Dive surveys of fish and invertebrates were carried out at Baeria Rocks Ecological Reserve on 7 June 2018, to continue a monitoring effort that began in 2007. Twelve divers (7 students from the Scientific Diving class of the Bamfield Marine Sciences Centre (BMSC), two Sci Diving Instructors, two course teaching assistants, and one additional diver) were present. All divers were well trained in survey techniques and identification. On each dive, one diver was assigned to tending duties, leaving 11 divers in the water. Surveys were conducted between 10.00 and 13.30 by five dive teams. Two teams conducted timed roving surveys and three teams conducted transects. As in previous years, the teams were deployed around the north islets for the first dive, and around the south islet for the second dive, alternating roving and transect teams along the shore (Figure 1).

Roving survey method

Each roving team carried out a 40-50 min roving survey, from a maximum depth of 50 ft (14.5 m) depth (where possible), to the top of the reef, swimming in a semi-systematic zigzag pattern from deep to shallow water. Both divers counted every individual observed of each species listed on an underwater roving survey sheet. When a species was very abundant (i.e. more than ~100 individuals), surveyors recorded numbers as ‘lots’. Divers noted the duration of each roving survey, as well as the depth range surveyed.

The maximum number of each species recorded between the two divers in each buddy pair was retained, and maximum numbers were averaged across roving teams for each islet. This method generates an index of abundance for each species expressed in number of individuals per 30 min.

The roving survey datasheet used in 2018 is attached.

Transect survey method

The transect method used in 2018 is identical to that used since 2009. Each transect team ran three transects, one at each of three depths (10 ft, 25 ft and 40 ft; 3 m, 8 m, 13 m). Each transect was 20 m long and 4 m wide when the visibility allowed it (2 m when visibility was poor). Once a team had laid a transect line, the divers waited for three
minutes away from the line to allow fish to re-enter the transect area. The divers then swam slowly along either side of the transect in one direction, recording the number of individuals of all fish species listed on a printed transect survey sheet. In the return direction, they recorded all individuals of all invertebrates species on the survey sheet. Each member of a buddy pair surveyed one side of the transect.

For each species, the numbers were summed within a buddy pair for each transect, and then averaged across teams for each depth at each site. This method generates estimates of absolute density.

**Figure 1.** Location of subtidal survey teams around the north and south islets of Baeria Rocks. Teams 2 and 4 carried out roving surveys, and teams 1, 3 and 5 carried out transect surveys.

**Results and Discussion**

*Descriptive summary*

Two roving surveys (total time: 97 min) were carried out around the North islets, and two surveys around the South islets (total time: 100 min), at depths ranging from 50 ft (14.5 m) to 10 ft (3.6 m).

A total of seven transects (total area: 400 m²) were surveyed around the North islets. Nine transects (total area: 560 m²) were surveyed around the South islets. Two transects at 10 ft (3 m) could not be done because of air limitation.
Visibility, at about 1 m, was poorer than in previous years.

**Comparisons with previous years**

Sixteen species of fish (of 34 listed on the spreadsheet) and 30 species of invertebrates (of 85 listed) were recorded during roving surveys, which is similar to previous years (2016: 17 fish and 29 invertebrates; 2014: 19 fish and 31 invertebrates). Five species of invertebrates (of 9 listed) and seven species of fish (of 33 listed) were recorded on the linear transects. Spreadsheets of raw and summary data can be found in the Excel file ‘Baeria Survey 2018’.

**Invertebrates**

In both Howe Sound (Schultz et al. 2016) and at Baeria Rocks, we documented a large increase in abundance of green urchins in 2015/2016 following the heavy mortality of sunflower stars in 2013/2014. The 2018 survey of Baeria allows us, for the first time, to follow the dynamics of these populations beyond the immediate aftermath of the mass mortality. We discover that green urchins declined by 95% between 2016 and 2018, returning to densities similar to those observed prior to the seastar mortality (Fig. 2).

The 2018 survey also reveals a similar pattern for purple urchins (Fig. 2), bat stars (Fig. 3) and ochre stars (Fig. 3). The latter appear to have been unaffected by the seastar wasting disease, unlike intertidal populations along most of the Pacific coast of the US and Canada (Schiebelhut et al. 2018). Another notable trend is the seven-fold increase in the abundance of abalone since 2007, which is found in the roving data (Fig. 2). However, the transect data suggests a continued decline of abalone density, which roughly halved between 2014 and 2016, and declined by a further 25% between 2014 and 2016.

There is no evidence that the seastars most affected by the seastar mass mortality of 2014, i.e. the sunflower star *Pycnopodia helianthoides* (Fig. 2), have begun to recover. Divers found only one small sunflower star (6-7 cm diameter) across all transect and roving surveys.
Figure 2. Abundance of invertebrate species from 2007 to 2018, derived from roving surveys, at Baeria Rocks Ecological Reserve. The invertebrates are: sunflower star (black line; effect of year in General Additive Model, $F = 3.86$, $P = 0.012$), purple urchin (purple line; $F = 6.17$, $P = 0.02$); green urchin (green line; $F = 8.17$, $P = 0.008$); northern abalone (blue line; $F = 5.31$, $P = 0.03$). Means are shown with standard errors. The pink area denotes the time window during which seastar mortality and marked sea warming occurred.

Figure 3. Abundance of invertebrate species from 2007 to 2018, derived from roving surveys, at Baeria Rocks Ecological Reserve. The invertebrates are: sunflower star (black line; repeated from Fig. 2 for reference), ochre star (yellow line; effect of year in General Additive Model, $F = 3.83$, $P = 0.06$); bat star (purple line; $F = 7.88$, $P = 0.0004$). Means are shown with standard errors. The pink area denotes the time window during which seastar mortality and marked sea warming occurred.
Two invasive species – European green crab and gold star tunicate – are still absent from Baeria Rocks. We will keep monitoring these species, although it seems unlikely that they will become established at Baeria because of its isolation and lack of suitable habitat.

Fishes

Seven species of rockfish were recorded across transects and roving surveys, which is the largest number since the start of monitoring. Two new rockfish species were recorded: Puget Sound rockfish and tiger rockfish (the latter including two very gravid individuals; Fig. 4). However, overall rockfish density of rockfish was low on transects, standing at only 6% of the maximum density observed (in 2011). The densities of kelp greenling and lingcod show significant or near-significant, gradual declines since 2009 – in both roving surveys (Fig. 5) and in transect surveys. These patterns of decline clearly predate the period of anomalously warm seawater. Divers reported no evidence of lost or derelict fishing gear on the bottom, but divers did see the remains of a fish carcass on the bottom.

Figure 4. Apparently gravid tiger rockfish, observed on 7 June 2018 at the Baeria Ecological Reserve. Photo credit: Rachel Munger
Figure 5. Abundance of select fish species from 2007 to 2018, derived from roving surveys, at Baeria Rocks Ecological Reserve. The fish species are: kelp greenling (yellow line; effect of year in General Additive Model, \( F = 10.04, P = 0.004 \)), black rockfish (black line; \( F = 1.68, P = 0.21 \)); lingcod (brown line; \( F = 3.49, P = 0.07 \)). Means are shown with standard errors. The pink area denotes the time window during which seastar mortality and marked sea warming occurred.

Bird and mammal surveys

For the first time, the monitoring team included an experienced bird surveyor, Dr John Reynolds (SFU). A total of 14 species of birds (Table 1) and one mammal species (harbor seal, \( N = 7 \) individuals) was recorded. No one went ashore.

The bird sightings were uploaded onto the citizen science site e-bird, and can be found at: https://ebird.org/hotspot/L4882533
Table 1. Birds present on and around Baeria Rocks Ecological Reserve on 7 June 2018

<table>
<thead>
<tr>
<th>Species</th>
<th>Common name</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Haliaeetus leucocephalus</em></td>
<td>Bald eagle</td>
<td>1</td>
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<tr>
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<td><em>Haematopus bachmani</em></td>
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<td><em>Phalacrocorax penicillatus</em></td>
<td>Brandt’s cormorant</td>
<td>22</td>
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<tr>
<td><em>Phalacrocorax pelagicus</em></td>
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<tr>
<td><em>Histrionicus histrionicus</em></td>
<td>Harlequin duck</td>
<td>2</td>
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<tr>
<td><em>Brachyramphus marmoratus</em></td>
<td>Marbled murrelet</td>
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<tr>
<td><em>Cephus columba</em></td>
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<td><em>Ptychoramphus aleuticus</em></td>
<td>Cassin’s auklet</td>
<td>1</td>
</tr>
<tr>
<td><em>Aechmophorus occidentalis</em></td>
<td>Western grebe</td>
<td>2</td>
</tr>
<tr>
<td><em>Tringa incana</em></td>
<td>Wandering tattler</td>
<td>1</td>
</tr>
<tr>
<td><em>Corvus caurinus</em></td>
<td>Northwestern crow</td>
<td>12</td>
</tr>
</tbody>
</table>

Baeria species list

The ongoing compilation of the Baeria Rocks subtidal species is attached. The list currently stands at 122 species, 49 of which were added in 2018.

One notable species observed in 2018 by diver Rachel Munger is shown on Fig. 6. According to Dr Leslie Harris, manager of the polychaete collection at the LA County Museum of Natural History, this might be an undescribed species in the genus *Bispira*, temporarily named *Bispira* sp. 8.
A Baeria Rocks Ecological Reserves project was initiated on iNaturalist to provide a pictorial record of species found in the reserve. There are currently 71 species recorded, and this number is sure to grow with every monitoring survey.

The Baeria project can be accessed at: https://www.inaturalist.org/projects/baeria-rocks-ecological-reserve

**Recommendations for future years**

The Baeria Rocks surveys now span the years 2007 to 2018, and represent a valuable time-series of information on an area that experiences relatively limited human impact. Surveying the sites every other year, coinciding with the offering of Scientific Diving at BMSC, is a convenient way to continue high-quality surveys with a team of well-trained divers.

We did not provide survey datasheets with a fixed list of species to a few of the most experienced roving divers. Instead, these divers listed all species that they could positively identify, along with estimated numbers seen. We will continue to do this in the future so that we can develop a more exhaustive list of marine species present at Baeria Rocks.

One possible addition for the future could be to take photographs of the bottom to
generate a permanent record of the substrate composition. The decline in herbivorous urchins detected at Baeria over the past 2 years might be linked to food limitation, but we cannot definitely ascribe cause to effect without baseline information about benthic community composition.

We should like to invite one or more seaweed experts on future monitoring expedition because this is a species-rich taxon that BMSC divers are not well trained at identifying. Finally, we will seek permission to sample a few individuals of *Bispira* sp. 8, to aid in its identification (and possibly naming).

**Acknowledgements**

Thank you to BMSC for providing the staff and logistical support, and to the BC Parks Living Lab for Climate Change & Conservation Program for funding, which made the 2018 Baeria Rocks survey possible.

**References**


### Total list of birds of Baeria Rocks Ecological Reserve (to June 2018)

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corvus caurinus</td>
<td>Northwestern crow</td>
</tr>
<tr>
<td>Uria aalge</td>
<td>Common murre</td>
</tr>
<tr>
<td>Haliaeetus leucocephalus</td>
<td>Bald eagle</td>
</tr>
<tr>
<td>Larus glaucescens</td>
<td>Glaucous-winged gull</td>
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<tr>
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<td>Black oystercatcher</td>
</tr>
<tr>
<td>Phalacrocorax auritus</td>
<td>Double-crested cormorant</td>
</tr>
<tr>
<td>Phalacrocorax penicillatus</td>
<td>Brandt’s cormorant</td>
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<tr>
<td>Phalacrocorax pelagicus</td>
<td>Pelagic cormorant</td>
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<tr>
<td>Aechmophorus occidentalis</td>
<td>Western grebe</td>
</tr>
<tr>
<td>Tringa incana</td>
<td>Wandering tattler</td>
</tr>
</tbody>
</table>
List of marine species from Baeria Rocks Ecological Reserve (updated 2018)
(species in bold were added in 2018; rough guide to abundance score: Abundant = >
100 per dive; Common = 10 – 100 per dive; Occasional = 5-10 per dive; Uncommon =
2-5 per dive; Rare = 0-1 per dive)

Sponges

**Cliona californiana**  Yellow boring sponge  Common
**Tethya californiana**  Orange rough ball sponge  Uncommon

Cnidarians

Anemones

**Anthopleura artemisia**  Burrowing anemone  Abundant
**Anthopleura elegantissima**  Aggregating anemone  Abundant
**Anthopleura xanthogrammica**  Giant green anemone  Abundant
**Epiactis prolifera**  Brooding anemone  Uncommon
**Metridium farcimen**  Giant plumose anemone  Common
**Metridium senile**  Short plumose anemone  Common
**Pachycerianthus fimbriatus**  Tube-dwelling anemone  Common
**Urticina coriacea**  Stubby rose anemone  Abundant
**Urticina lofotensis**  White-spotted anemone  Common
**Urticina piscivora**  Fish-eating anemone  Abundant

Zoanthids

**Epizoanthus scotinus**  Orange zoanthid  Common

Corals

**Balanophyllia elegans**  Orange cup coral  Abundant
**Ptilosarcus gurneyi**  Orange sea pen  Uncommon

Hydrocorals

**Stylaster sp.**  Pink hydrocoral  Common

Hydroids

**Clava sp.**  White hydroid  Common
**Plumularia setacea**  Glassy plume hydroid  Abundant
**Schizoporella unicornis**  Orange encrusting bryozoan  Abundant
**Selaginopsis sp.**  Fish-bone hydroid  Abundant
**Sertularella sp.**  Garland hydroid  Abundant

Stalked jellies

**Manania gwilliami**  Red stalked jelly  Uncommon

Ectoprocts (bryozoans)
<table>
<thead>
<tr>
<th>Organism</th>
<th>Description</th>
<th>Abundance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Crisia sp.</strong></td>
<td>White tuft bryozoan</td>
<td>Abundant</td>
</tr>
<tr>
<td><strong>Heteropora pacifica</strong></td>
<td>Northern staghorn bryozoan</td>
<td>Abundant</td>
</tr>
<tr>
<td><strong>Phidolopora pacifica</strong></td>
<td>Lattice-work bryozoan</td>
<td>Uncommon</td>
</tr>
</tbody>
</table>

**Molluscs**

**Bivalves**

- **Crassadoma gigantea**  Giant rock scallop  Abundant
- **Mytilus californianus** California mussel  Common

**Limpets**

- **Acmaea mitra**  Whitecap limpet  Abundant
- **Diodora aspera**  Rough keyhole limpet  Common

**Chitons**

- **Placiphorella velata**  Veiled-chiton  Rare
- **Tonicella insignis**  White-lined chiton  Occasional

**Gastropods**

- **Amphissa columbiana**  Wrinkled amphissa  Abundant
- **Astraea gibberosa**
- **Calliostoma annulatum**  Purple-ring topsnail  Uncommon
- **Calliostoma ligatum**  Blue topsnail  Abundant
- **Cerastoma foliatum**  Leafy hornmouth  Abundant
- **Fusitriton oregonensis**
- **Haliotis kamtschatkana**  Northern abalone  Common
- **Tegula pulligo**  Dusky turban  Abundant

**Nudibranchs**

- **Acanthodoris lutea**  Orange-peel nudibranch  Uncommon
- **Cadлина luteomarginata**  Yellow-margin nudibranch  Common
- **Ceratosa amoenum**  Clown nudibranch  Uncommon
- **Diaulula sandiegensis**  Leopard dorid  Uncommon
- **Dendronotus iris**  Giant nudibranch  Uncommon
- **Dirona albolineata**
- **Doris montereyensis**
- **Flabellina triophina**
- **Hermissenda crassicornis**
- **Tritonia festiva**  Diamond-back nudibranch  Rare

**Annelids**

**Polychaetes**

- **Bispira sp. 8**
- **Demonax medius**  Parasol feather-duster  Uncommon
- **Dodecaceria concharum**  Coralline-encased filament-worm  Abundant
- **Dodecaceria newkies**  Fringed filament-worm  Abundant
<table>
<thead>
<tr>
<th><strong>Myxicola infundibulum</strong></th>
<th>Slime-tube feather-duster</th>
<th>Abundant</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Serpula columbiana</strong></td>
<td>Red-trumpet calcareous tubeworm</td>
<td>Common</td>
</tr>
</tbody>
</table>

### Arthropods

**Shrimp**

*Pandalus danae* | Coonstripe shrimp | Occasional |

**Crabs**

*Cancer antennarius*  
*Cancer oregonensis*  
*Cancer productus*  
*Cryptolithodes sitchensi*  
*Lopholithodes mandtii*  
*Loxorhynchus crispatus*  
*Mimus foliatus*  
*Oregonia gracilis*  
*Petrolisthes sp*  
*Pugettia productus*  
*Scyra acutifrons*  

*Cancer antennarius*  
*Cancer oregonensis*  
*Cancer productus*  
*Lopholithodes mandtii*  
*Loxorhynchus crispatus*  
*Mimus foliatus*  
*Oregonia gracilis*  
*Petrolisthes sp*  
*Pugettia productus*  
*Scyra acutifrons*  

**Hermit crabs**

*Pagurus armatus*  
*Pagurus hemphili*  

*Pagurus armatus* | Black-eyed hermit crab | Common  |
<table>
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<tbody>
<tr>
<td><em>Pagurus hemphili</em></td>
<td>Maroon hermit crab</td>
<td>Common</td>
</tr>
</tbody>
</table>

**Barnacles**

*Balanus nubilus* | Giant barnacle | Common  |

### Echinoderms

**Sea stars**

*Asterina miniata*  
*CROSSASTER PAPPUS*  
*Dermasterias imbricata*  
*Evasterias troschelli*  
*HENRICIA LEVIUSCULA*  
*Hippasteria spinosa*  
*Mediaster aequalis*  
*Orthasterias koehleri*  
*Pisaster brevispinus*  
*Pisaster ochraceous*  
*Pycnopodia helianthoides*  
*PTERASTER TESSELLATUS*  
*Solaster dawsoni*  
*Solaster endeca*  
*Solaster stimpsoni*  
*Stylasterias forreri*  

*Asterina miniata*  
*CROSSASTER PAPPUS*  
*Dermasterias imbricata*  
*Evasterias troschelli*  
*HENRICIA LEVIUSCULA*  
*Hippasteria spinosa*  
*Mediaster aequalis*  
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*PTERASTER TESSELLATUS*  
*Solaster dawsoni*  
*Solaster endeca*  
*Solaster stimpsoni*  
*Stylasterias forreri*  

**Bat star**  
**Rose star**  
**Leather star**  
**Mottled star**  
**Blood star**  
**Spiny red star**  
**Vermillion star**  
**Painted star**  
**Spiny pink star**  
**Ochre star**  
**Sunflower star**  
**Cushion star**  
**Morning sun star**  
**Northern sunstar**  
**Striped sun star**  
**Velcro star**  

**Bat star**  
**Rose star**  
**Leather star**  
**Mottled star**  
**Blood star**  
**Spiny red star**  
**Vermillion star**  
**Painted star**  
**Spiny pink star**  
**Ochre star**  
**Sunflower star**  
**Cushion star**  
**Morning sun star**  
**Northern sunstar**  
**Striped sun star**  
**Velcro star**  

**Abundant**  
**Rare**  
**Abundant**  
**Common**  
**Rare**  
**Rare**  
**Common**  
**Abundant**  
**Rare**  
**Rare**  
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**Rare**  
**Uncommon**  
**Rare**  
**Uncommon**  
**Common**  

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<td>Mammals</td>
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