Resource polygon geometry predicts Bayesian stable isotope mixing model bias

Michael T. Brett*

Civil & Environmental Engineering, University of Washington, Seattle, Washington 98105, USA

*Corresponding author: mtbrett@uw.edu

Marine Ecology Progress Series 514: 1-12 (2014)

Supplement. Data comparing the results of MixSIR and SIAR based model outputs. Figures that visualize the structure of several of the experiments summarized in the main paper are presented, as well as a list of the studies included in the meta-analysis of 3 resource polygons.

Table S1. Outcomes of MixSIR and SIAR based analyses for equilateral 3 end-member scenarios. These outputs are for the resource that contributed 80% to the hypothetical consumer. The mean ± SD, median, 2.5th and 97.5th percentiles, and 95% confidence interval are presented. The 95% confidence interval is calculated as the difference between the 97.5th and 2.5th percentiles. The polygon surface area has units of SD². These outcomes show that the SIAR based outputs are less accurate and much less precise than the MixSIR based outputs. For the resources that contributed 10% to the hypothetical consumer, very comparable results were obtained. For a rectangular case (not shown), similar outcomes were obtained, i.e. MixSIR was more accurate and much more precise.

<table>
<thead>
<tr>
<th>Polygon surface area</th>
<th>MixSIR Mean</th>
<th>MixSIR SD</th>
<th>MixSIR Median</th>
<th>MixSIR 2.5</th>
<th>MixSIR 97.5</th>
<th>MixSIR 95% CI</th>
<th>SIAR Mean</th>
<th>SIAR SD</th>
<th>SIAR Median</th>
<th>SIAR 2.5</th>
<th>SIAR 97.5</th>
<th>SIAR 95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.100</td>
<td>0.341</td>
<td>0.223</td>
<td>0.315</td>
<td>0.018</td>
<td>0.806</td>
<td>0.787</td>
<td>0.342</td>
<td>0.227</td>
<td>0.312</td>
<td>0.016</td>
<td>0.819</td>
<td>0.803</td>
</tr>
<tr>
<td>0.316</td>
<td>0.362</td>
<td>0.226</td>
<td>0.341</td>
<td>0.020</td>
<td>0.816</td>
<td>0.796</td>
<td>0.354</td>
<td>0.228</td>
<td>0.329</td>
<td>0.018</td>
<td>0.818</td>
<td>0.800</td>
</tr>
<tr>
<td>1.00</td>
<td>0.402</td>
<td>0.229</td>
<td>0.394</td>
<td>0.026</td>
<td>0.840</td>
<td>0.814</td>
<td>0.394</td>
<td>0.233</td>
<td>0.387</td>
<td>0.021</td>
<td>0.836</td>
<td>0.815</td>
</tr>
<tr>
<td>3.16</td>
<td>0.541</td>
<td>0.205</td>
<td>0.556</td>
<td>0.097</td>
<td>0.883</td>
<td>0.786</td>
<td>0.484</td>
<td>0.229</td>
<td>0.505</td>
<td>0.041</td>
<td>0.871</td>
<td>0.829</td>
</tr>
<tr>
<td>10.0</td>
<td>0.690</td>
<td>0.136</td>
<td>0.694</td>
<td>0.455</td>
<td>0.919</td>
<td>0.464</td>
<td>0.586</td>
<td>0.217</td>
<td>0.628</td>
<td>0.072</td>
<td>0.904</td>
<td>0.832</td>
</tr>
<tr>
<td>31.6</td>
<td>0.765</td>
<td>0.089</td>
<td>0.766</td>
<td>0.607</td>
<td>0.928</td>
<td>0.321</td>
<td>0.653</td>
<td>0.212</td>
<td>0.711</td>
<td>0.103</td>
<td>0.917</td>
<td>0.814</td>
</tr>
<tr>
<td>100</td>
<td>0.796</td>
<td>0.062</td>
<td>0.795</td>
<td>0.690</td>
<td>0.912</td>
<td>0.222</td>
<td>0.688</td>
<td>0.207</td>
<td>0.755</td>
<td>0.113</td>
<td>0.915</td>
<td>0.802</td>
</tr>
<tr>
<td>316</td>
<td>0.802</td>
<td>0.038</td>
<td>0.801</td>
<td>0.737</td>
<td>0.874</td>
<td>0.137</td>
<td>0.704</td>
<td>0.202</td>
<td>0.775</td>
<td>0.119</td>
<td>0.910</td>
<td>0.791</td>
</tr>
<tr>
<td>1000</td>
<td>0.801</td>
<td>0.022</td>
<td>0.800</td>
<td>0.763</td>
<td>0.841</td>
<td>0.077</td>
<td>0.713</td>
<td>0.196</td>
<td>0.785</td>
<td>0.133</td>
<td>0.909</td>
<td>0.776</td>
</tr>
</tbody>
</table>
Fig. S1. Schematic of the first experiment. The left-hand plot depicts a normalized polygon with a surface area of 100 SD$^2$ and the right-hand plot depicts a polygon with a surface area of 1 SD$^2$. The meta-analysis of triangular resource polygons indicated that 16% of the surveyed polygons had surface areas <1 SD$^2$ and none had surface areas >100 SD$^2$. The grey dot represents a hypothetical 80/10/10 consumer

Fig. S2. Regular 3, 4, 5, and 6 end-member polygons tested for this study. Each of these polygons has the same radius (distance from center to a vertex) and the same centroid. The grey dot represents a fixed consumer comprised of 80% of the upper left resource, and 10% of the next 2 resources in a clockwise direction
Studies included in the triangular polygon meta-analysis

Two stable isotope polygons


Cases considered: 1, Wailoa/Low; 2, Wailuku/Low; 3, Wailoa/High; and 4, Wailuku/High. Polygons were comprised of terrestrial particulate organic matter [POM], estuarine POM, and marine POM.


Polygon comprised of large pelagics, small pelagics, and demersal fish.


Polygon comprised of <2 μm, Arthrospira fusiformis, and Anabaenopsis elenkinii.


Polygon comprised of macroalgae, seagrass, and gelatinous macroplankton.


Cases considered: 1, autumn and 2, winter. Polygons comprised of copepods, microplankton, and appendicularians.


Polygon comprised of macrophytes, epiphytes, and suspended particulate matter [SPM].


Polygon comprised of fish, crayfish, and bird [pigeon].


Polygon comprised of shallow snails, deep snails, and salmon eggs.


Polygon comprised of Groups 1,2 [combined], Group 3, and Group 4.


From Fig. 3, Saanaj. Polygon comprised of zooplankton, profundal zoobenthos, and littoral zoobenthos.

Three lakes grouped. Polygon comprised of zooplankton, profundal zoobenthos, and littoral zoobenthos.

Eloranta AP, Knudsen R, Amundsen PA (2013) Niche segregation of coexisting Arctic charr (Salvelinus alpinus) and brown trout (Salmo trutta) constrains food web coupling in subarctic lakes. Freshw Biol 58:207–221
Fig. 3, Lilla Rost, Fjell, Takv, Sagelv, and Josef. Polygons comprised of zooplankton, profundal zoobenthos, and littoral zoobenthos.

Polygon comprised of epilimnetic POM, hypolimnetic POM, and terrestrial.

Galloway AWE, Brett MT, Holtgrieve GW, Ward EJ and others (unpublished data)
Polygon comprised of diatom, green algae, and cyanobacterial phytoplankton.

Polygon comprised of amphipod, planarian, and chironomid.

Polygon comprised of predatory macroinvertebrates, benthic primary consumers, and zooplankton.

Lakes Kilpis, Tsahkal, Raha, Vuontis, Aksu, Kivi, Muddus, and Vastus. Polygons comprised of littoral benthic macroinvertebrates, profundal benthic macroinvertebrates, and pelagic zooplankton.

Polygon comprised of plants, animals, and human food.

Fig. 4. Polygon comprised of zooplankton, fish, and benthic invertebrates.

Fig. 3B. Polygon comprised of jumbo cephalopods, coastal cephalopods, and sardines.

Table 6 and Fig. 9, North, Central, and South. Polygons comprised of zooplankton, POM, and reef-derived.

Fig. 1, BLKI. Polygon comprised of sandlance, capelin, and shrimp.


Polygon comprised of sardine, squid, and supplement.


Fig. 2a,b, polygon comprised of C3, C4, and epiphyton. Fig. 2d,e, polygon comprised of phytoplankton, SPOM, and biofilm. 2f,g,h,i,j, polygon comprised of BSOM+CPOM, biofilm, and epiphyton.


Fig. 4a. Polygon comprised of mussels, shag prey, and krill.


Polygon comprised of offshore plankton, forereef turf algae, and lagon turf algae.


Polygon comprised of invertebrates, fishes, and mammals.


Polygons comprised of green algae, brown algae, and terrestrial plants; also chironomids, collembolans, and terrestrial herbivores.


Polygon comprised of Sargassum, Posidona, and terrestrial plants.


Polygon comprised of benthic algae, Zostera, and phytoplankton.


Polygon comprised of lobster krill, fish, and squid.


Amphiura/summer and Haploops/summer. Polygons comprised of POM, SOM, and epiphytes.
Polygon comprised of bivalves [mainly *Macoma*], small worms, and *Zostera*.


http://dx.doi.org/10.1051/kmae/2013034
Polygon comprised of littoral, profundal, and terrestrial.

Polygon comprised of bacteria-like filaments, POM, and pooled macroalgae.

Polygon comprised of marine mammals, salmon, and deer.

Shaner PJL, Macko SA (2011) Trophic shifts of a generalist consumer in response to resource pulses. PLoS ONE 6:e17970
Control, grid#1, site#1. Polygon comprised of fungi/detritus, arthropods, and plants.

Polygon comprised of marine fish, freshwater fish, intertidal marine invertebrates.

Polygon comprised of littoral, profundal, and pelagic.

Polygon comprised of whitefish, garfish, and mackerel.

Case #3. Polygon comprised of lemming, grey vole, and root vole.

Polygon comprised of microplankton, mesozooplankton, and macroplankton.

Polygon comprised of phytoplankton, algae, and seagrass.
Wootton JT (2012) River food web response to large-scale riparian zone manipulations. PLoS ONE 7:e51839
Polygon comprised of salmon, leaves, and algae.

Polygon comprised of coral mucus, macroalgae, and zooplankton.

Polygon comprised of zooplankton, benthic primary invertebrates, and shrimps/fishes.

Polygon comprised of snails/limpets, mussel, and barnacles.

**Three stable isotope polygons**

Polygon comprised of epi/meta phytoplankton [combined], terrestrial, and littoral/benthic [combined].

Crampton and Paul Lakes. Polygons comprised of terrestrial vegetation, surface phytoplankton, and deep phytoplankton; benthic algae excluded.

Fig. 3 control, Fig. 4 control. Polygons comprised of benthic microalgae, suspended particulate matter, and salt marsh plants.

Polygon comprised of microalgae, macrophytes, and macroalgae.

Crampton, Paul, Peter, and Tuesday Lakes. Polygons comprised of terrestrial, benthic, and pelagic.

Polygon comprised of leaf litter, zooplankton, and periphyton.

The length of each side of these triangular polygons was determined using the 3 coordinate Distance Formula:

\[ d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2 + (z_2 - z_1)^2} \]  

(S1)

where \(x, y,\) and \(z\) represent the normalized \(\delta^{13}C, \delta^{15}N,\) and \(\delta^2H\) or \(\delta^{34}S\) coordinates, respectively.