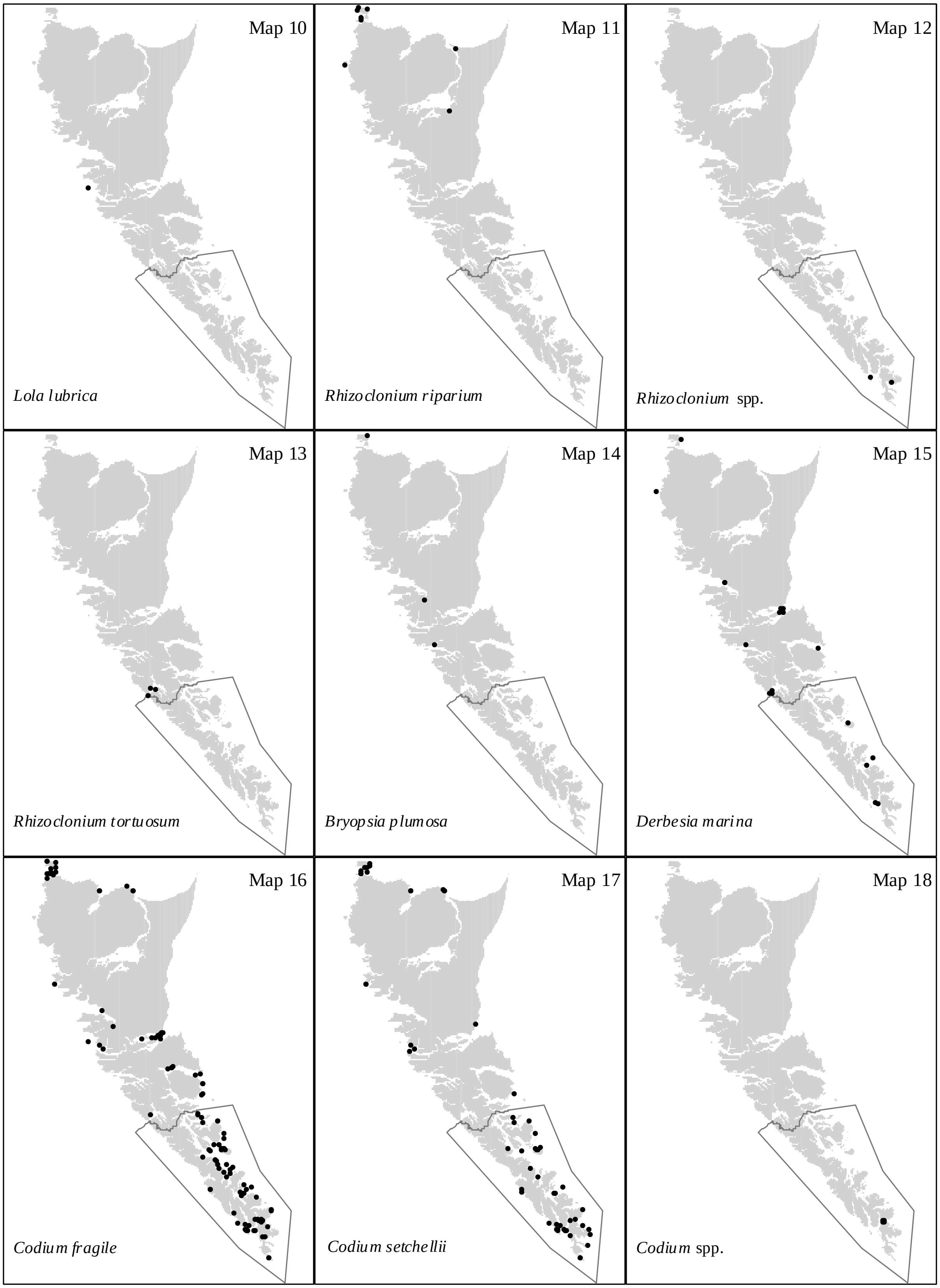
Notes.

1. The distribution maps in this appendix are at a scale of almost one to three million (1:3,000,000). The radius of the observation dots at this scale is approximately 500 metres.

2. Two or more dots located close together (< 1000 metres) sometimes may appear as a single dot on the distribution maps.



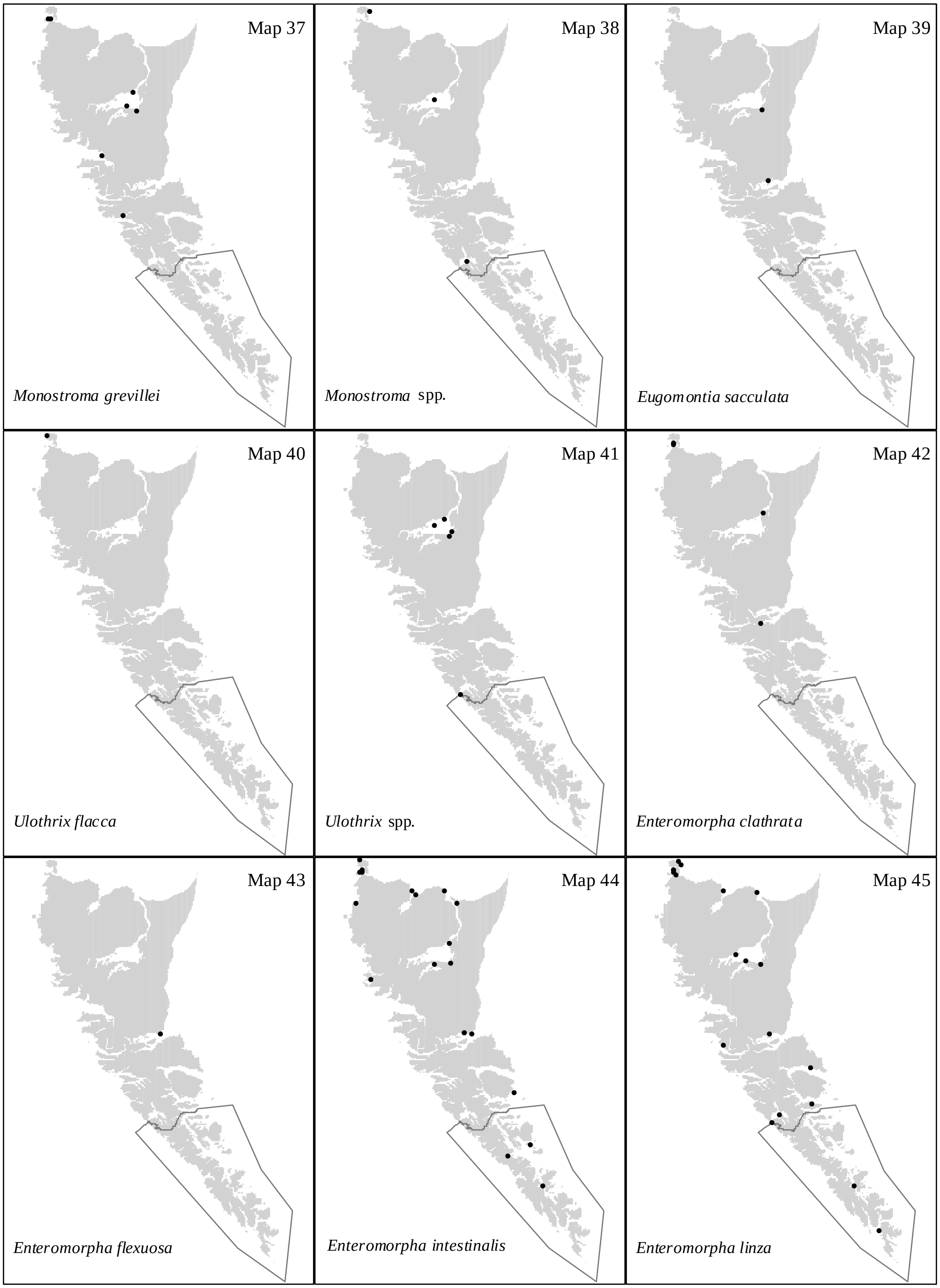
Chrysophyta and Chlorophyta.



Chlorophyta continued.

Chlorophyta continued.

Chlorophyta continued.



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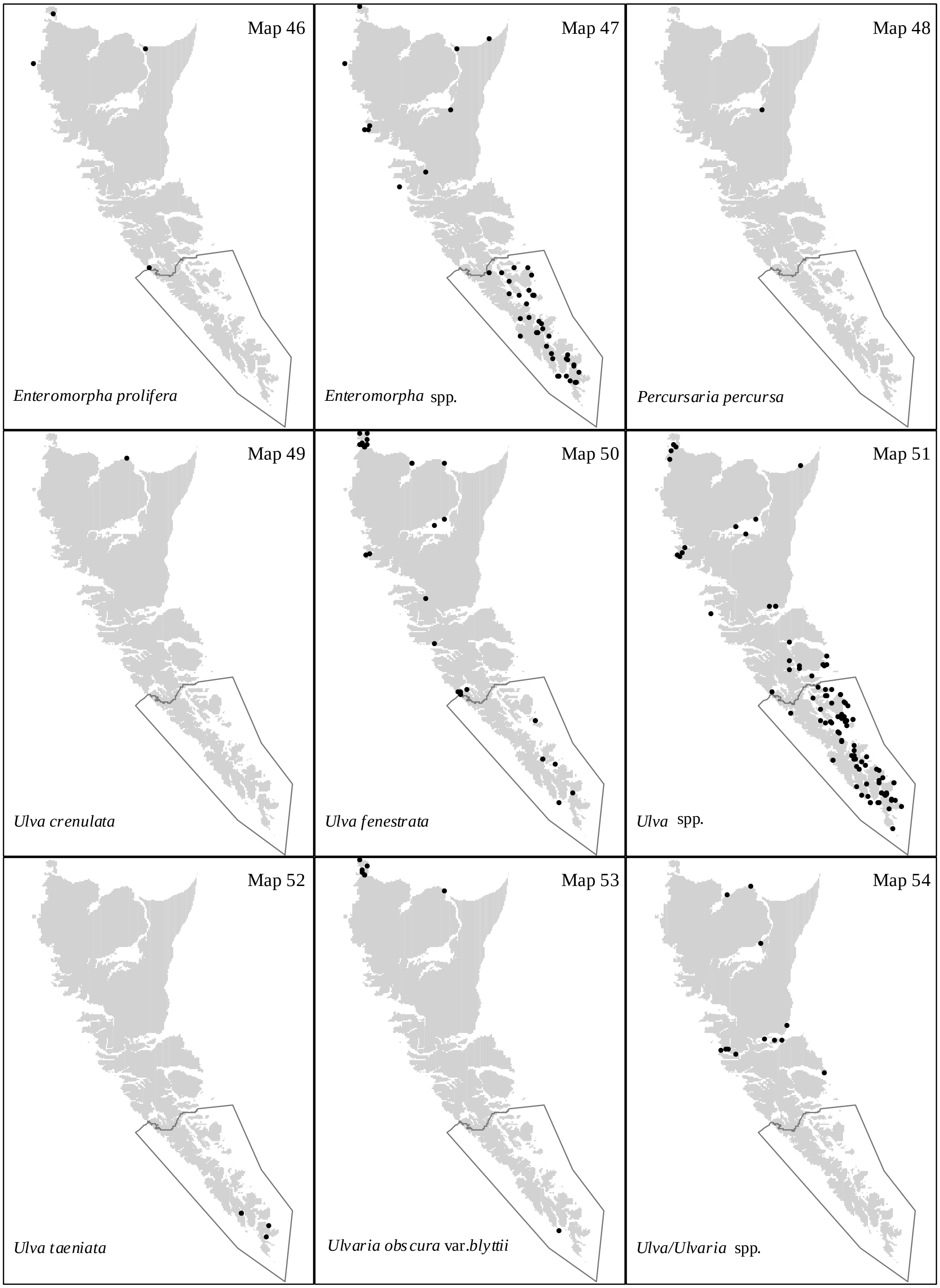
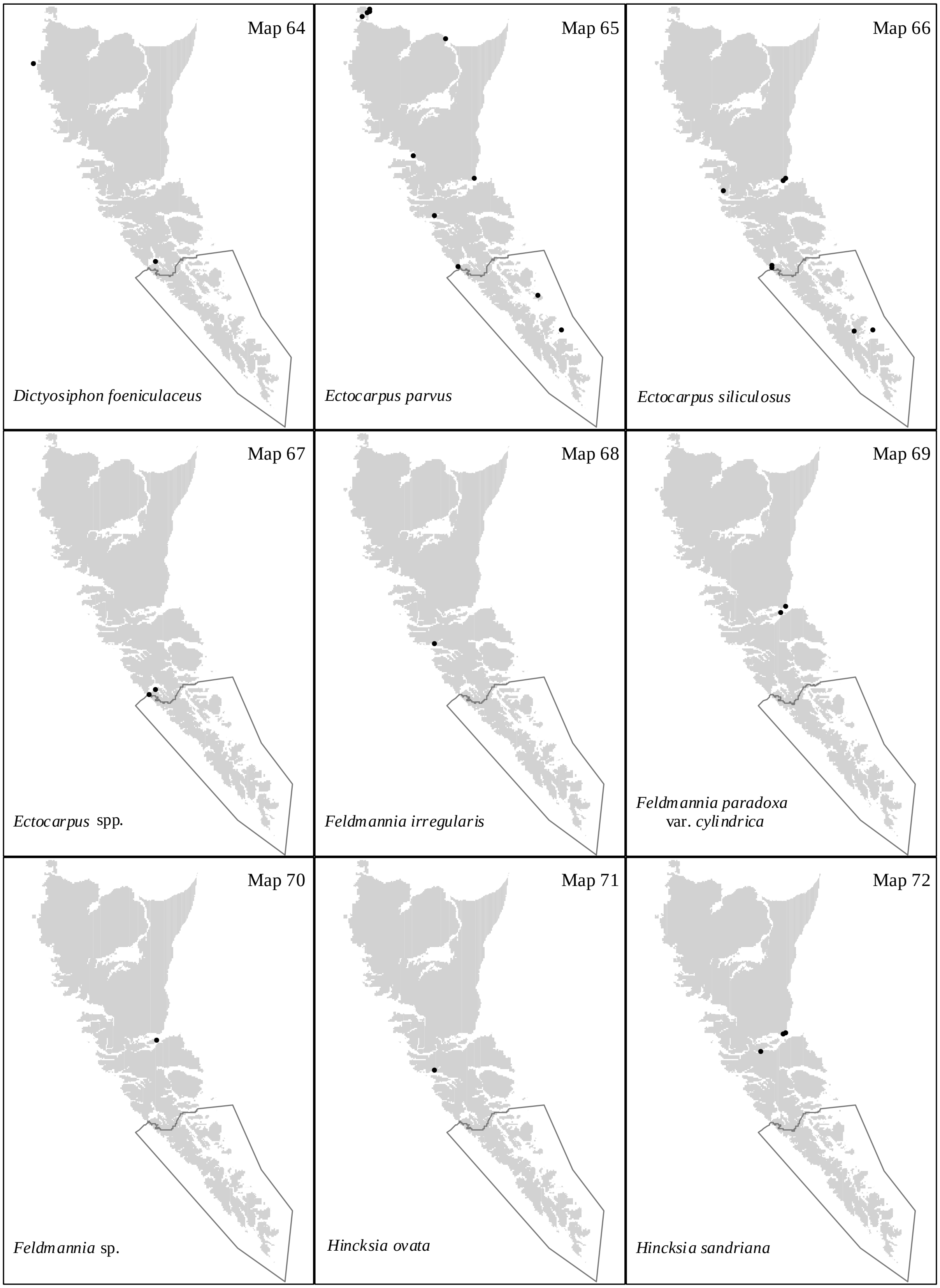


Chlorophyta continued.

Chlorophyta and Phaeophyta.



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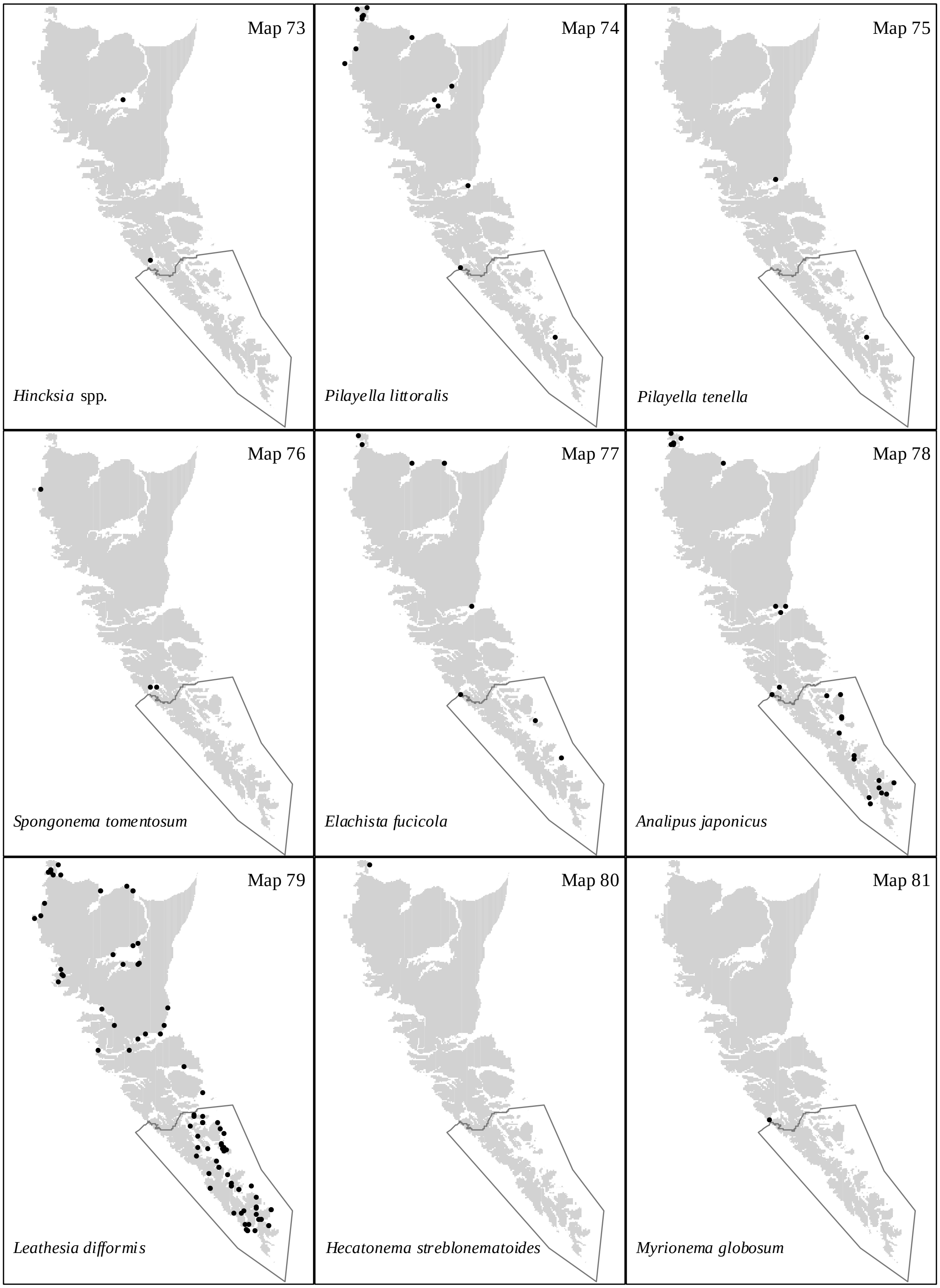

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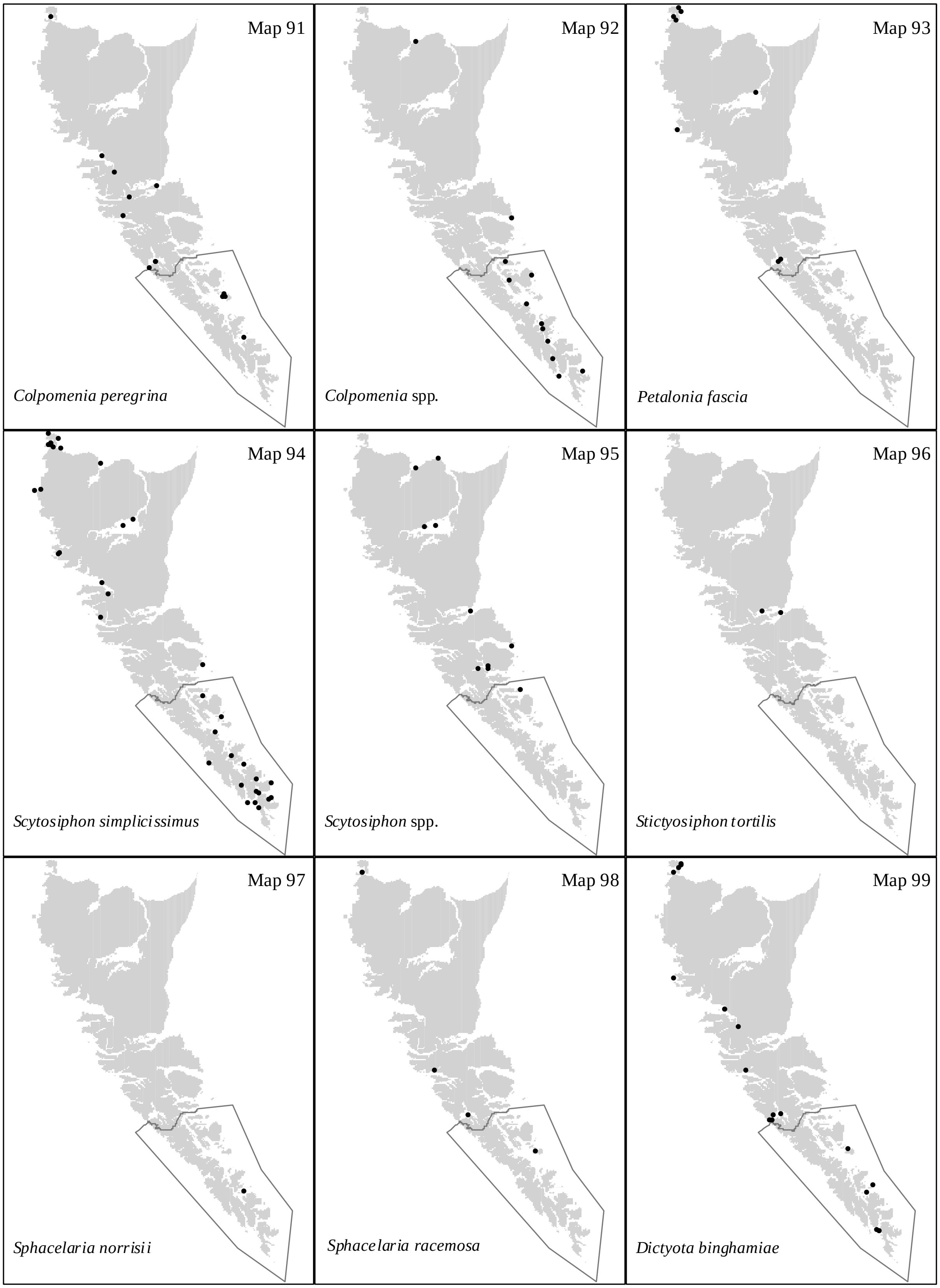

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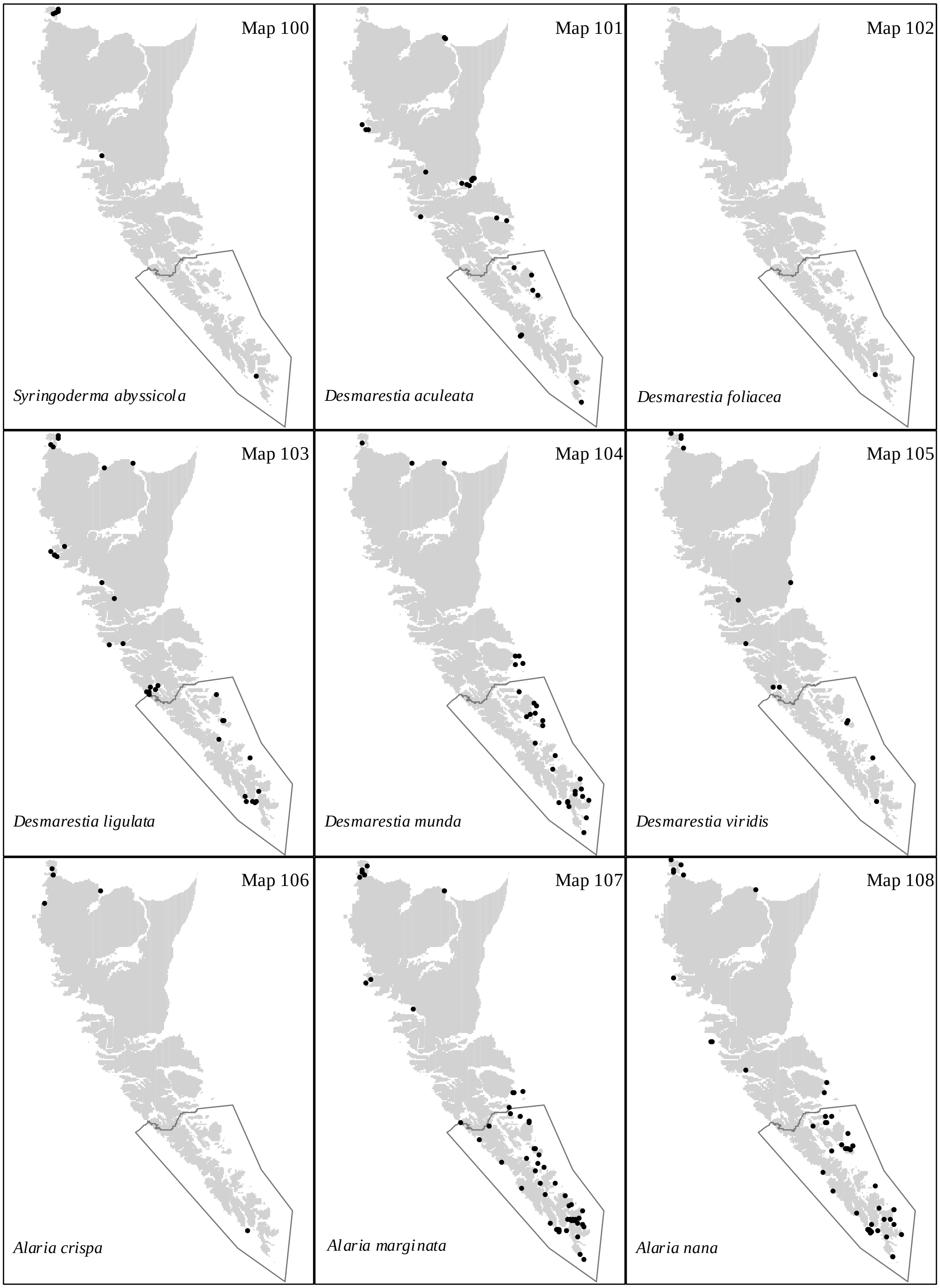

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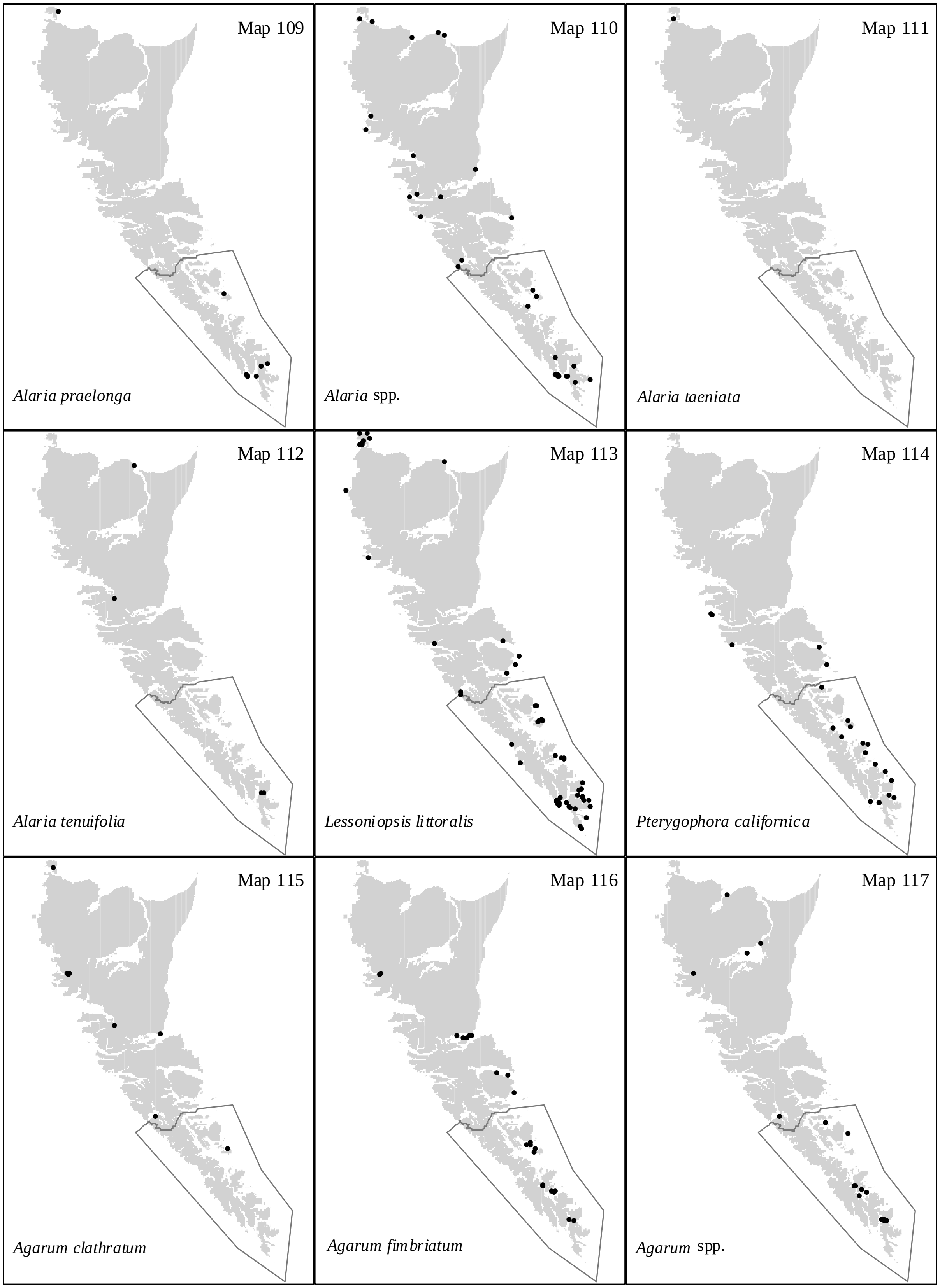

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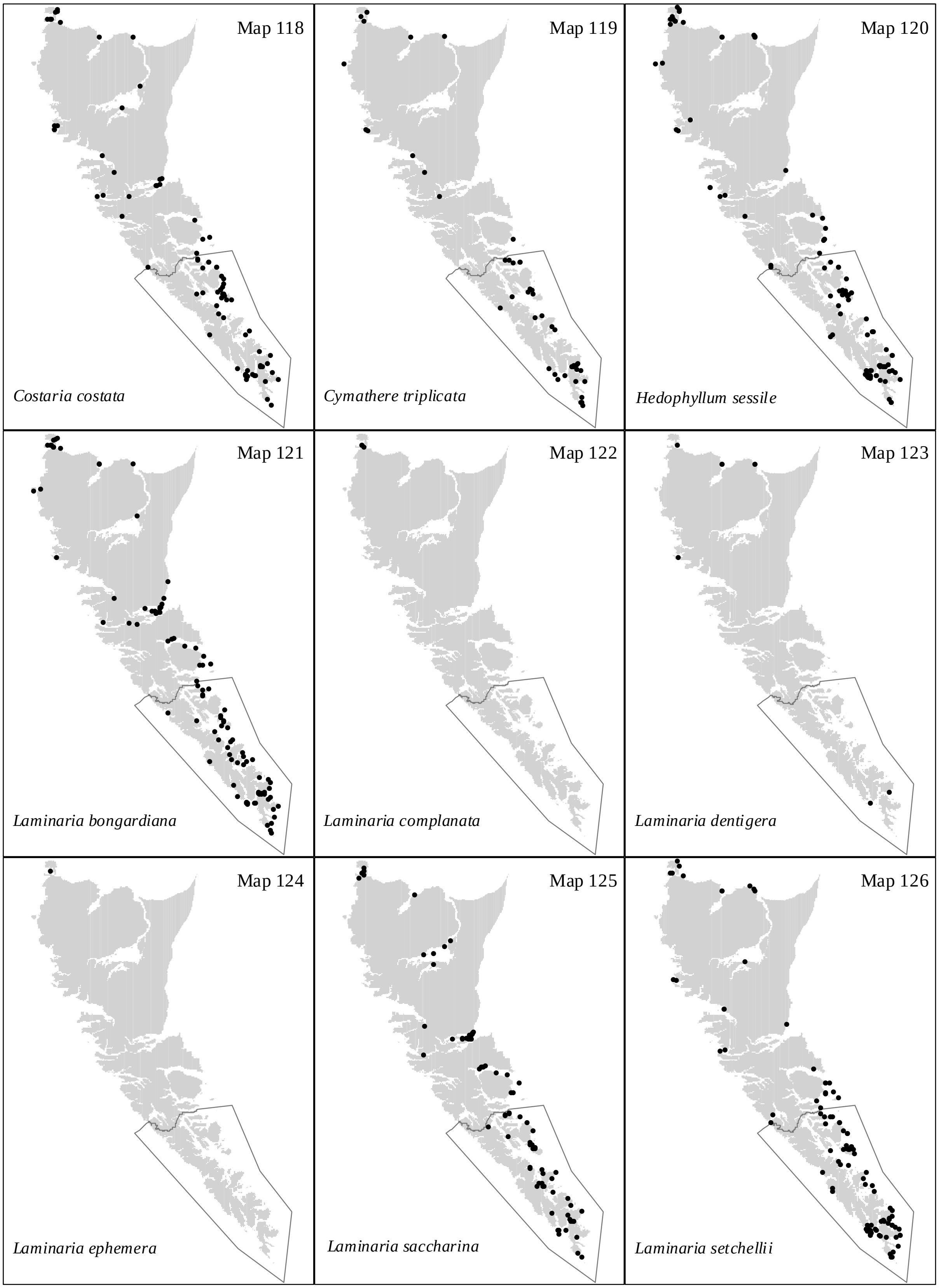

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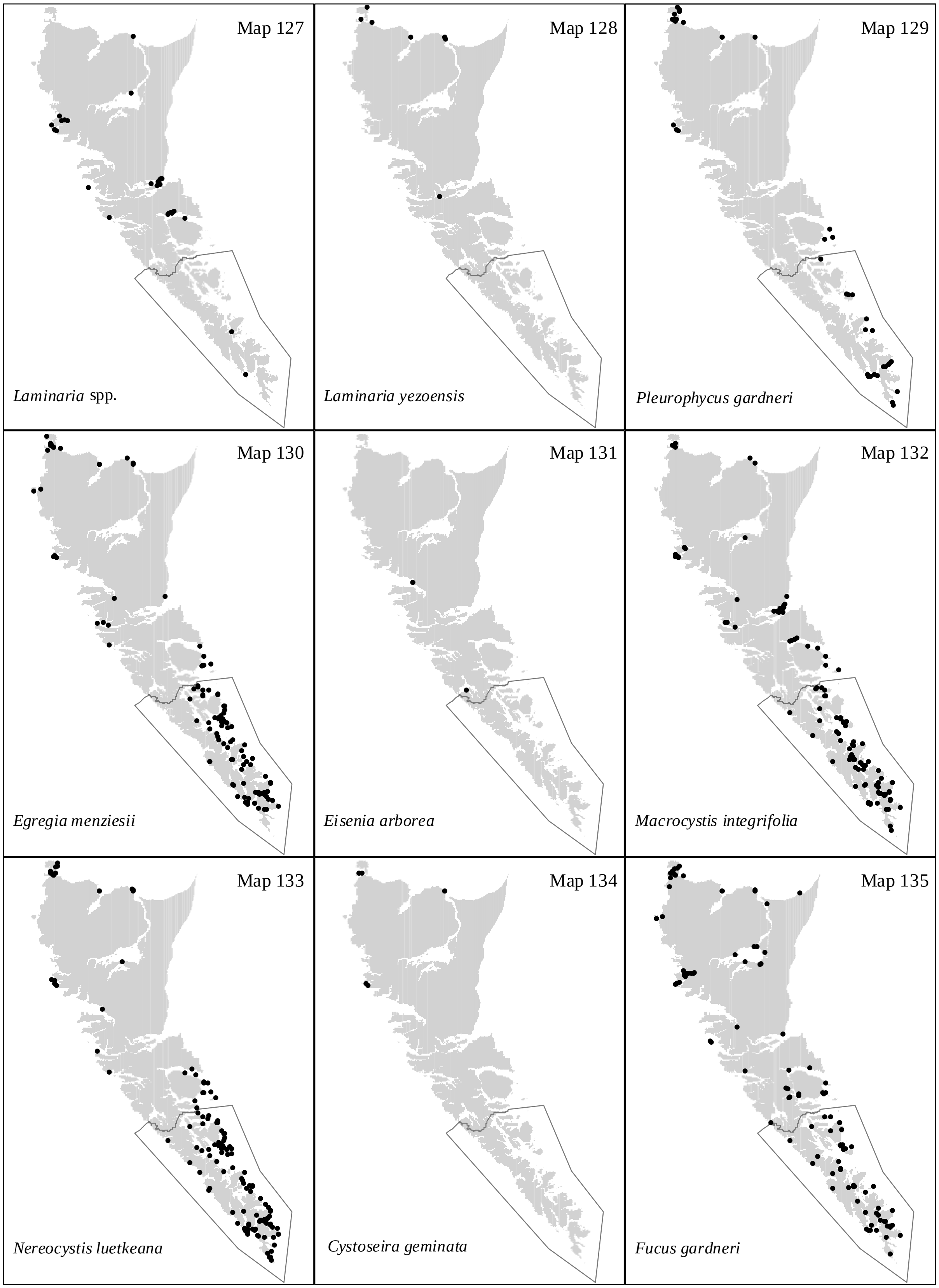

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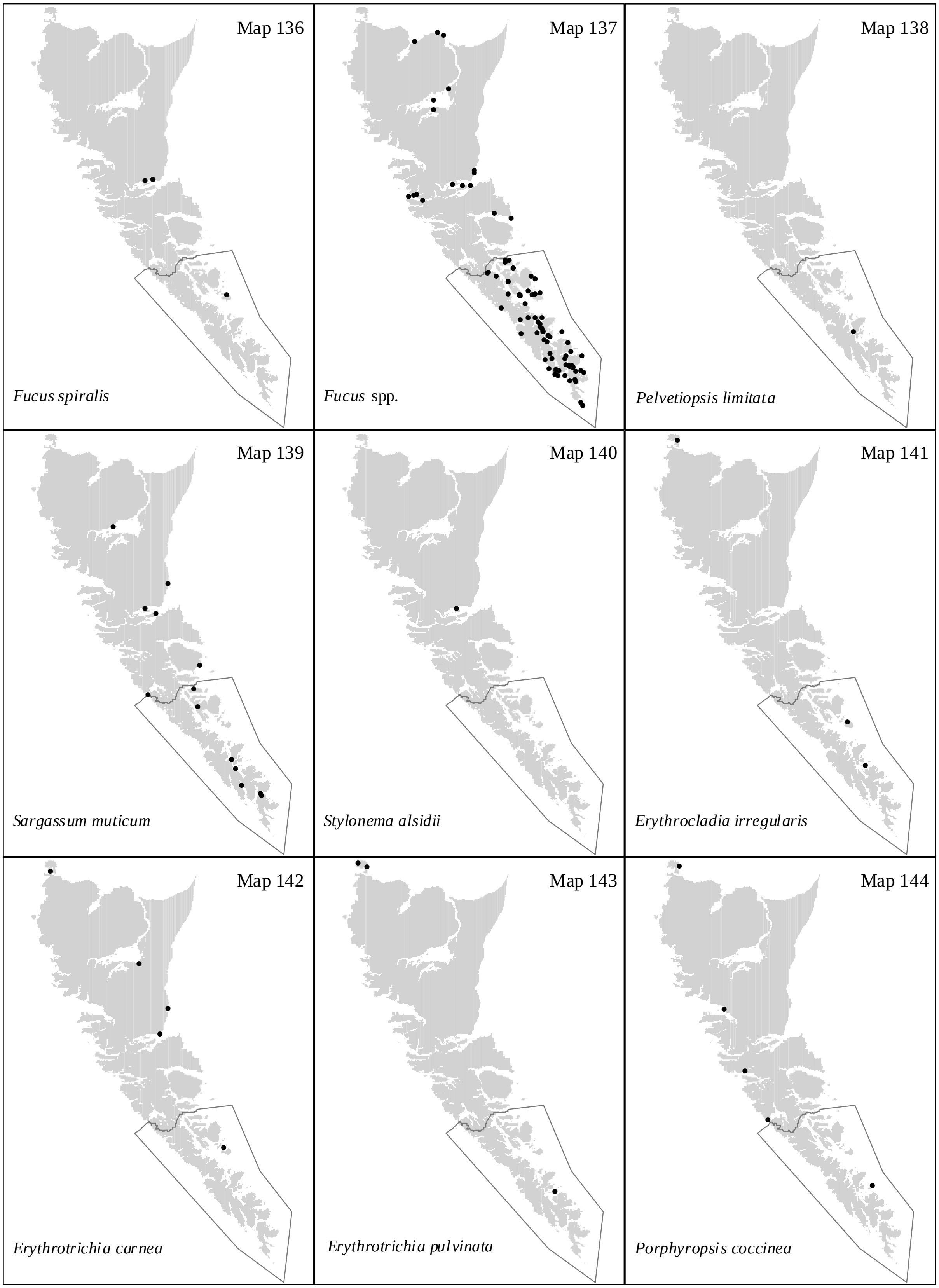
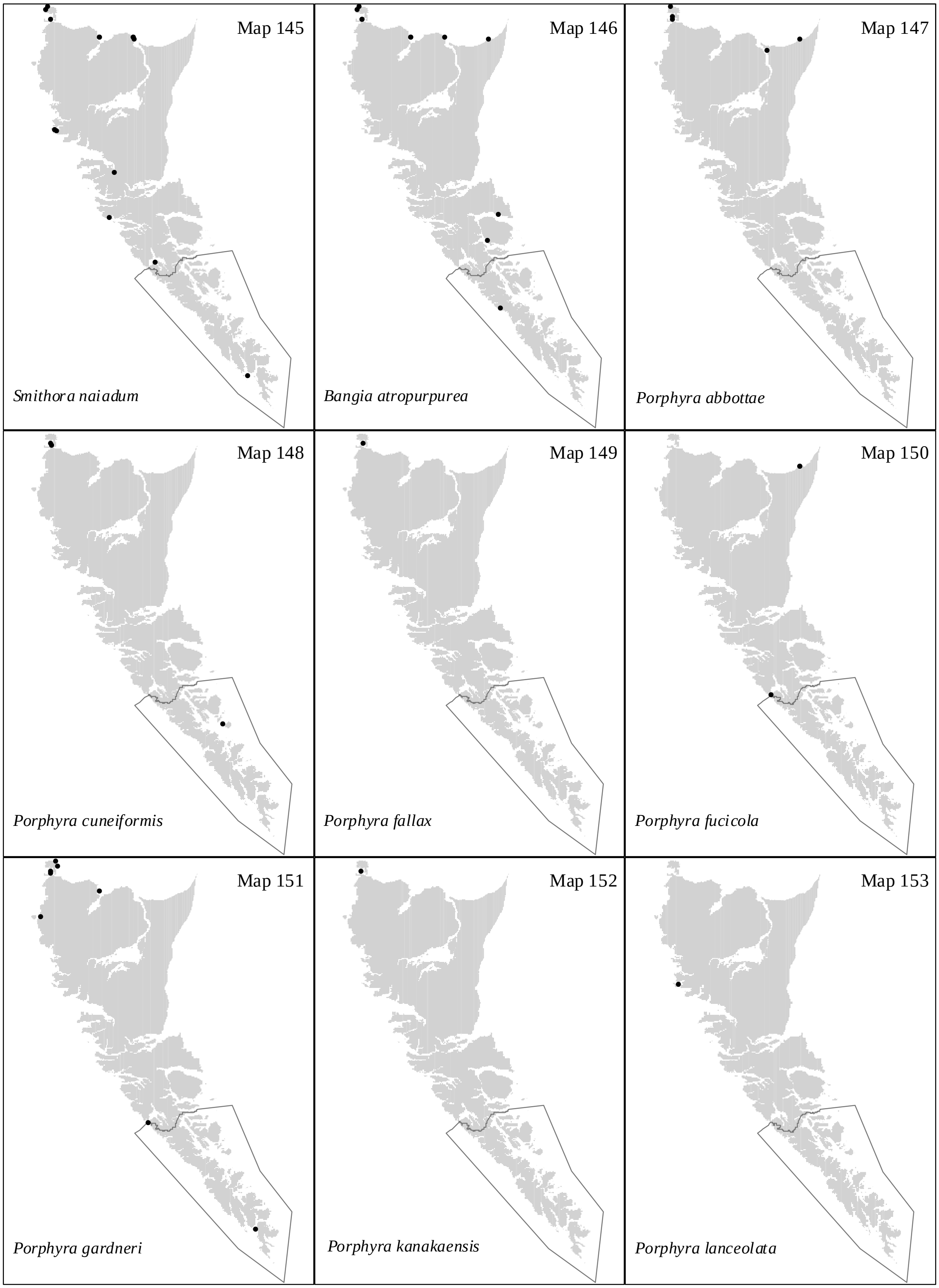


Phaeophyta and Rhodophyta.



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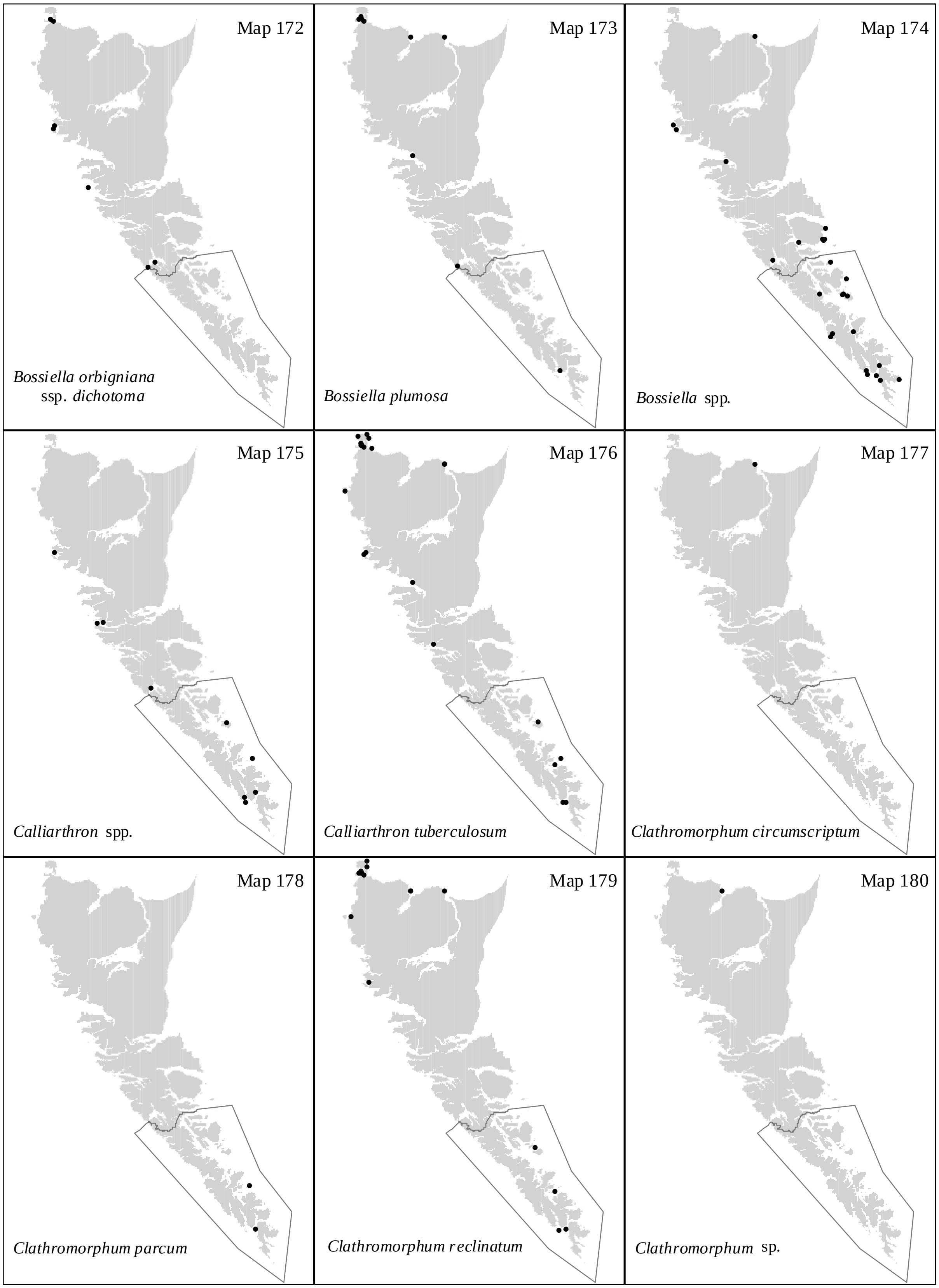

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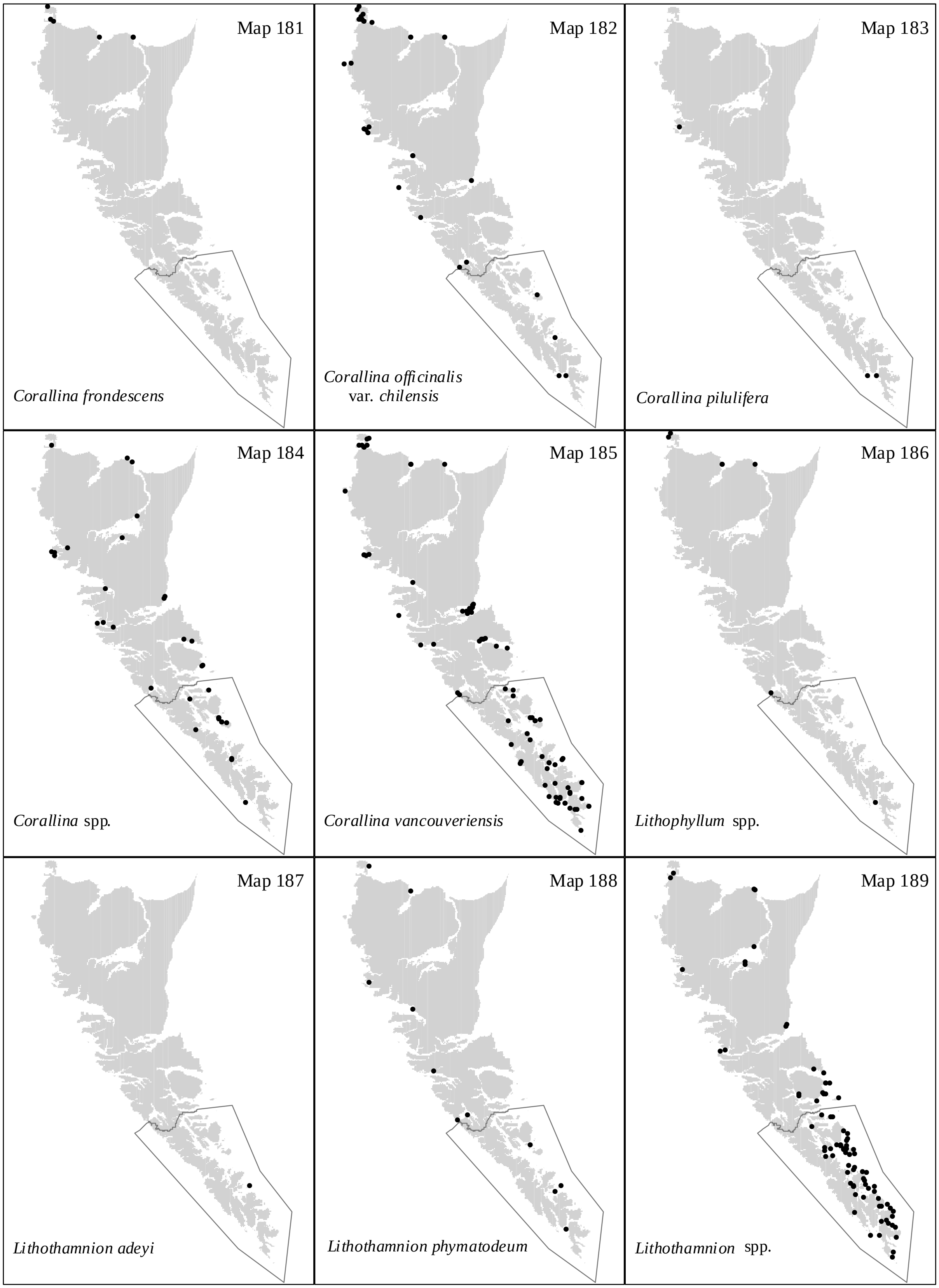

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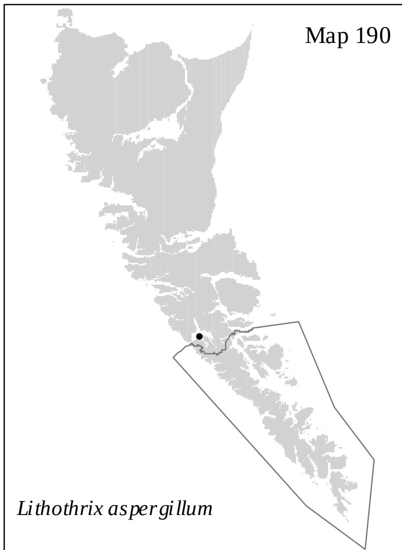
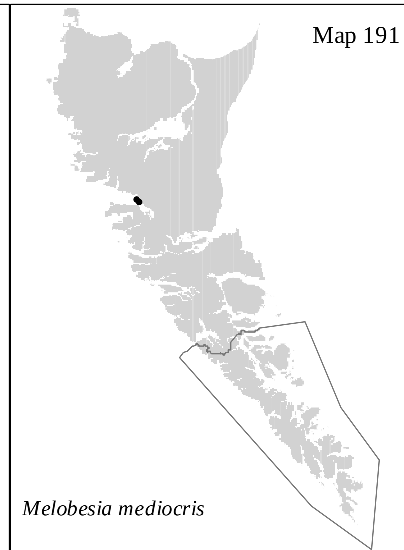
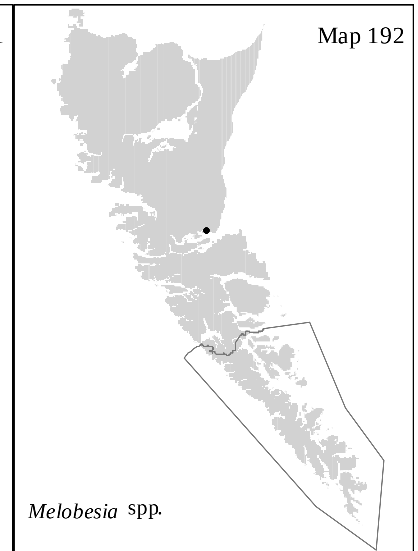
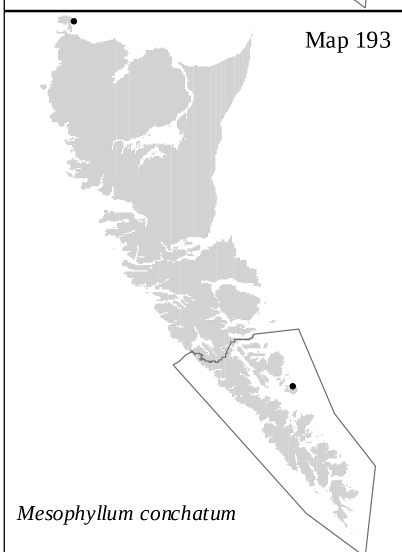
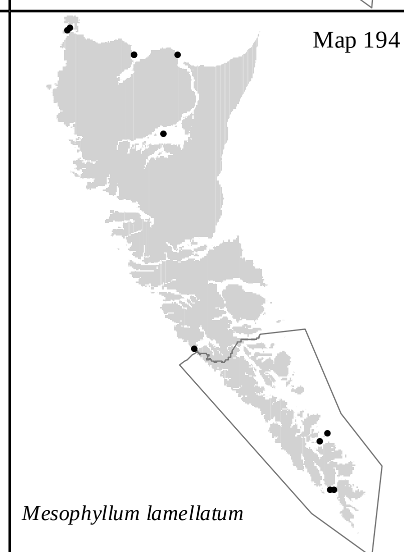
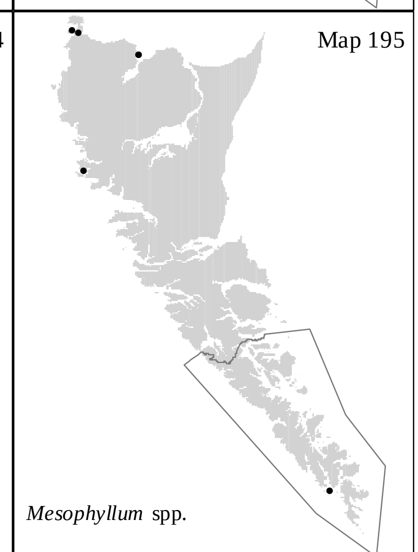


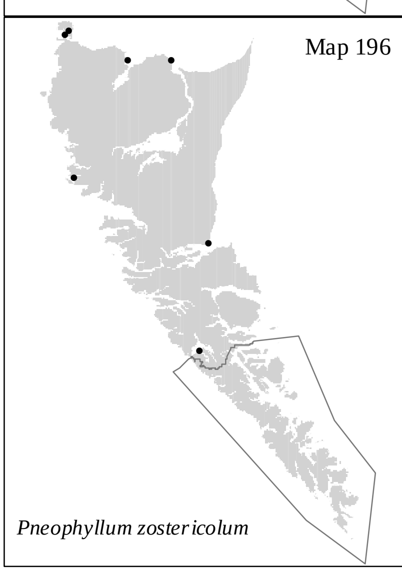


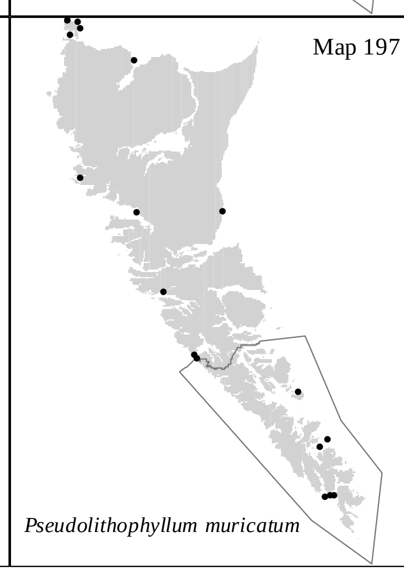


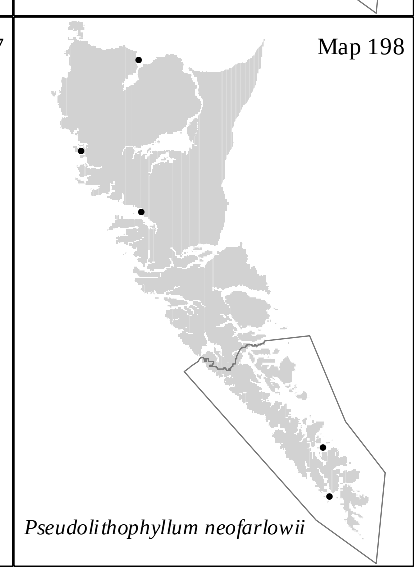






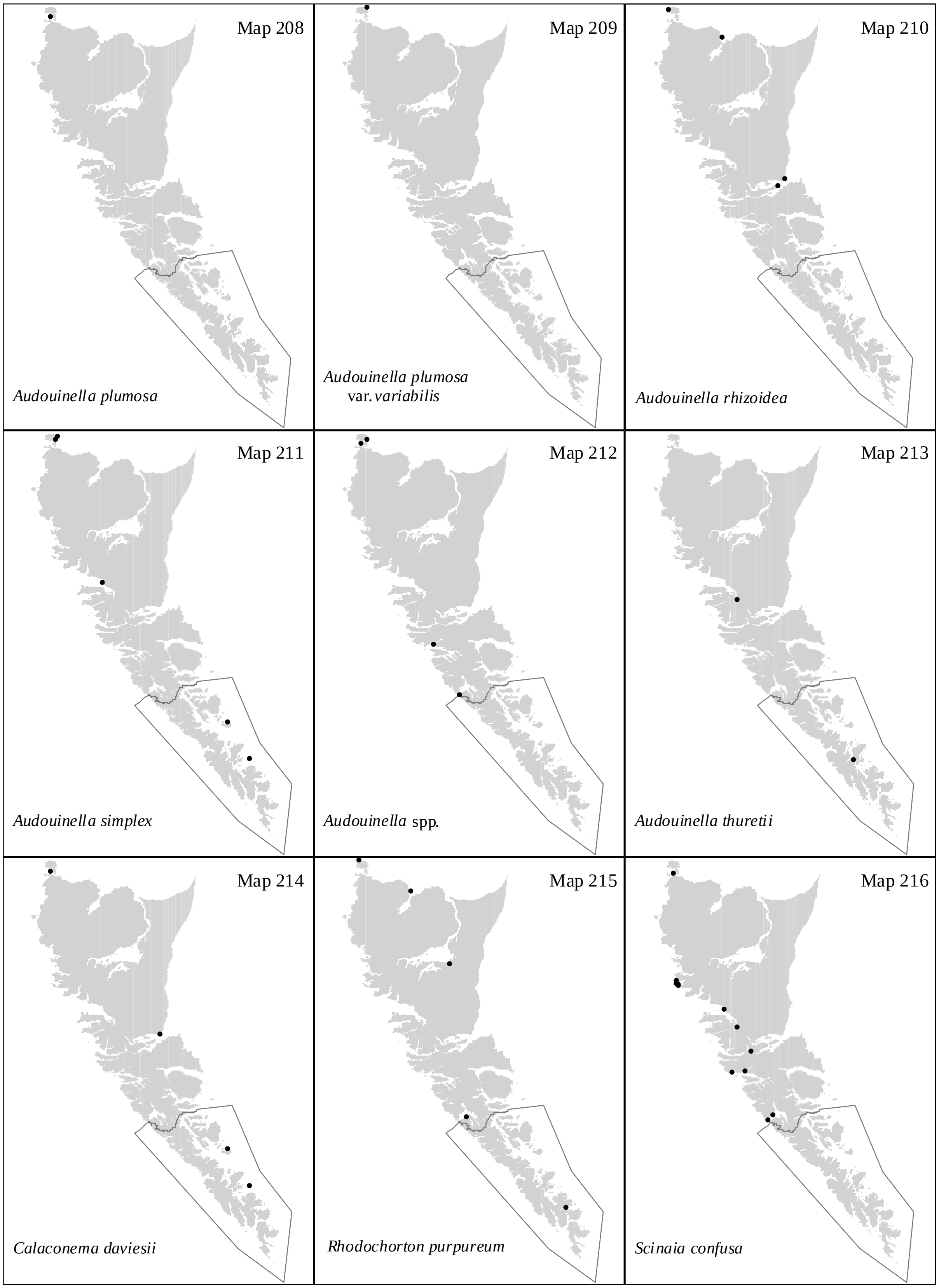






Rhodophyta continued.

Rhodophyta continued.



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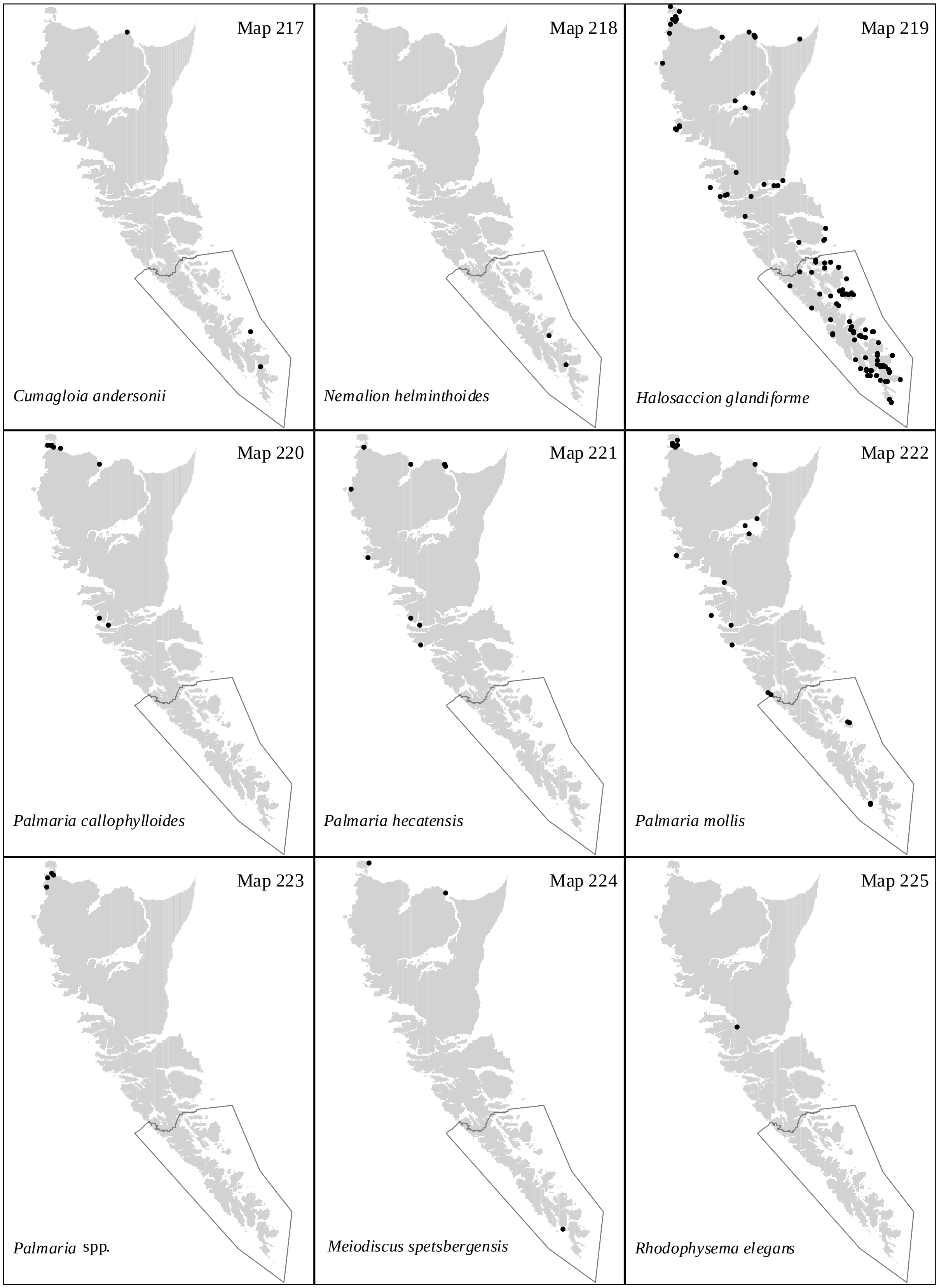

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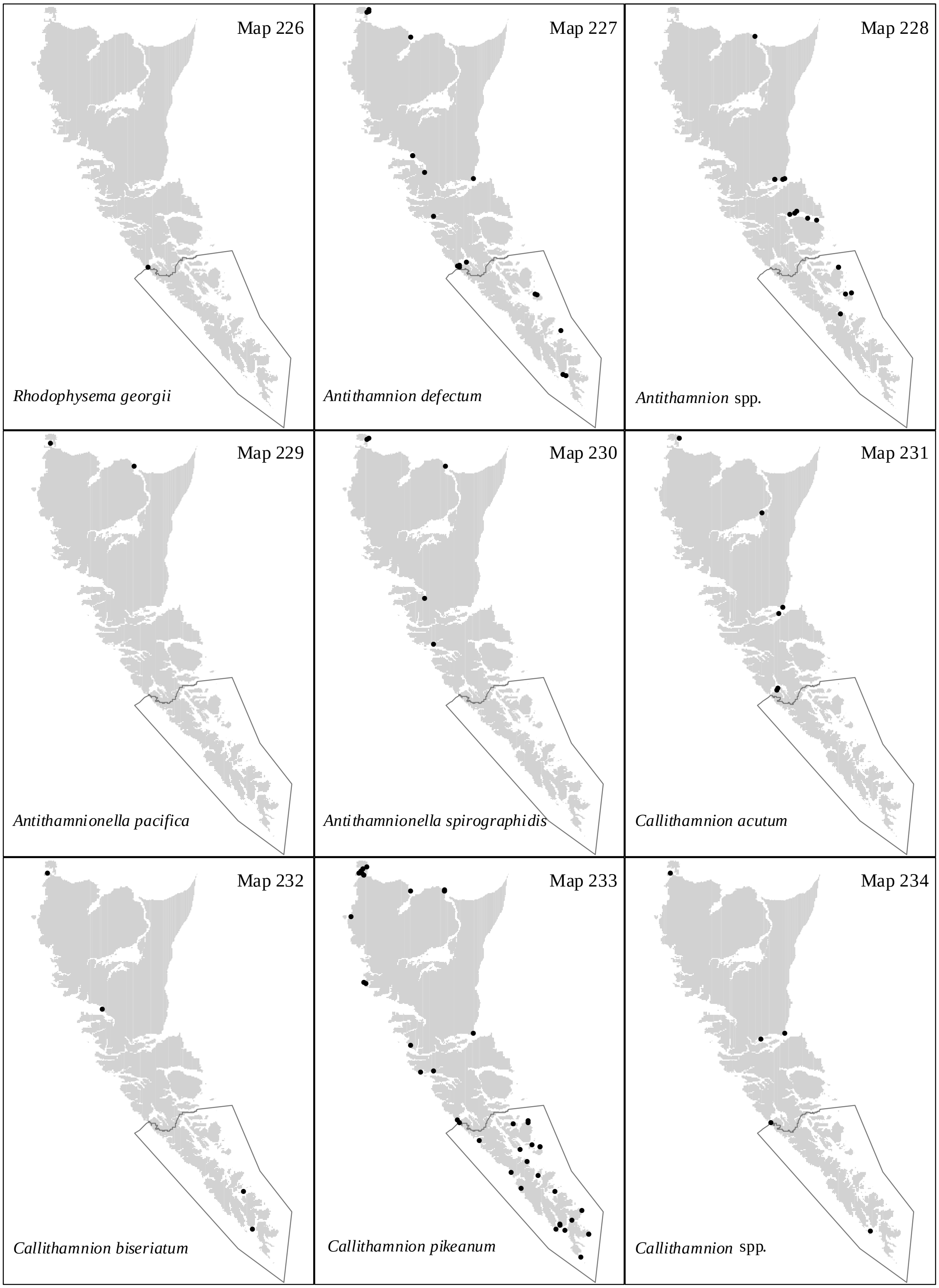

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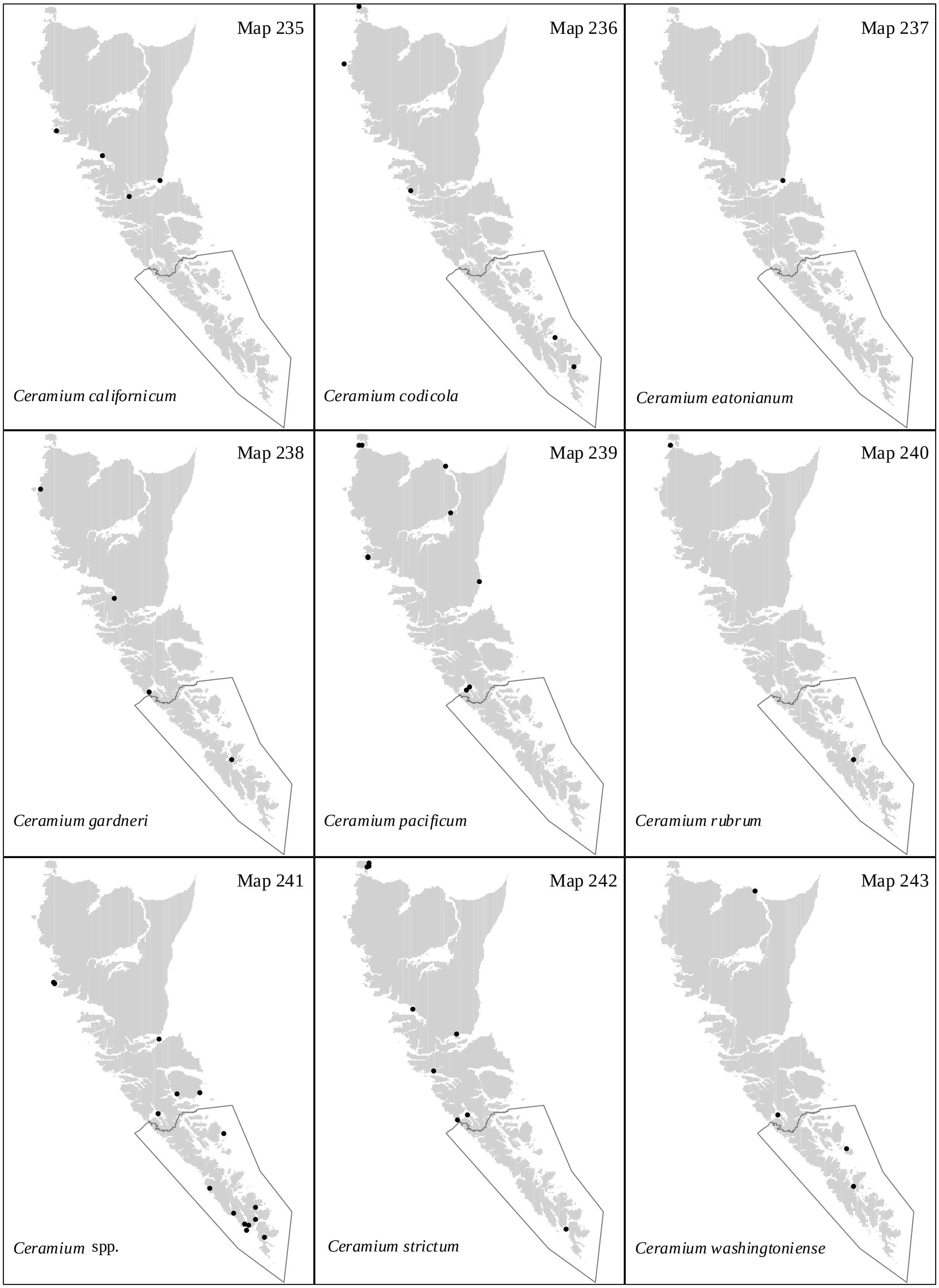

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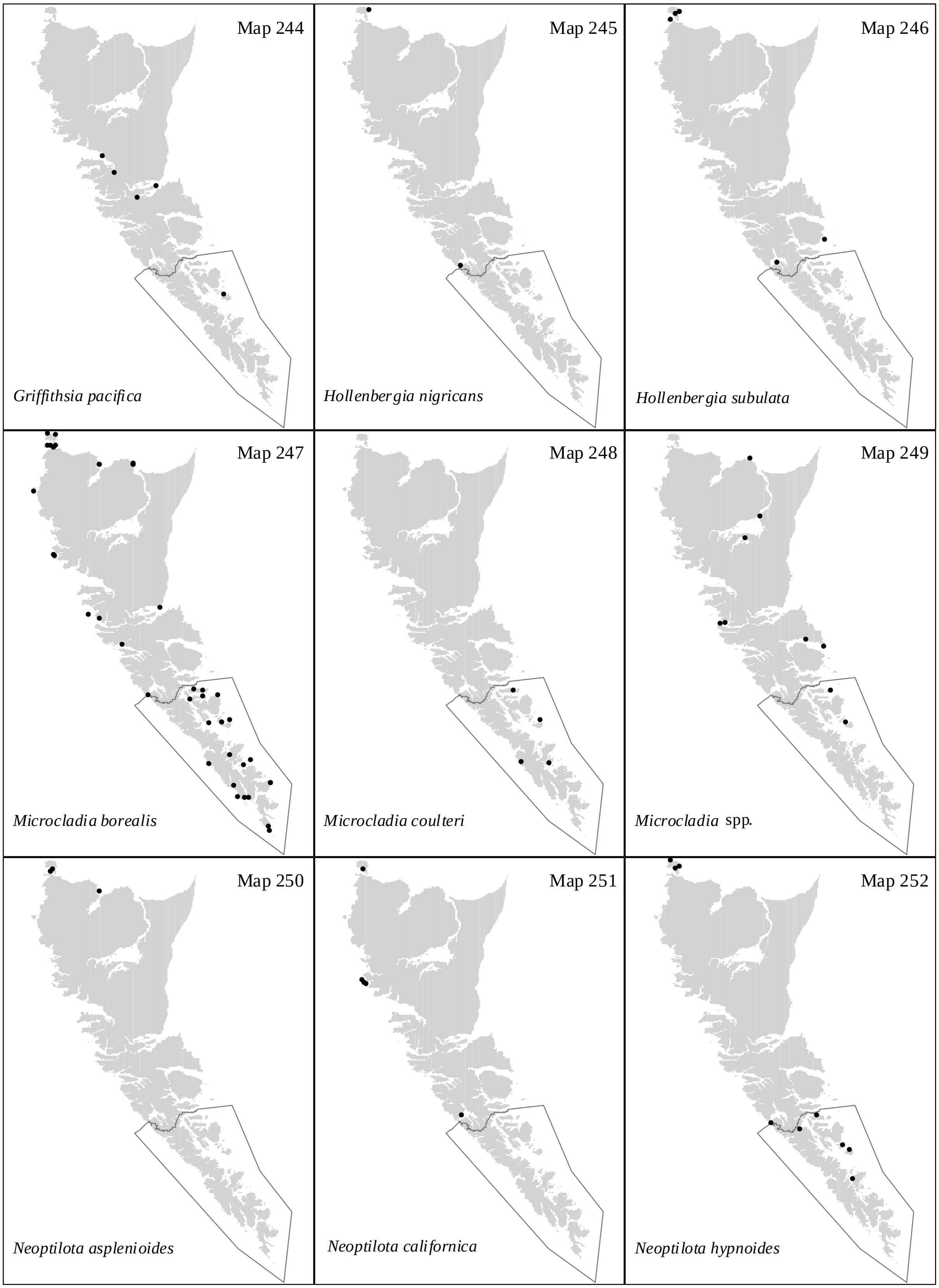

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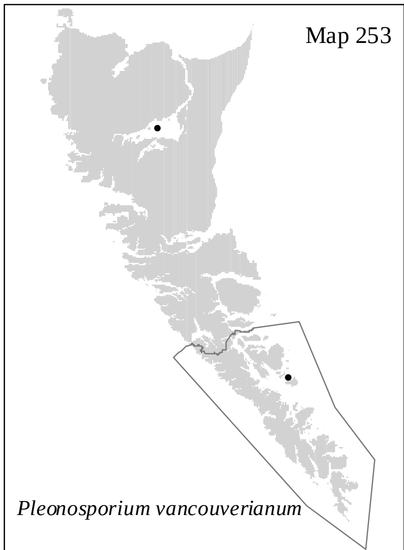

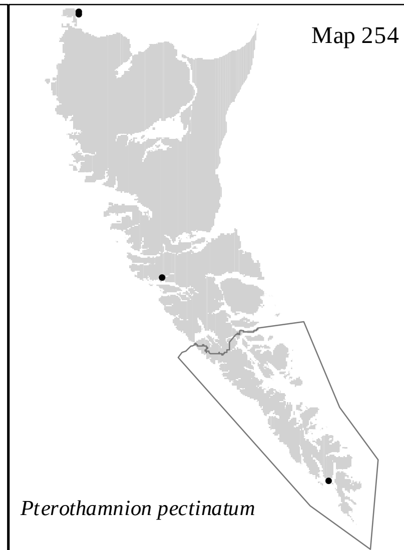

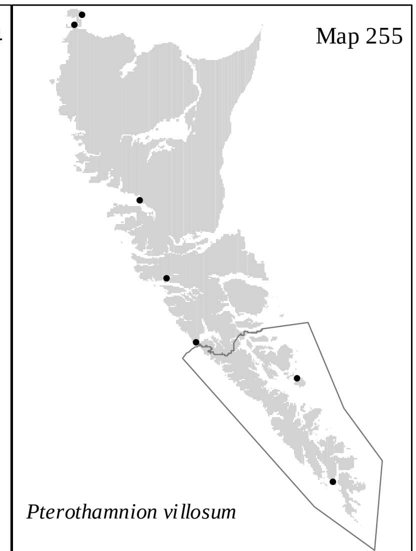

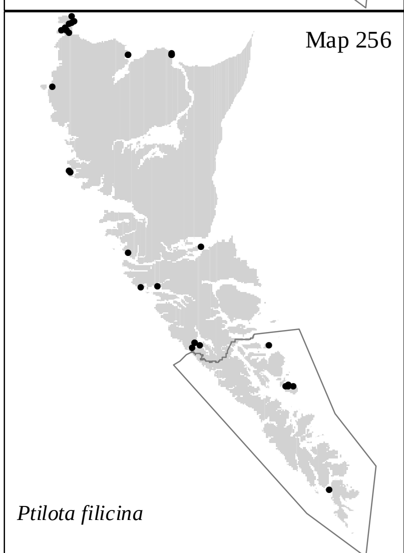

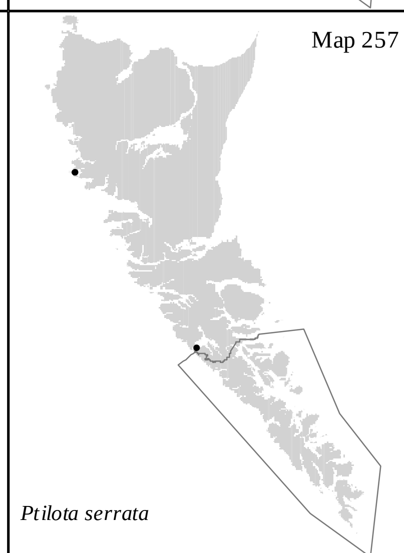

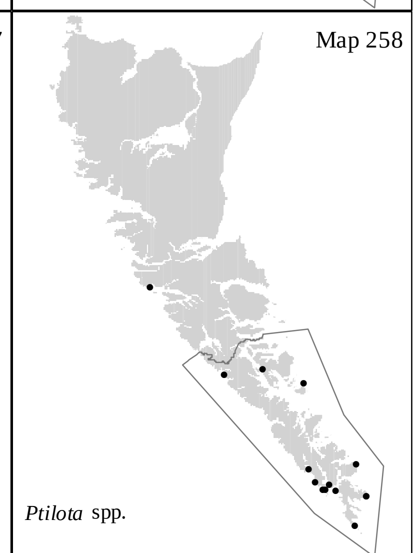

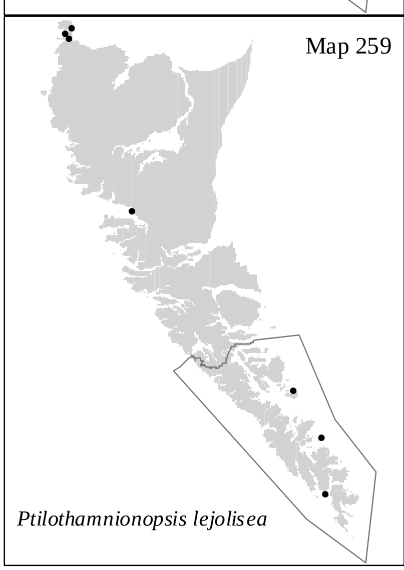

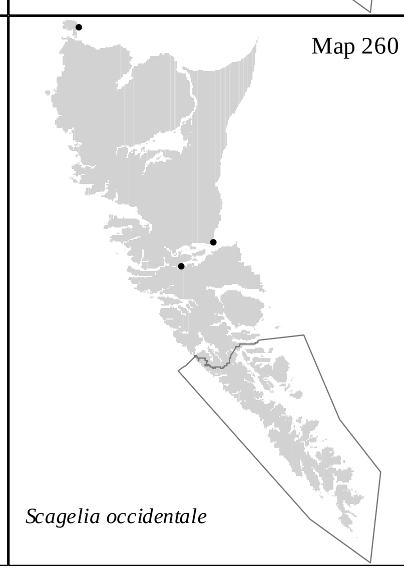

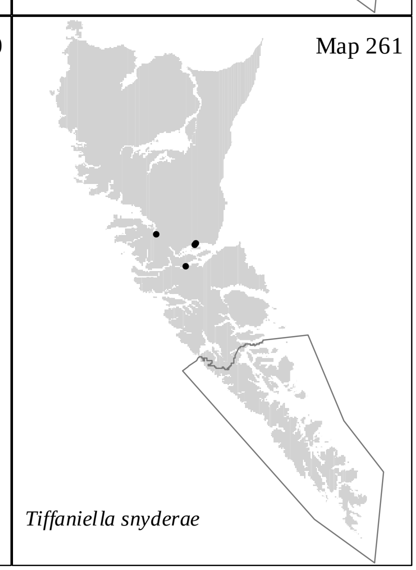

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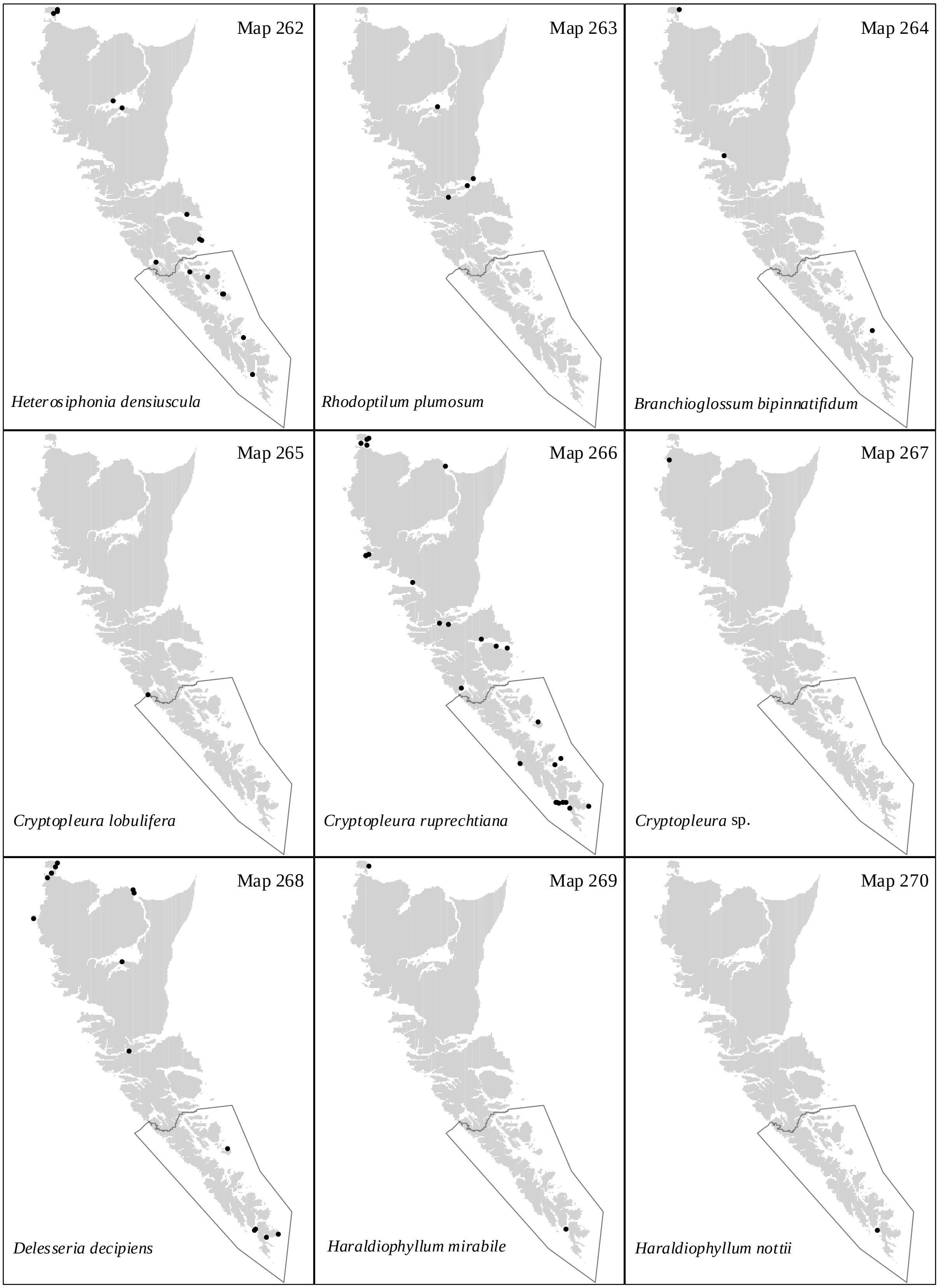

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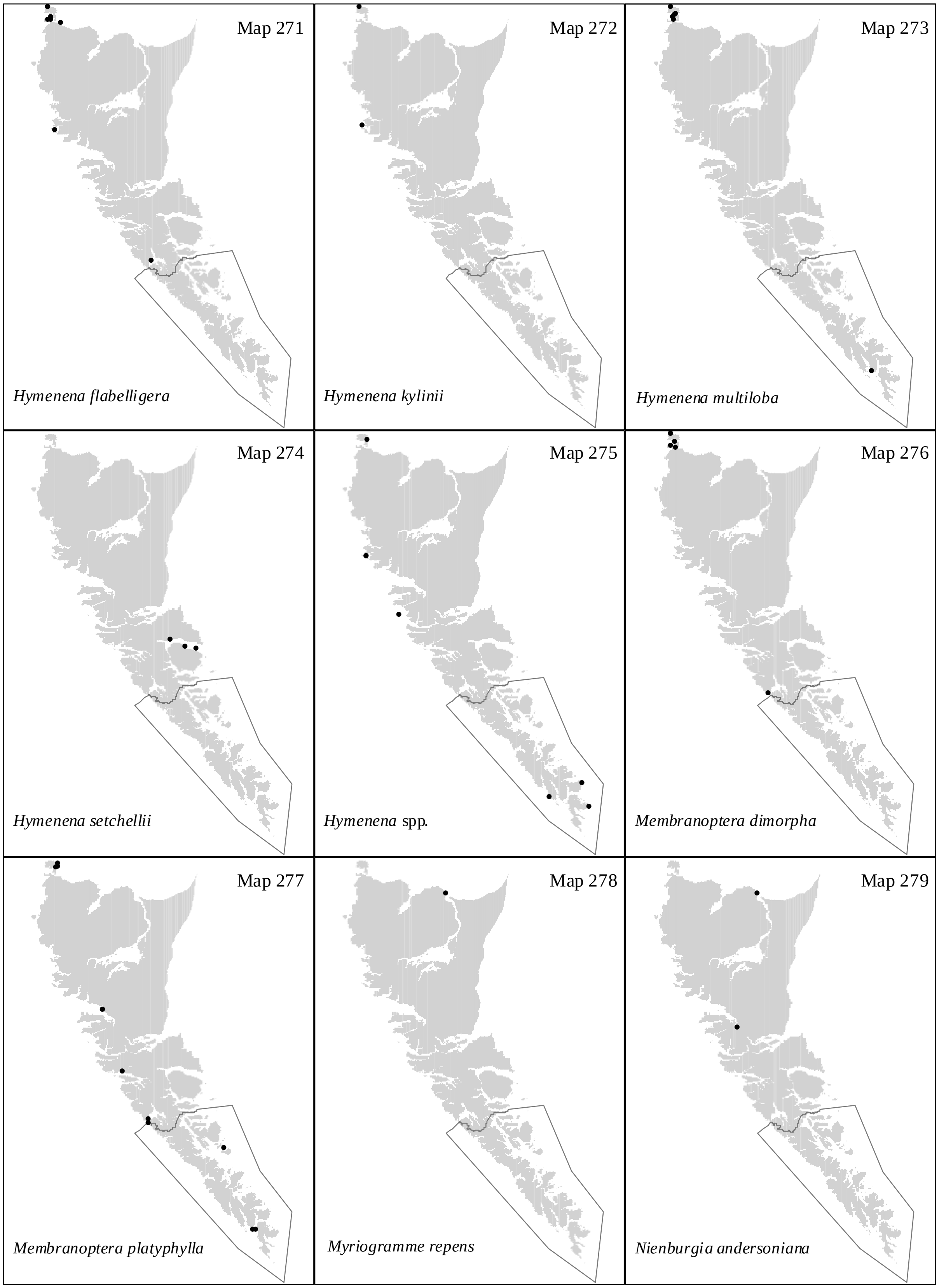

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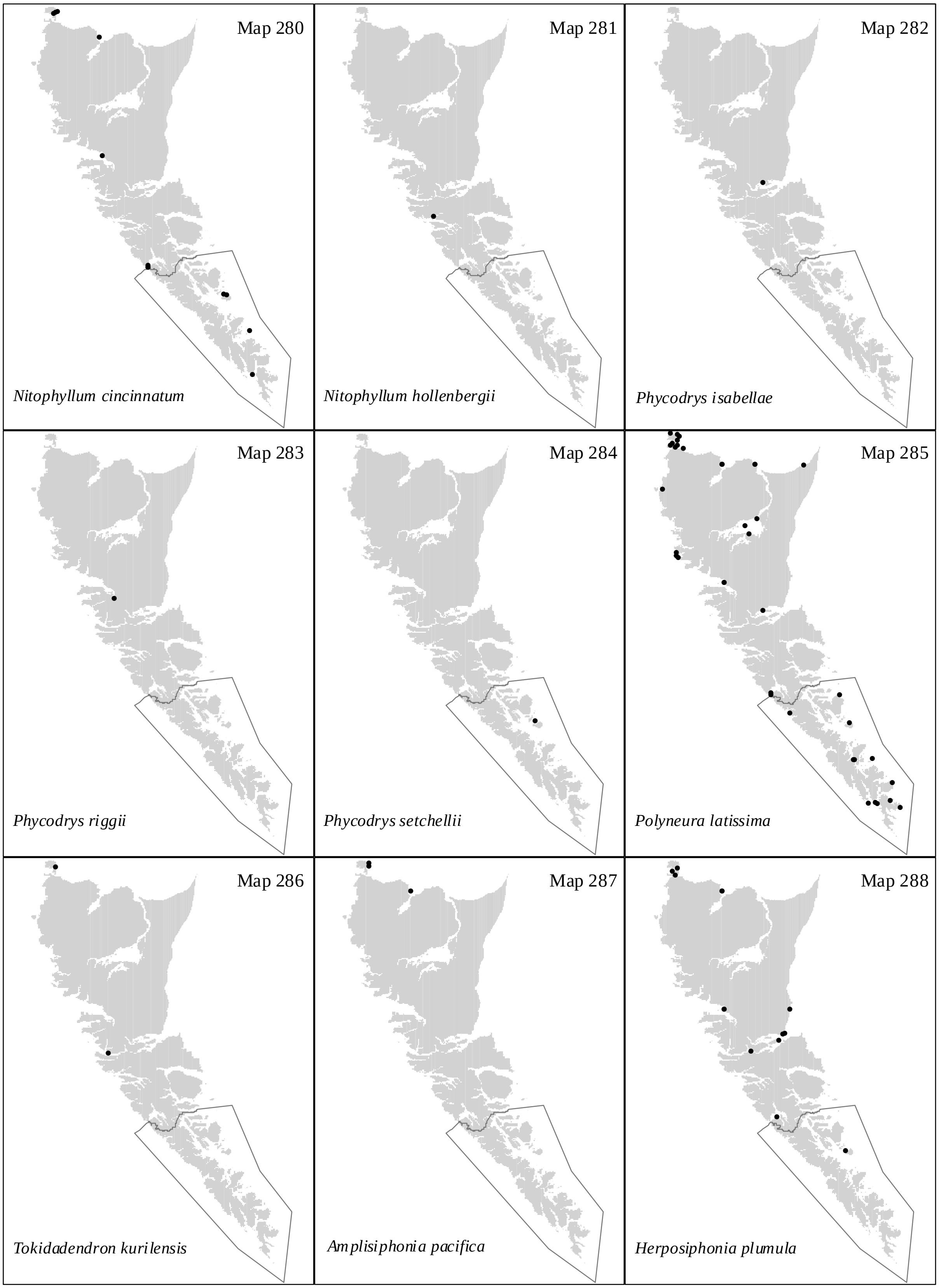

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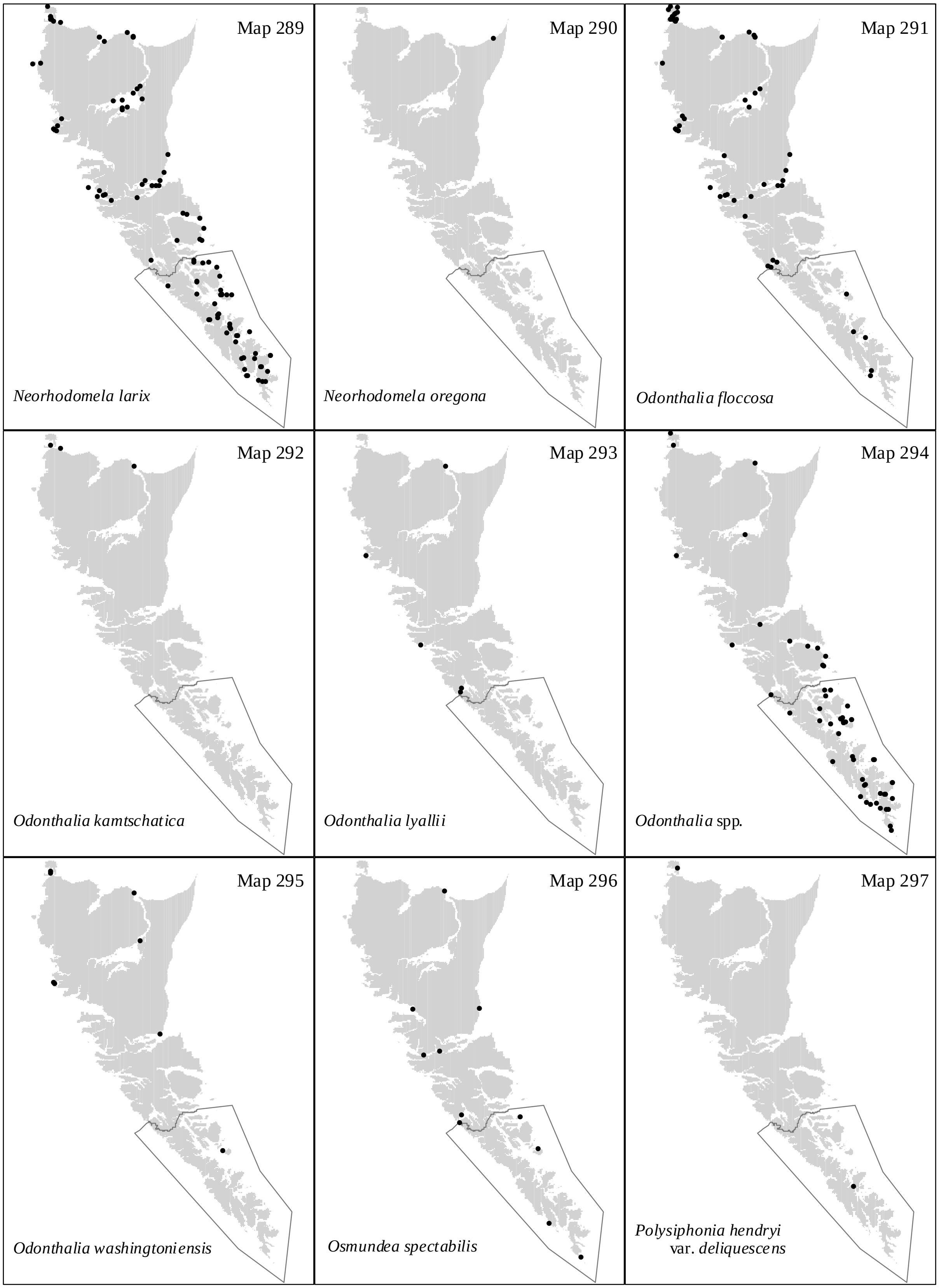

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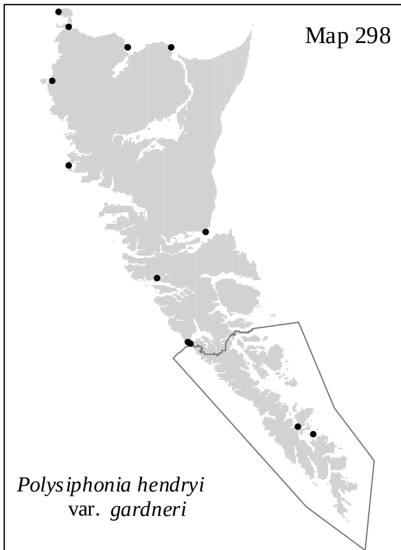

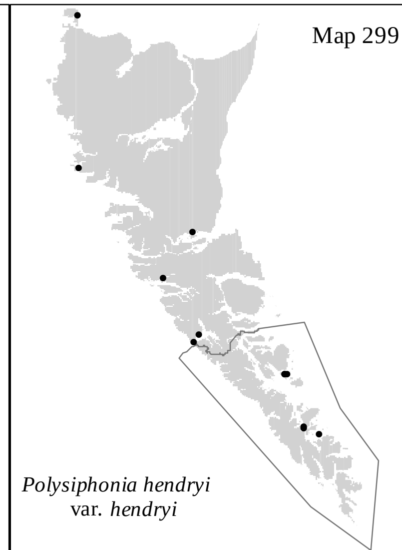

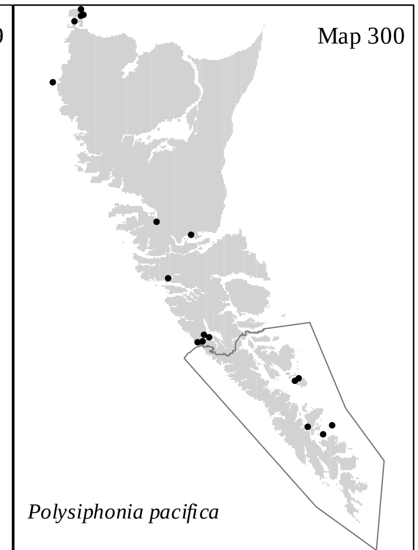

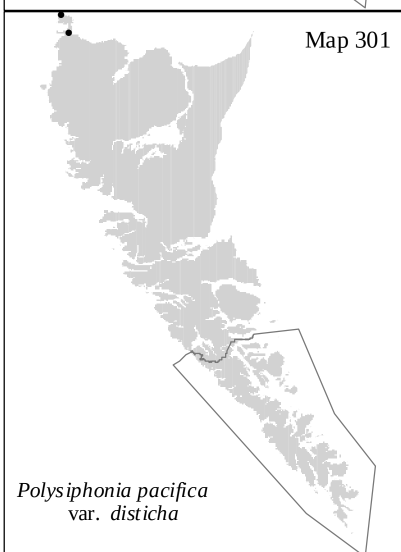

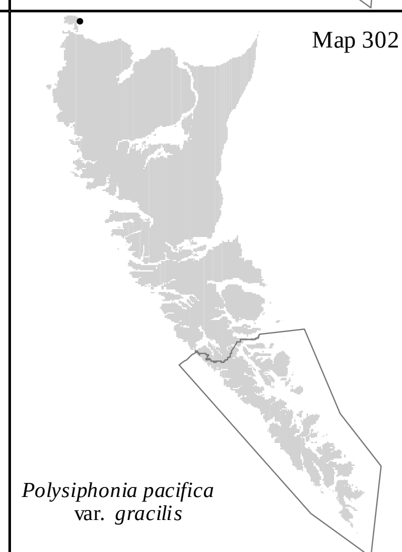

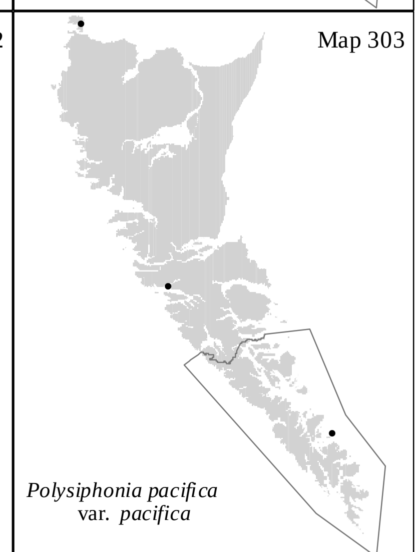

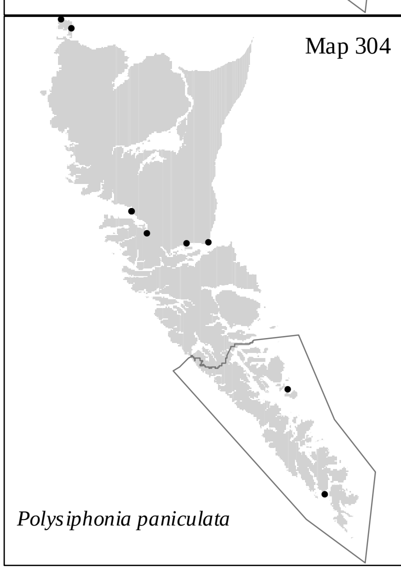

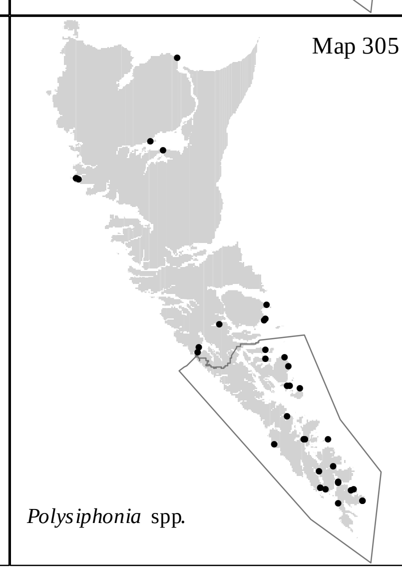

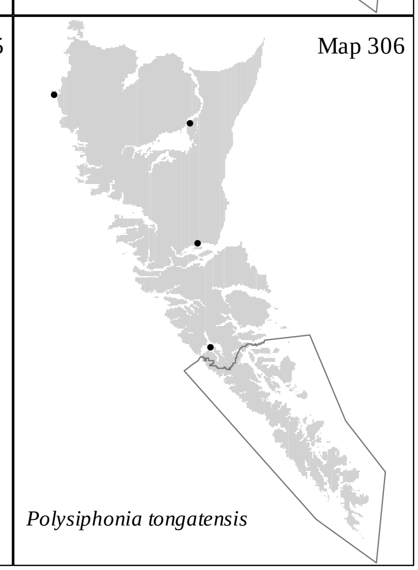

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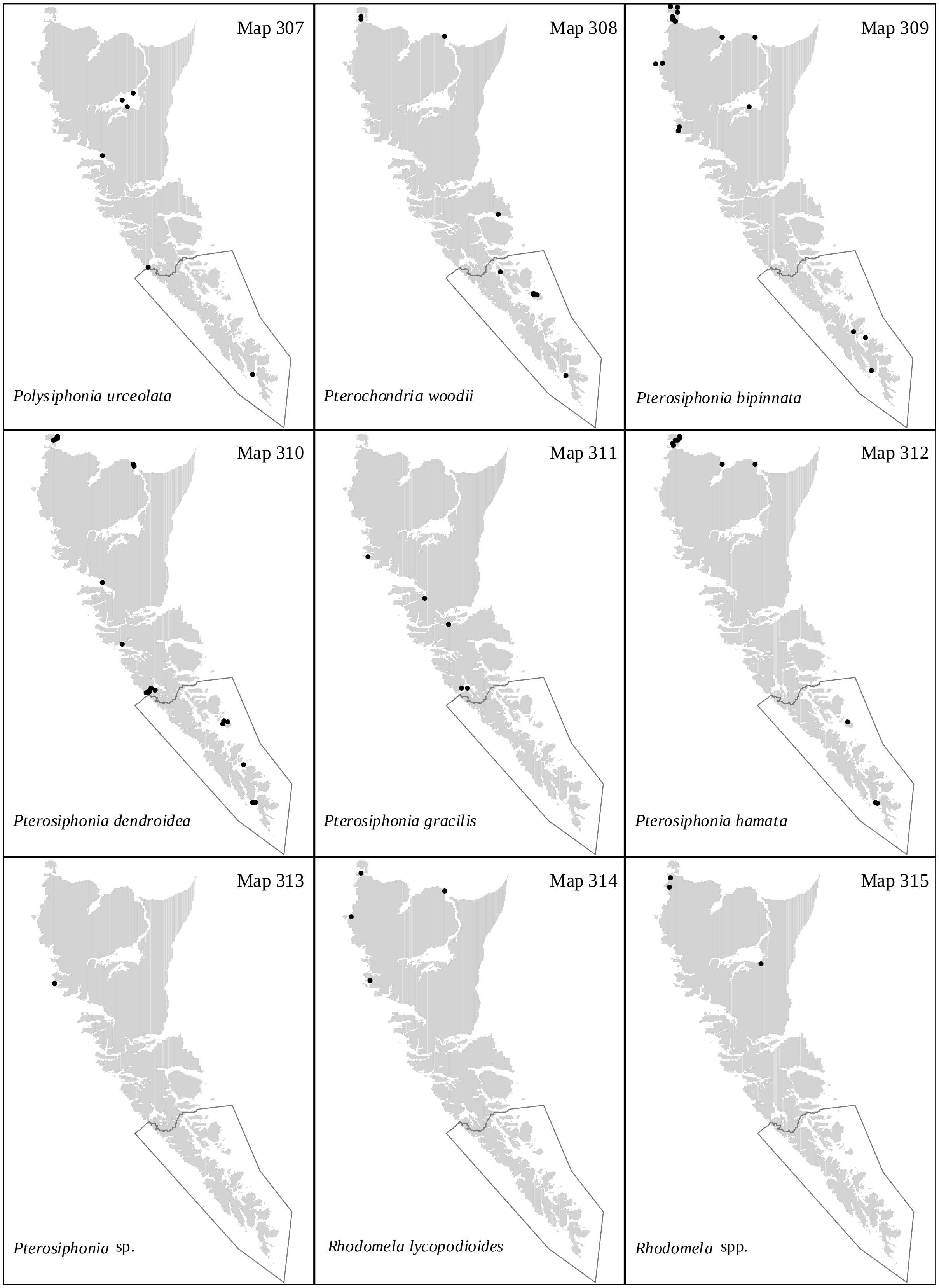

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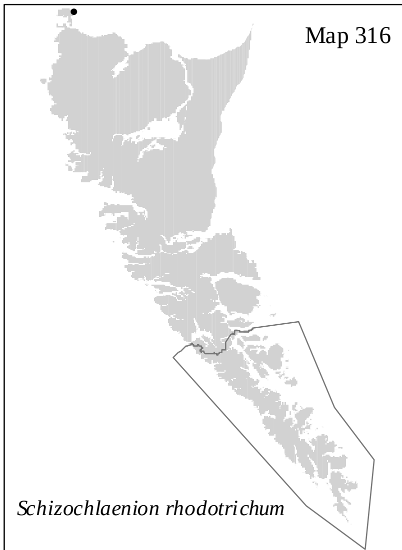

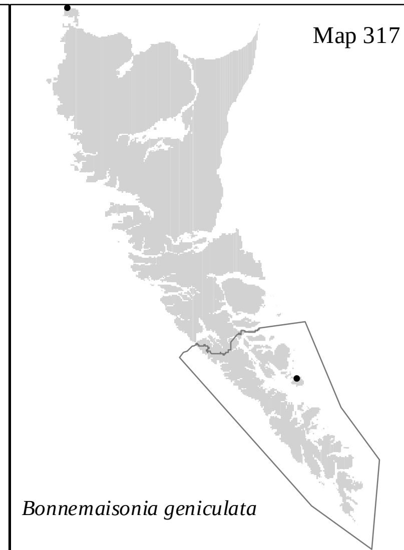

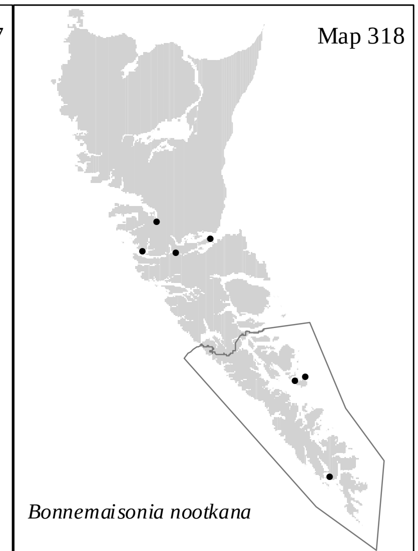

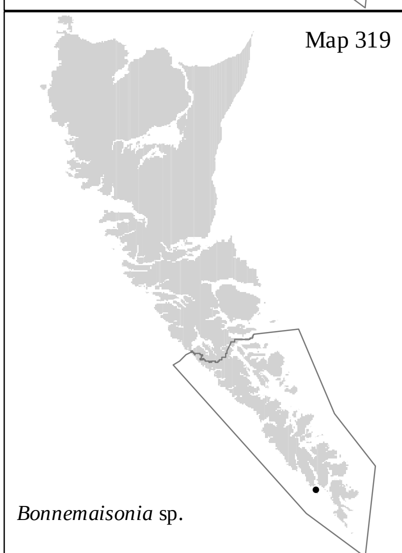

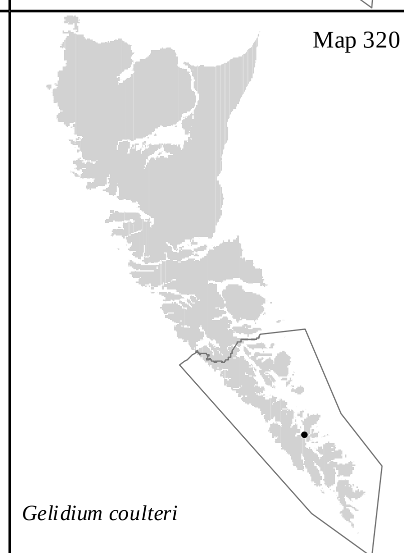

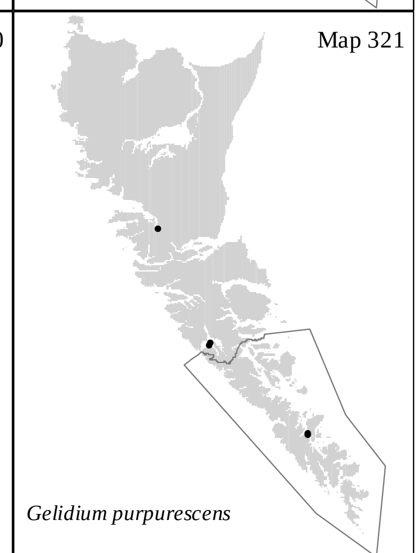

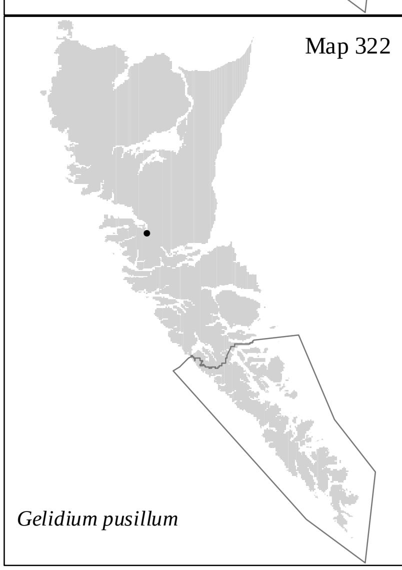

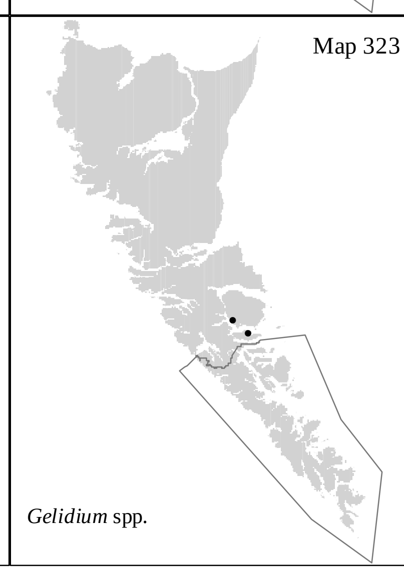

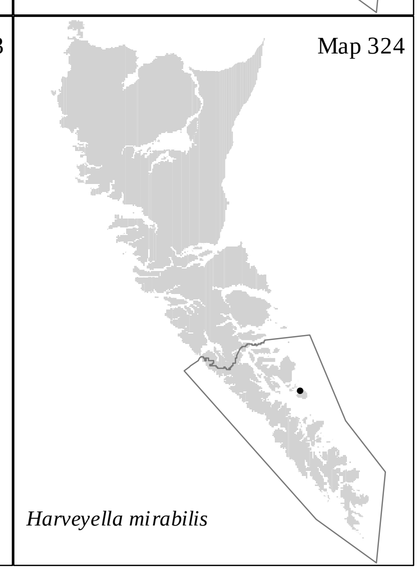

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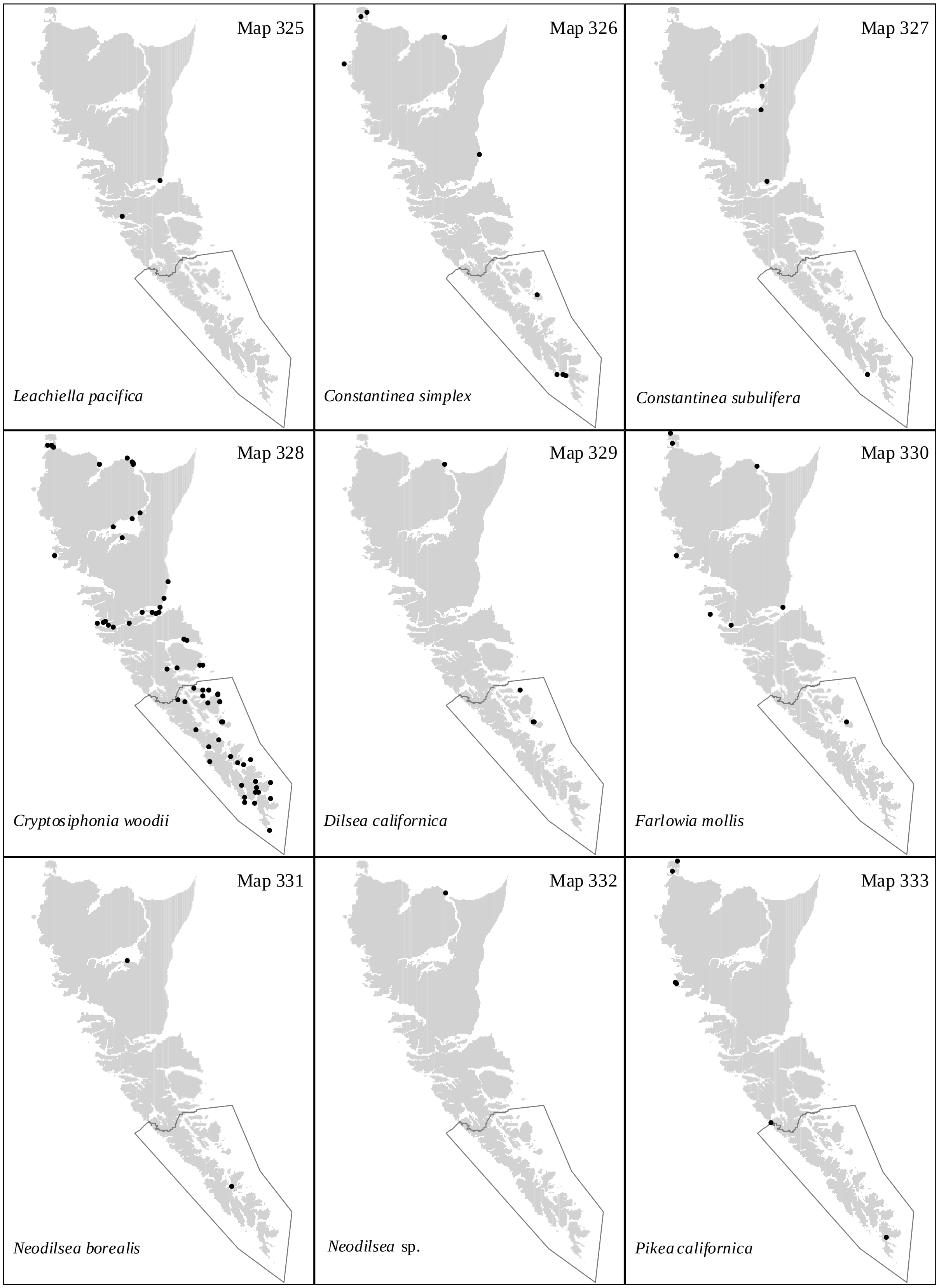

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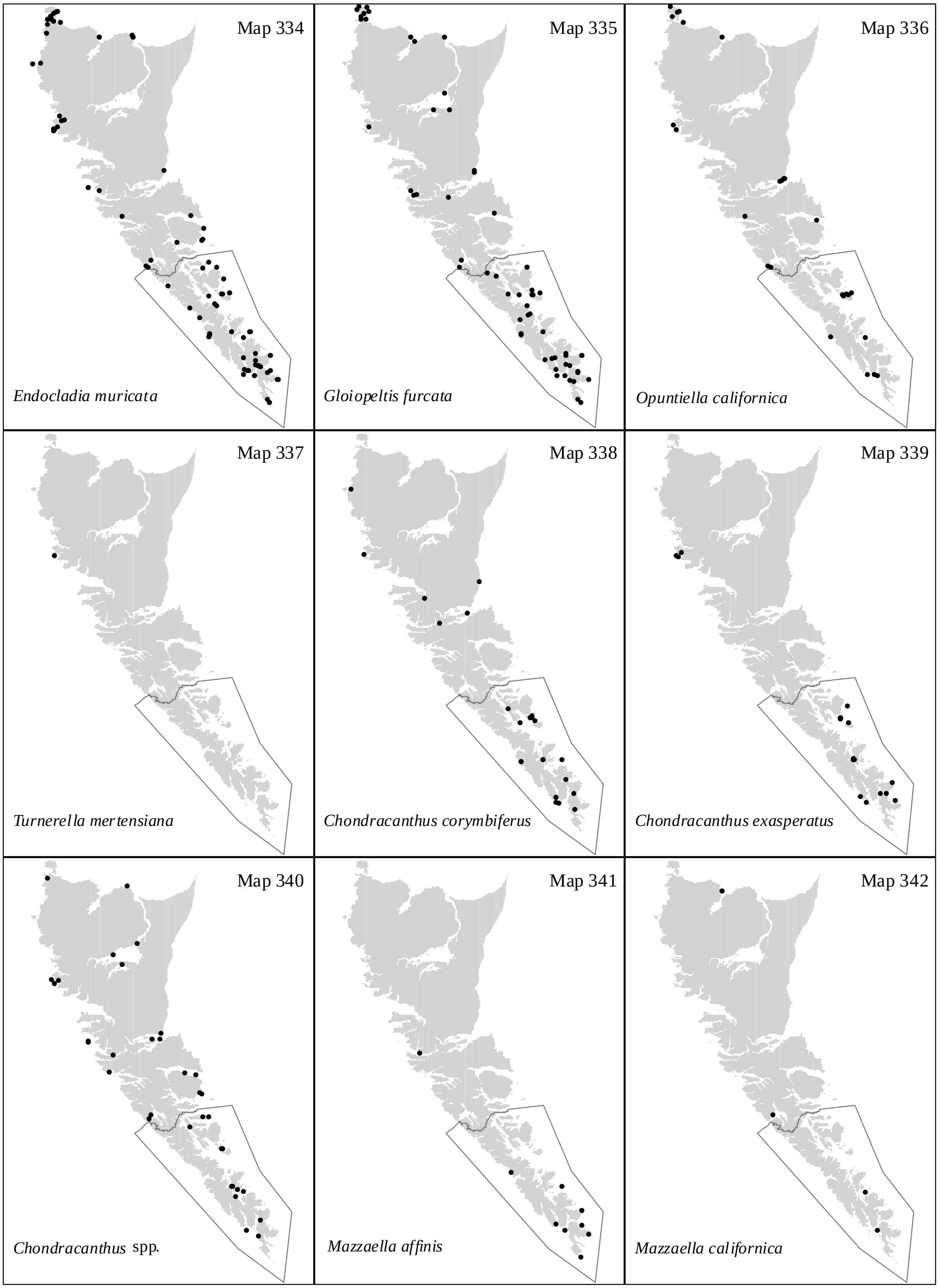

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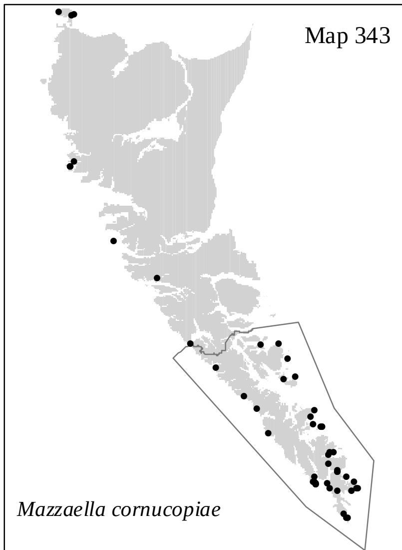

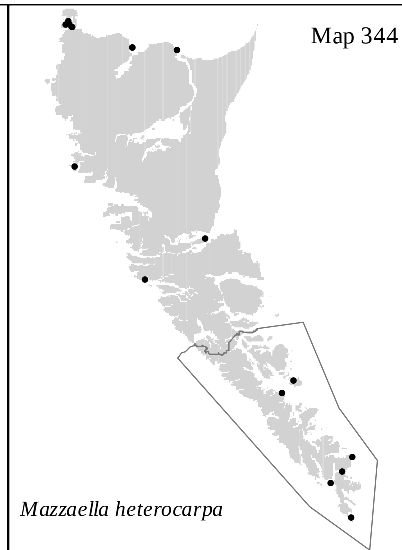

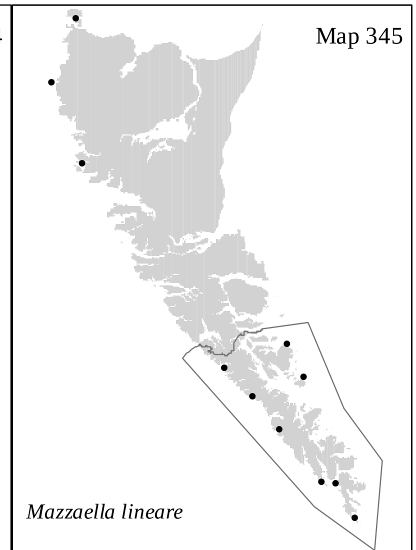

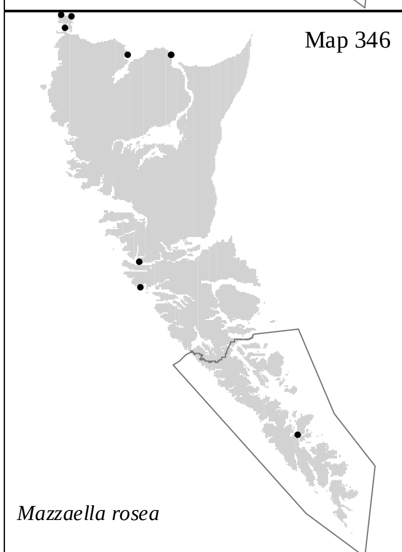

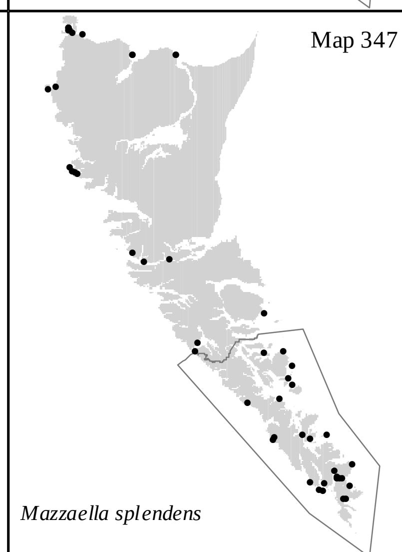

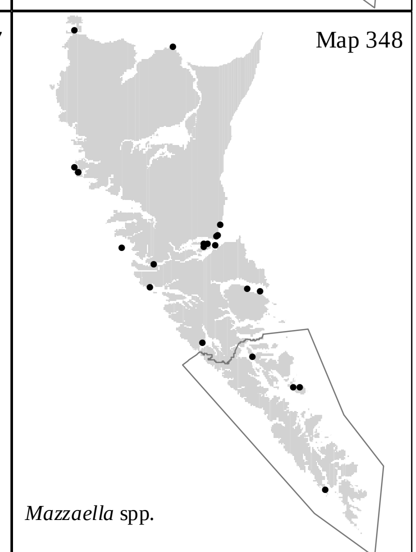

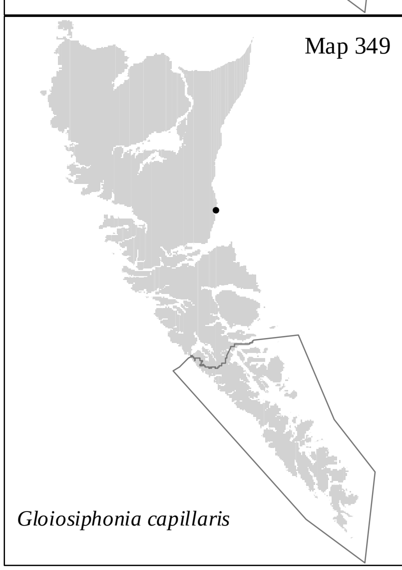

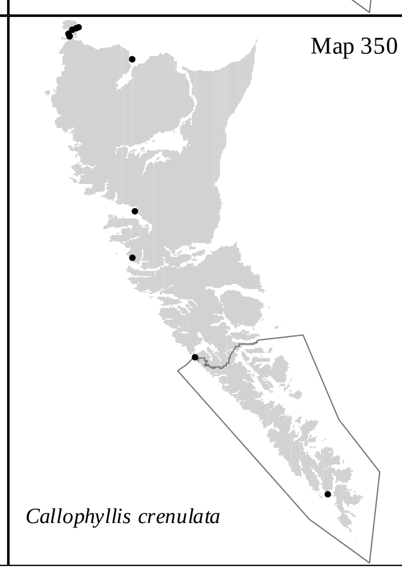

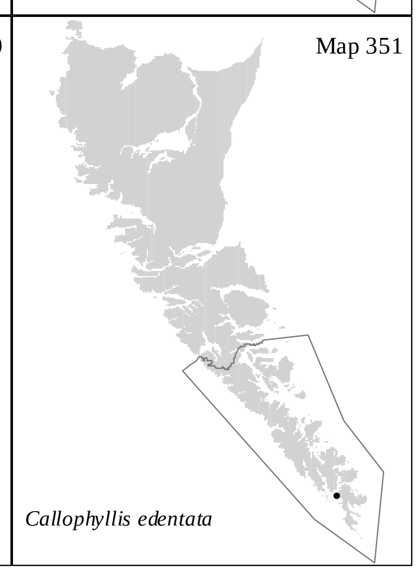

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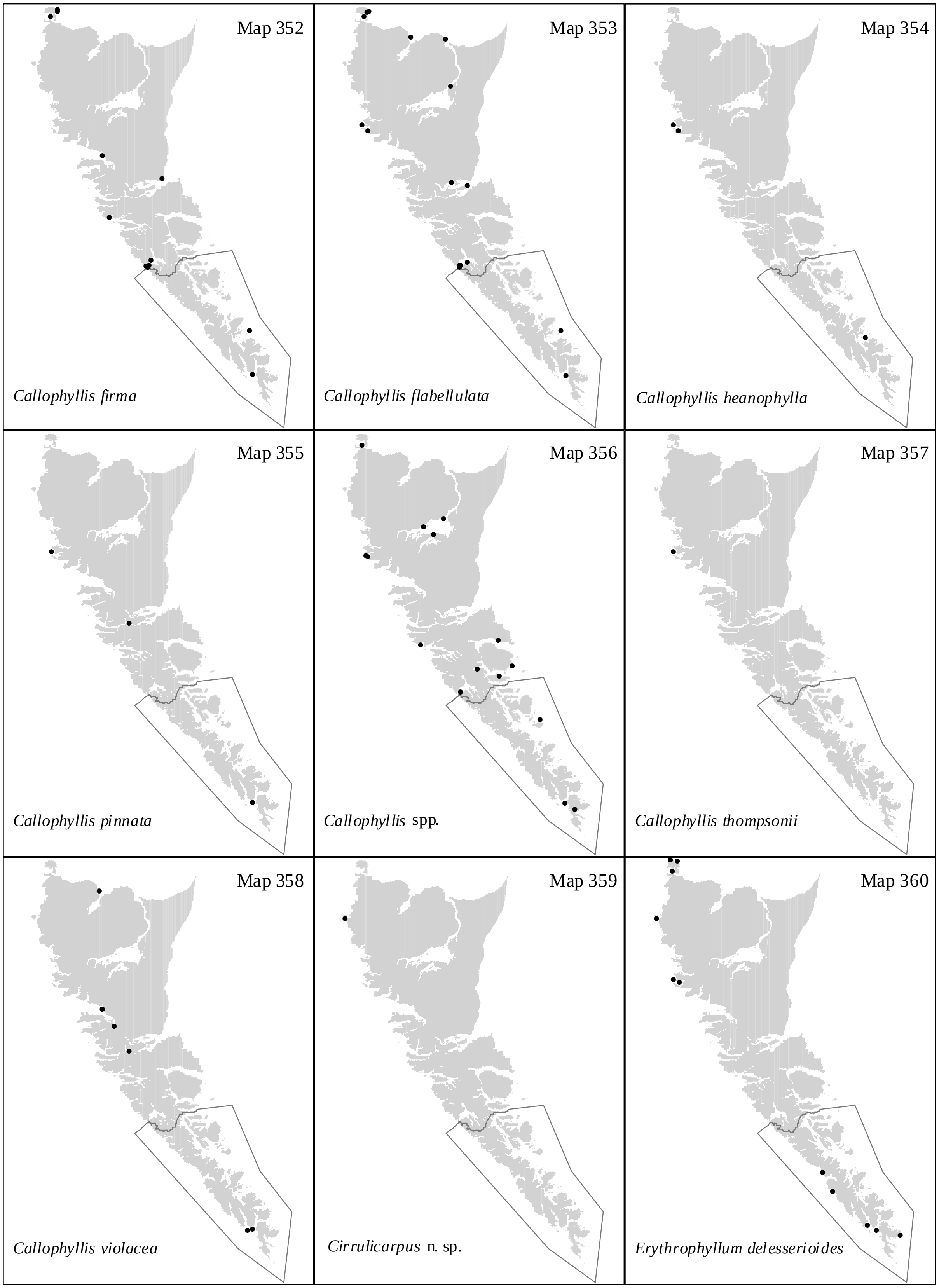

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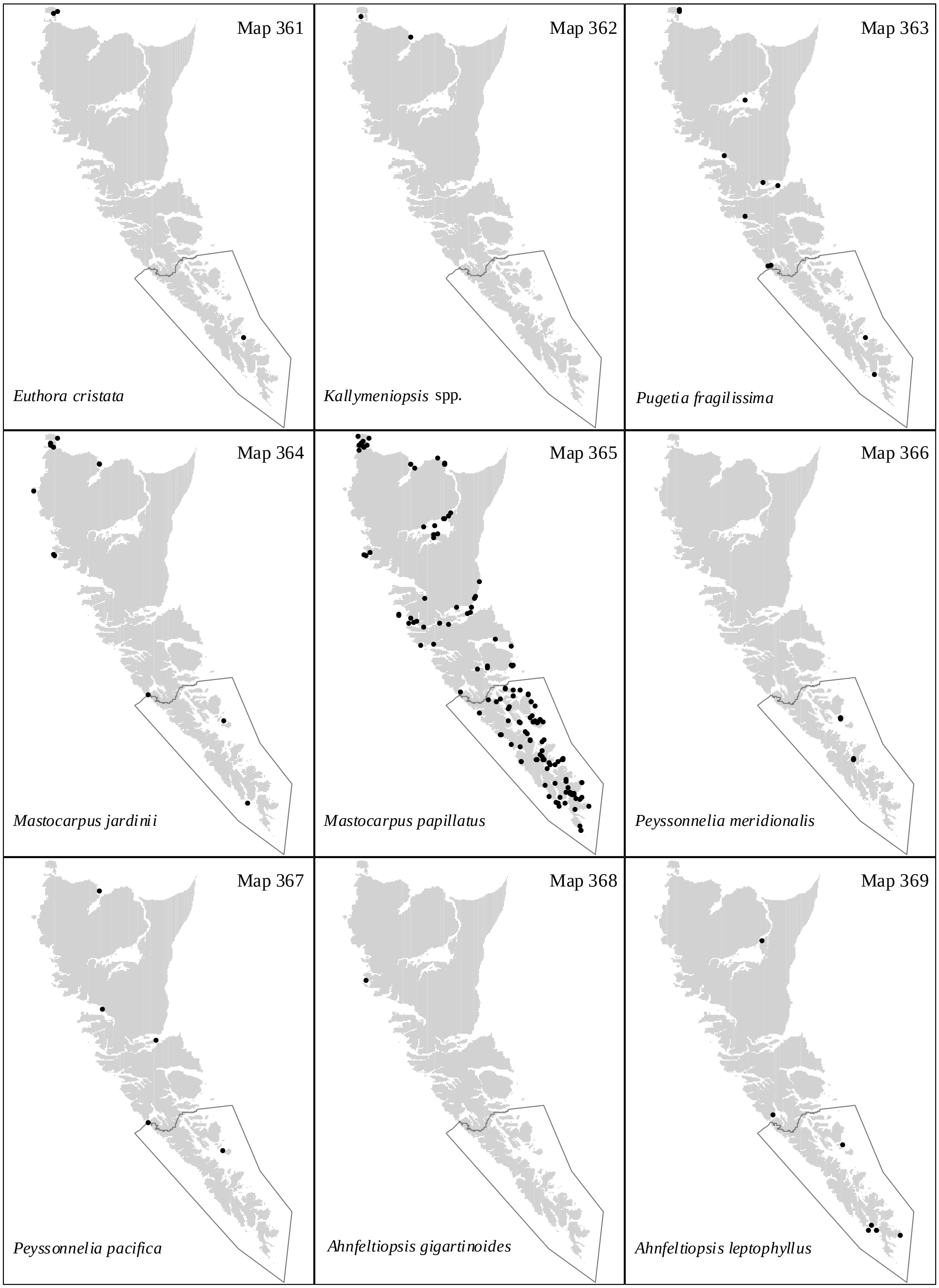

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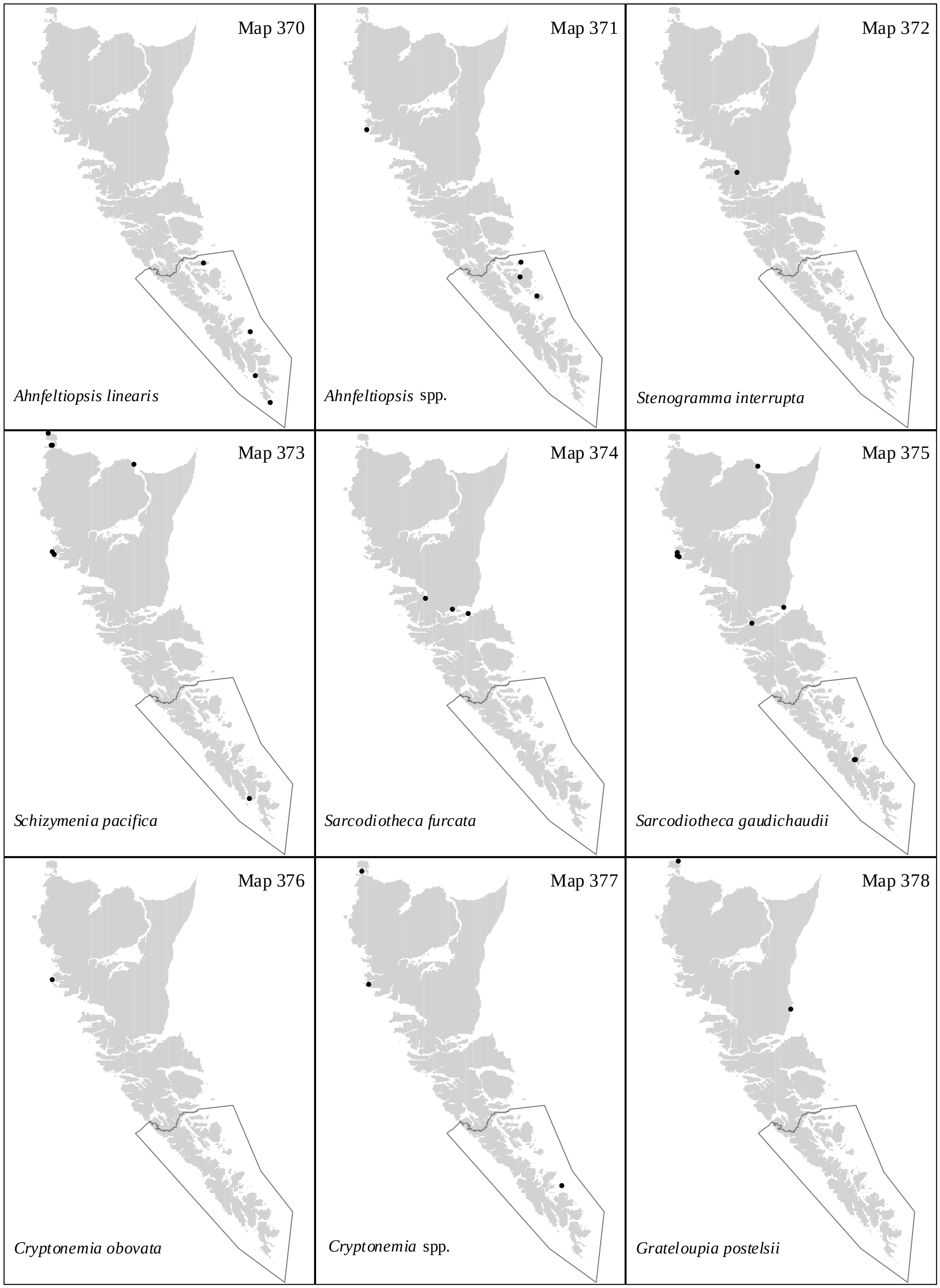

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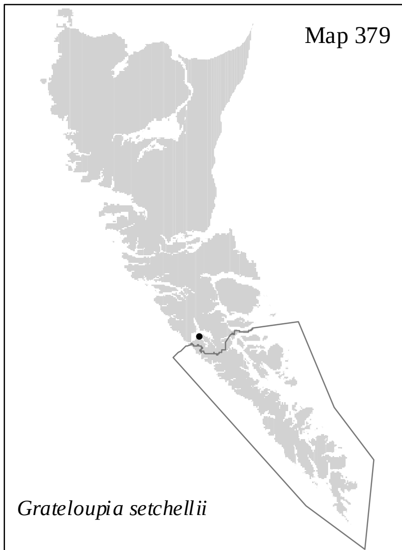

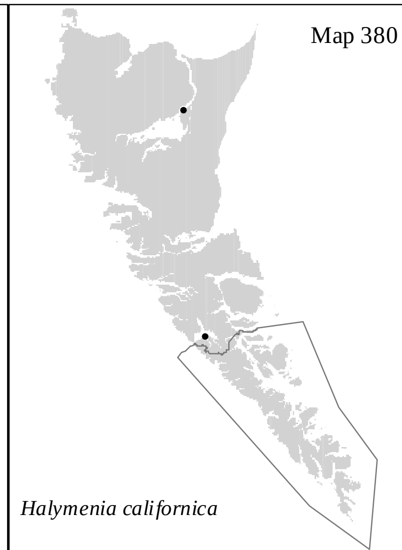

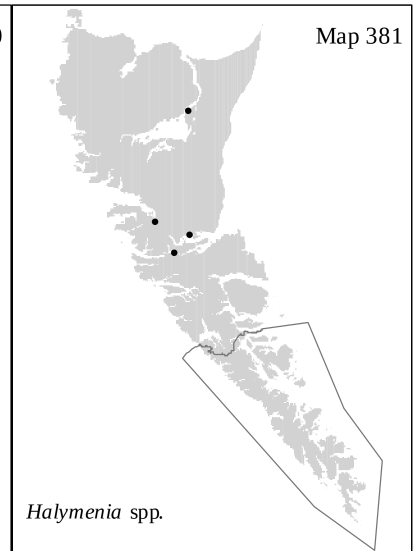

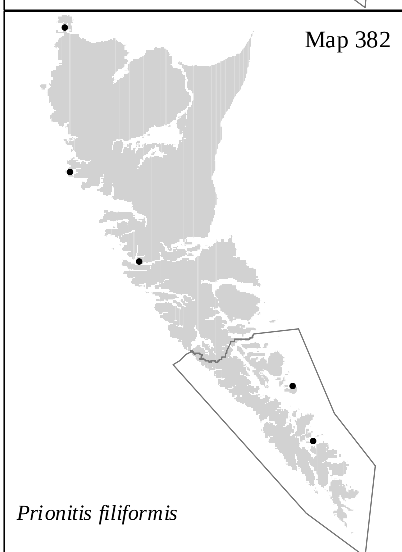

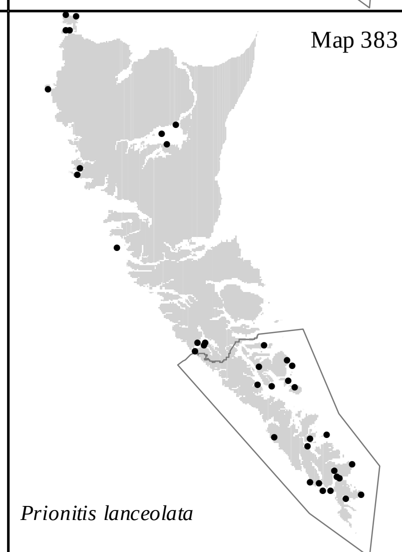

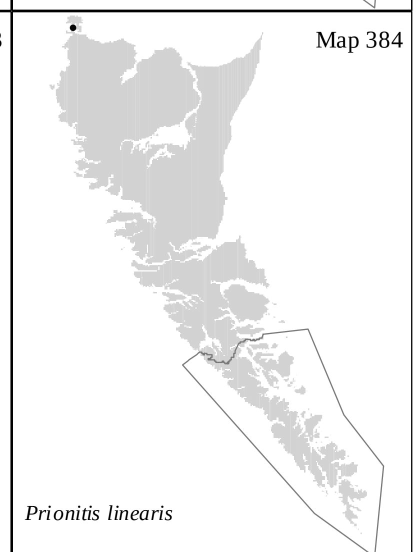

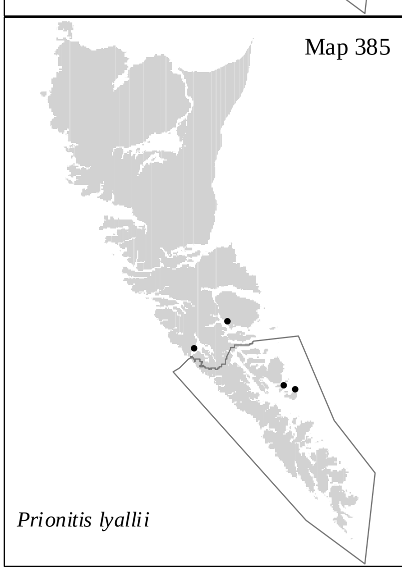

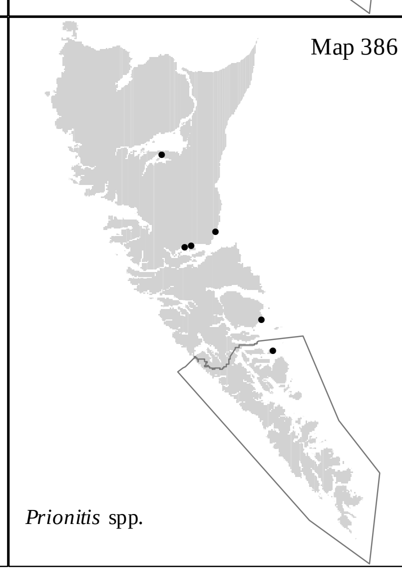

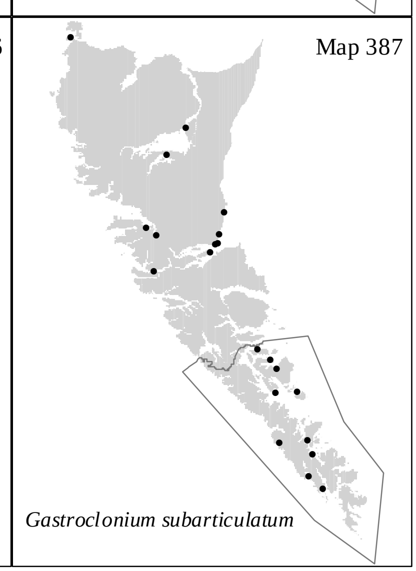

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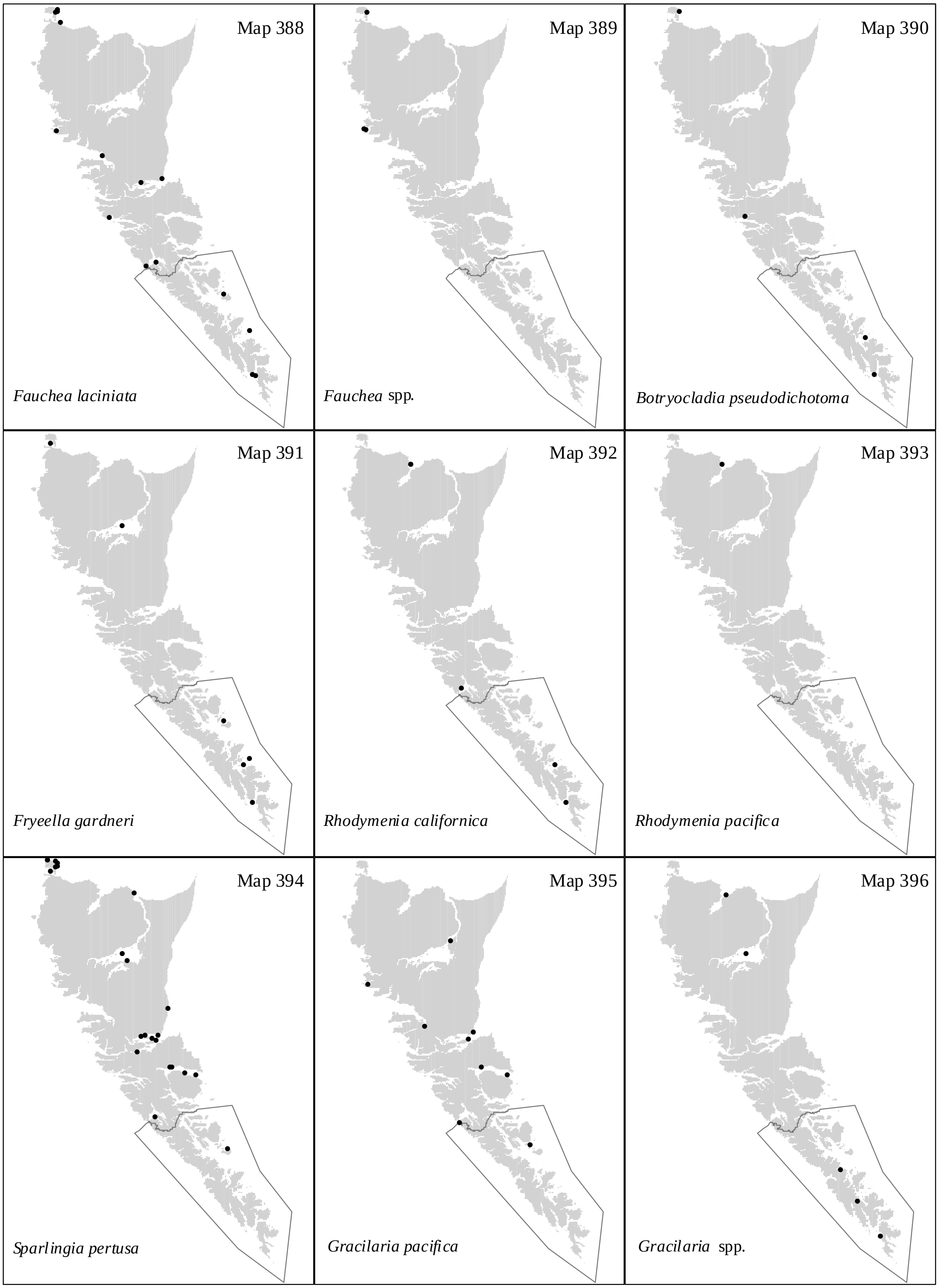

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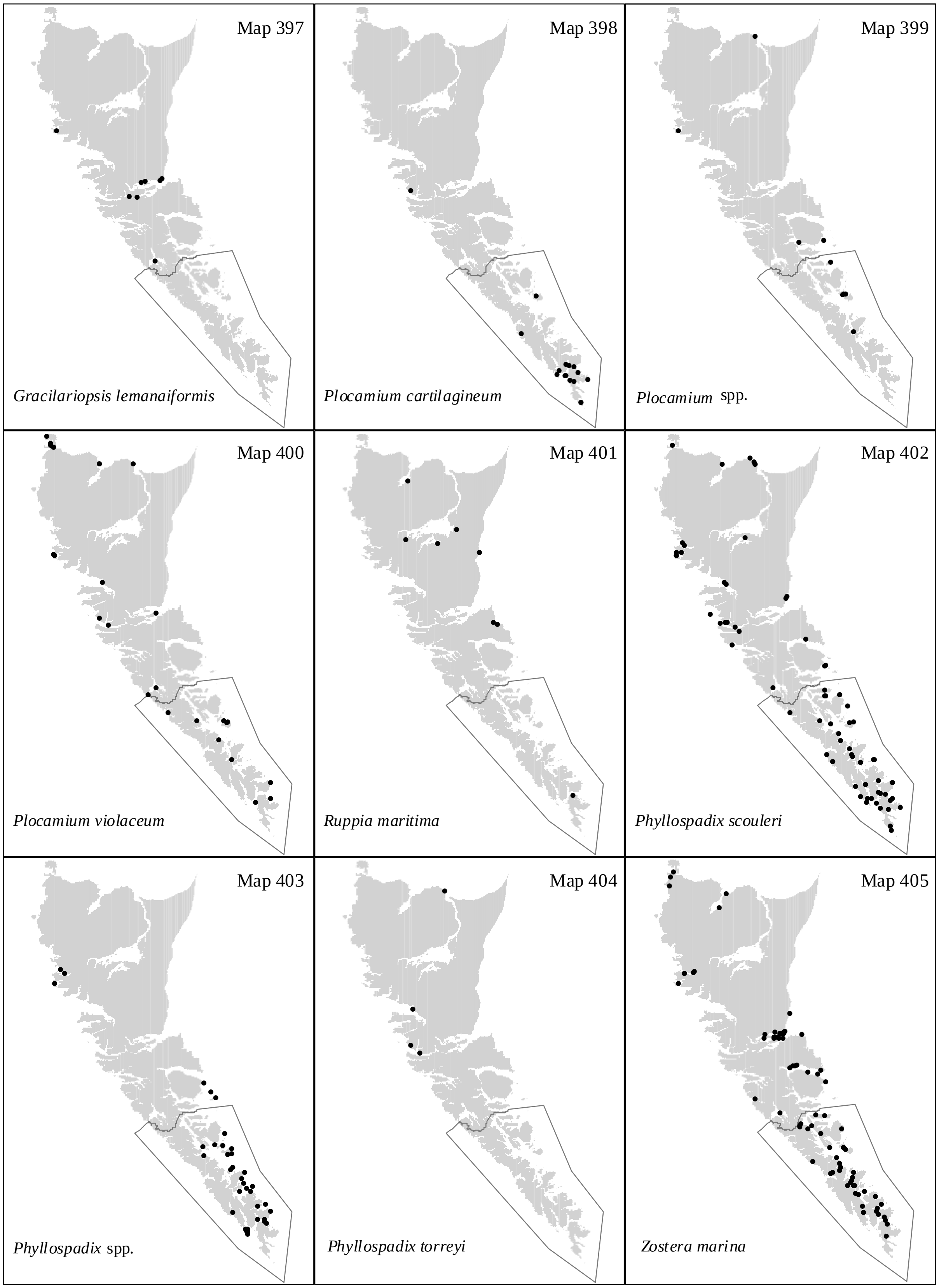

Rhodophyta and Anthophyta.