pacea

New Canadian and US information added to pacea (since last year)

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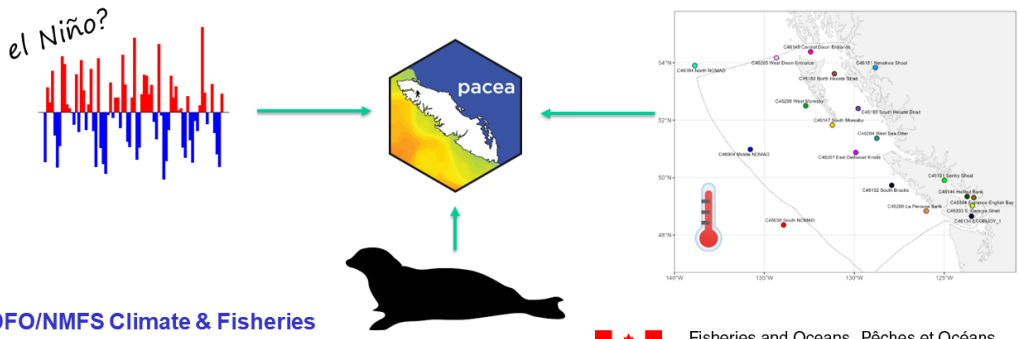
Pacific Biological Station, Fisheries and Oceans Canada, Nanaimo, BC.



DFO/NMFS Climate & Fisheries Pacific Working Group, Seattle, Jan 2025

Fisheries and Oceans Canada | Pêches et Océans Canada

Motivation

pacea: An R package of Pacific ecosystem information to help facilitate an ecosystem approach to fisheries management

- push to include ecosystem information in advice to fisheries managers
- leading impediment: availability of data and model output
  - where to find it, wrangling it (e.g netCDF into R), understanding it
  - Open Data is great, but have to convert raw data into usable information
- primary audience is DFO stock assessment scientists, but usable by anyone (with a minimal working knowledge of R)

Availability

- hosted free on GitHub at https://github.com/pbs-assess/pacea
- easy installation:

```
remotes::install_github("pbs-assess/pacea")
```

- all vignettes are rendered on GitHub for easy learning, custom plotting files, help for everything, fully open source
- all data (except oceanographic model output) is saved within the package
  - no further downloading required
  - not relying on external websites being functional

pacea objects (climatic/oceanographic)

Currently, pacea contains (red is updated/new since last year's meeting):

- ~~204,039~~ 209,626 calculations of daily sea surface temperature based on data from 19 buoys

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- NOAA's spatial Optimum Interpolation Sea Surface Temperature (OISST) record updated monthly

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- NOAA's spatial Optimum Interpolation Sea Surface Temperature (OISST) record updated monthly
- ~~9~~ 10 climatic and oceanographic indices, such as the Pacific Decadal Oscillation and those related to El Niño

pacea objects (biological)

- estimates of abundances for Harbour Seals
- estimates of spawning stock biomass and annual recruitments for Pacific Hake and Pacific Herring
- zooplankton biomass anomalies in the Strait of Georgia for 25 species groups

British Columbia Continental Margin (BCCM) model

Physical biogeochemical oceanographic model

- Regional Ocean Modelling Systen (ROMS)
- curvilinear grid at 3 km x 3 km resolution
- we interpolate to regular grids

Model output provided by Angelica Peña (DFO)

Peña, M.A., Fine, I. and Callendar, W. 2019. Interannual variability in primary production and shelf-offshore transport of nutrients along the northeast Pacific Ocean margin. Deep-Sea Research II, doi:10.1016/j.dsr2.2019.104637.

Mapping to grids

Original mapping:

- clipped to Canada's Pacific Exclusive Economic Zone
- inshore (2 km x 2 km) and offshore (6 km x 6 km)
- 40,480 cells
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- 40,480 cells
- monthly from 1993-2019

New additional mapping (request from Lisa last year):

- covers full domain (into US waters)
- 2 km x 2 km grid throughout
- 161,025 cells
- monthly from 1993-2019
- huge filesizes required hosting outputs on Zenodo not GitHub
- new grid also used for HOTSSea outputs, and has interpolated depths

Available variables

The variables are:

- dissolved oxygen concentration
- pH
- salinity
- temperature
- depth-integrated phytoplankton
- depth-integrated primary production.

For applicable variables these are given for

- sea surface
- 0-40 m integration
- 40-100 m integration
- 100 m to the sea bottom
- sea bottom.

List of available variables (original just Canada)

bccm_data for available variables

```
bccm_data
                        data_name
1             bccm_surface_oxygen
2                 bccm_surface_ph
3           bccm_surface_salinity
4        bccm_surface_temperature
5           bccm_avg0to40m_oxygen
6               bccm_avg0to40m_ph
7         bccm_avg0to40m_salinity
8      bccm_avg0to40m_temperature
9         bccm_avg40to100m_oxygen
10            bccm_avg40to100m_ph
11      bccm_avg40to100m_salinity
12   bccm_avg40to100m_temperature
13       bccm_avg100mtoBot_oxygen
14           bccm_avg100mtoBot_ph
15     bccm_avg100mtoBot_salinity
16 bccm_avg100mtoBot_temperature
17             bccm_bottom_oxygen
18                 bccm_bottom_ph
19           bccm_bottom_salinity
20        bccm_bottom_temperature
21             bccm_phytoplankton
22         bccm_primaryproduction
```

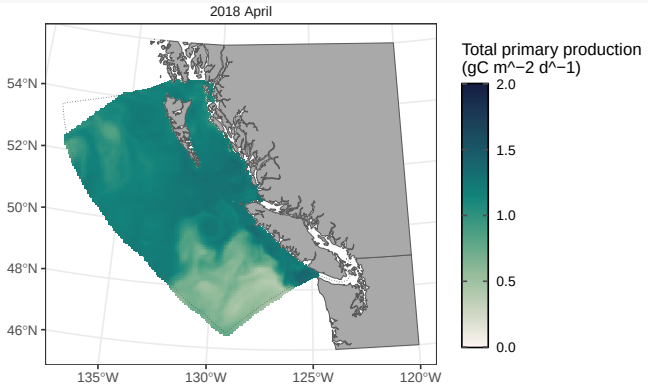
List of available variables (full domain)

bccm_data_full for available variables

```
bccm_data_full
                            data_name
1            bccm_surface_oxygen_full
2                bccm_surface_ph_full
3          bccm_surface_salinity_full
4       bccm_surface_temperature_full
5          bccm_avg0to40m_oxygen_full
6              bccm_avg0to40m_ph_full
7        bccm_avg0to40m_salinity_full
8     bccm_avg0to40m_temperature_full
9        bccm_avg40to100m_oxygen_full
10           bccm_avg40to100m_ph_full
11     bccm_avg40to100m_salinity_full
12  bccm_avg40to100m_temperature_full
13     bccm_avg100mtoBot_oxygen_full
14         bccm_avg100mtoBot_ph_full
15   bccm_avg100mtoBot_salinity_full
16 bccm_avg100mtoBot_temperature_full
17            bccm_bottom_oxygen_full
18                bccm_bottom_ph_full
19          bccm_bottom_salinity_full
20       bccm_bottom_temperature_full
21            bccm_phytoplankton_full
22        bccm_primaryproduction_full
```

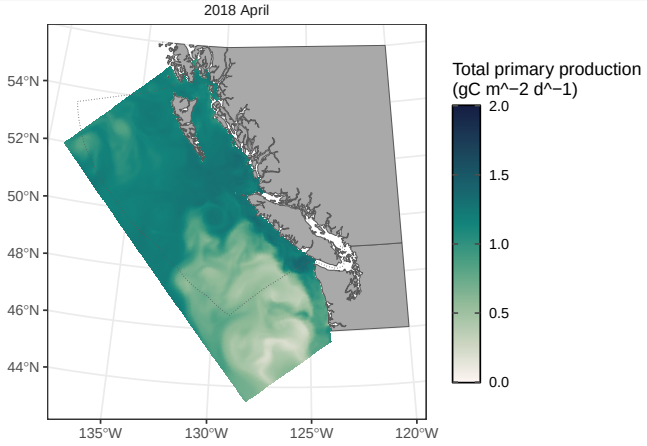
Built in plotting - primary production in Canadian waters

```
plot(bccm_primaryproduction())
```



Built in plotting - primary production in Canadian waters

```
plot(bccm_primaryproduction_full())
```



HOTSSea

- Hindcast of the Salish Sea (HOTSSea)
- physical ocean model from 1980 to 2018 Oldford et al., (*Geoscientific Model Development*, in press).
- pacea includes temperature and salinty
- mapped to same 2 km x 2 km grid as `bccm_full` (slight overlap in domain)
- 6,165 spatial cells
- every month from January 1980 to December 2018
- various depth ranges
- monthly statistics (`min`, `mean`, `max`, `std`)
- saved in the same format as BCCM and OISST output (so same plotting etc. functions can be used)

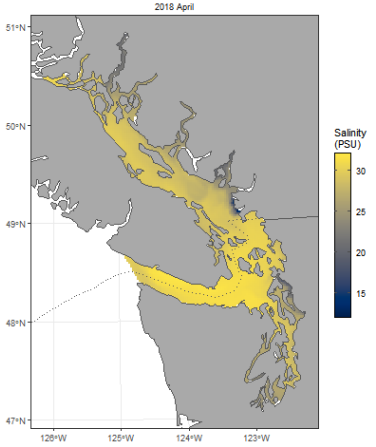
Available variables

HOTSSea objects in pacea are (40 in total):

```
hotssea_data
                            data_name
1          hotssea_surface_salinity_min
2         hotssea_surface_salinity_mean
3          hotssea_surface_salinity_max
4          hotssea_surface_salinity_std
5       hotssea_surface_temperature_min
6      hotssea_surface_temperature_mean
7       hotssea_surface_temperature_max
8       hotssea_surface_temperature_std
9        hotssea_avg0to30m_salinity_min
10      hotssea_avg0to30m_salinity_mean
11       hotssea_avg0to30m_salinity_max
12       hotssea_avg0to30m_salinity_std
13    hotssea_avg0to30m_temperature_min
14   hotssea_avg0to30m_temperature_mean
15    hotssea_avg0to30m_temperature_max
16    hotssea_avg0to30m_temperature_std
17     hotssea_avg30to150m_salinity_min
18    hotssea_avg30to150m_salinity_mean
19     hotssea_avg30to150m_salinity_max
20     hotssea_avg30to150m_salinity_std
```

Example plot

```
plot(hotssea_surface_salinity_max())
```



Climatic and oceanographic indices

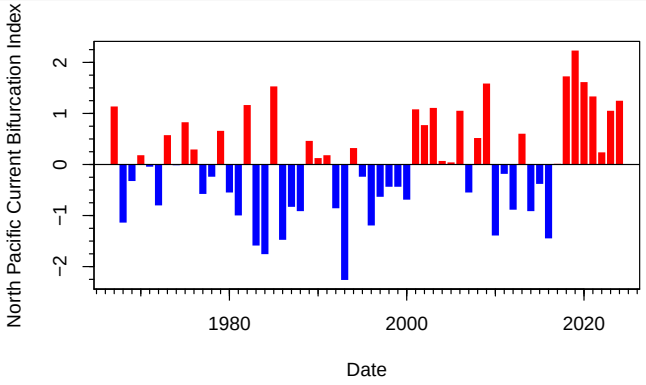
Various climate and oceanographic indices are currently included in pacea:

Object	Description	Resolution	Start year	End year
pdo	Pacific Decadal Oscillation	monthly	1854	2024
npi_monthly	North Pacific Index (monthly)	monthly	1899	2024
npi_annual	North Pacific Index (annual)	annual	1899	2024
alpi	Aleutian Low Pressure Index	annual	1900	2022
oni	Oceanic Niño Index	monthly	1950	2024
npgo	North Pacific Gyre Oscillation	monthly	1950	2024
ao	Arctic Oscillation	monthly	1950	2024
soi	Southern Oscillation Index	monthly	1951	2024
bi	North Pacific Bifurcation Index	annual	1967	2024
mei	Multivariate El Niño Southern Oscillation Index	monthly	1979	2024

New index

Now includes Mike Malick's North Pacific Current Bifurcation Index:

```
plot(bi, lwd = 6)
```



Zooplankton in the Strait of Georgia (new)

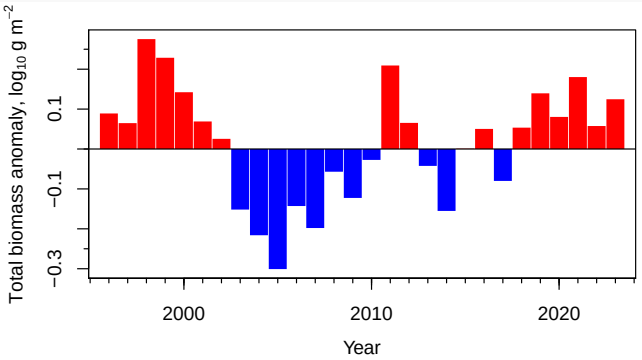
Anomalies of zooplankton biomass from 1996 onwards from Perry et al. (2021), as extended by Kelly Young each year for DFO's State of the Pacific Ocean Report.

```
zooplankton_sog
# A tibble: 28 x 28
   year number_samples volume_filtered total_biomass amphipods_gammarid
  <dbl>          <dbl>           <dbl>         <dbl>              <dbl>
1  1996              4            335.        0.0890             0.0338
2  1997             11            921.        0.0649             0.212
3  1998             22           1584.        0.275              0.184
4  1999              7            421.        0.229              0.0139
5  2000              4            484.        0.142              0.212
6  2001              8            430.        0.0690            -0.0154
# i 22 more rows
# i 23 more variables: amphipods_hyperiid <dbl>, benthic_larvae <dbl>,
#   calanoid_copepods_large <dbl>, calanoid_copepods_medium <dbl>,
#   calanoid_copepods_small <dbl>, cephalopoda <dbl>, chaetognatha <dbl>,
#   cladocera <dbl>, ctenophora <dbl>, euphausiids <dbl>, fish <dbl>,
#   larvacea <dbl>, medusae <dbl>, mysids <dbl>, natantia <dbl>,
#   non_calanoid_copeopods <dbl>, ostracoda <dbl>, other <dbl>, ...
```

Zooplankton in the Strait of Georgia (new)

Default plot of anomalies of total biomass:

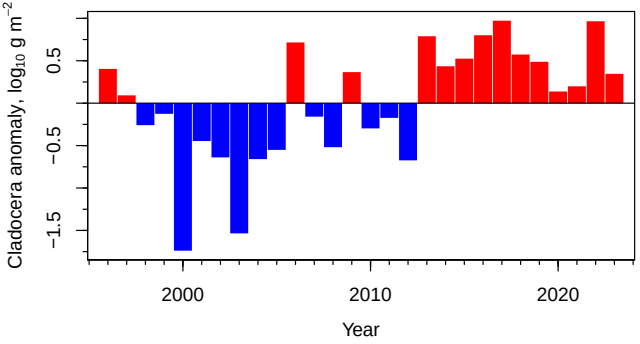
```
plot(zooplankton_sog)
```



Zooplankton in the Strait of Georgia (new)

Or plot anomalies for a specific species group:

```
plot(zooplankton_sog,
     species_group = "cladocera")
```



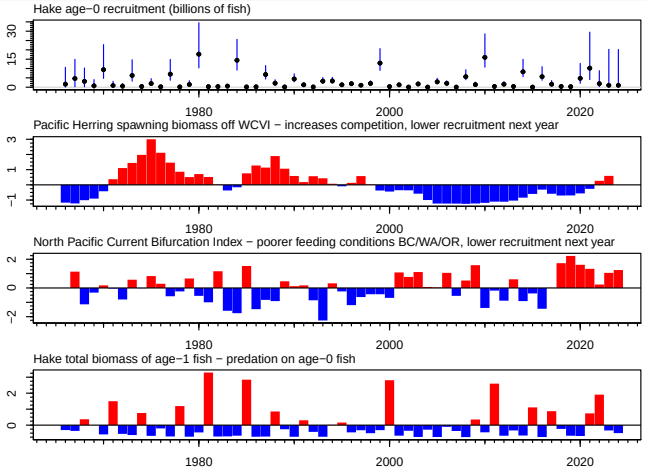
Current uses of pacea (that we know about)

- Petrale Sole stock assessment
- shrimp: impact of including environmental variables on predicting distributions
- Spiny Dogfish: understanding declines over the past 20 years
- humpback whales and porpoises: environmental covariates in species distribution models
- Pacific Saury assessment: finding links between two basin-scale indices and process errors
- State of the Pacific Ocean meeting Mar 2024

Ecosystem summaries

Idea is to head towards stock-specific functions like (rough version):

```
ecosystem_summary_hake()
```

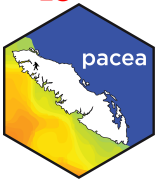


Acknowledgments

- Co-authors: Joe Watson, Angelica Peña, Andrea Hilborn, Charles Hannah, Chris Rooper, Kelsey Flynn, and Greig Oldford.
- Jessica Nephin, Lindsay Davidson, Strahan Tucker, Brianna Wright, Patrick Thompson, Matt Grinnell, Jaclyn Cleary, Sean Anderson, Philina English, Chris Grandin, Jennifer Boldt, and others.
- DFO's Competitive Science Research Fund for funding (project 21-FS-03-13).

Installation

- https://github.com/pbs-assess/pacea
- installation: `remotes::install_github("pbs-assess/pacea")`



We wrangle the data so you don't have to

```
citation("pacea")

Edwards AM, Tai TC, Watson J, Peña MA, Hilborn A, Hannah CG, Rooper CN, Flynn
  KL, Oldford GL (2024). "pacea: An R package of Pacific ecosystem
  information to help facilitate an ecosystem approach to fisheries
  management."
  https://github.com/pbs-assess/pacea.
```

good luck in the competition