The following supplement accompanies this article

Resource polygon geometry predicts Bayesian stable isotope mixing model bias

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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 paperare 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 SD^2. 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

Polygon surface area	MixSIR Mean	MixSIR SD	MixSIR Median	MixSIR 2.5	MixSIR 97.5	MixSIR 95% CI	SIAR Mean	SIAR SD	SIAR Median	SIAR 2.5	SIAR 97.5	SIAR 95% CI
0.100	0.341	0.223	0.315	0.018	0.806	0.787	0.342	0.227	0.312	0.016	0.819	0.803
0.316	0.362	0.226	0.341	0.020	0.816	0.796	0.354	0.228	0.329	0.018	0.818	0.800
1.00	0.402	0.229	0.394	0.026	0.840	0.814	0.394	0.233	0.387	0.021	0.836	0.815
3.16	0.541	0.205	0.556	0.097	0.883	0.786	0.484	0.229	0.505	0.041	0.871	0.829
10.0	0.690	0.136	0.694	0.455	0.919	0.464	0.586	0.217	0.628	0.072	0.904	0.832
31.6	0.765	0.089	0.766	0.607	0.928	0.321	0.653	0.212	0.711	0.103	0.917	0.814
100	0.796	0.062	0.795	0.690	0.912	0.222	0.688	0.207	0.755	0.113	0.915	0.802
316	0.802	0.038	0.801	0.737	0.874	0.137	0.704	0.202	0.775	0.119	0.910	0.791
1000	0.801	0.022	0.800	0.763	0.841	0.077	0.713	0.196	0.785	0.133	0.909	0.776

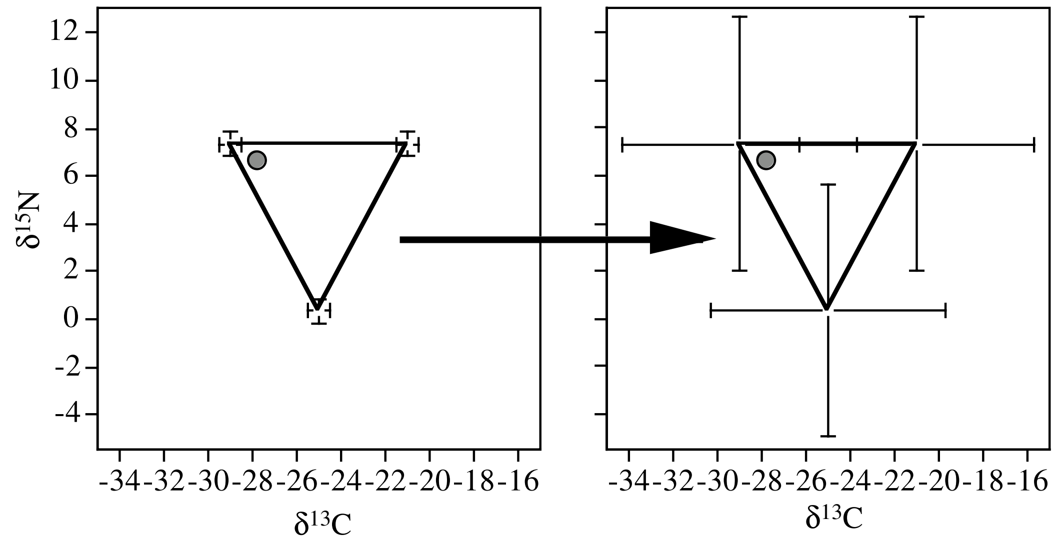

Fig. S1. Schematic of the first experiment. The left-hand plot depicts a normalized polygon with a surface area of 100 SD^2 and the right-hand plot depicts a polygon with a surface area of 1 SD^2. The meta-analysis of triangular resource polygons indicated that 16% of the surveyed polygons had surface areas <1 SD^2 and none had surface areas >100 SD^2. The grey dot represents a hypothetical 80/10/10 consumer

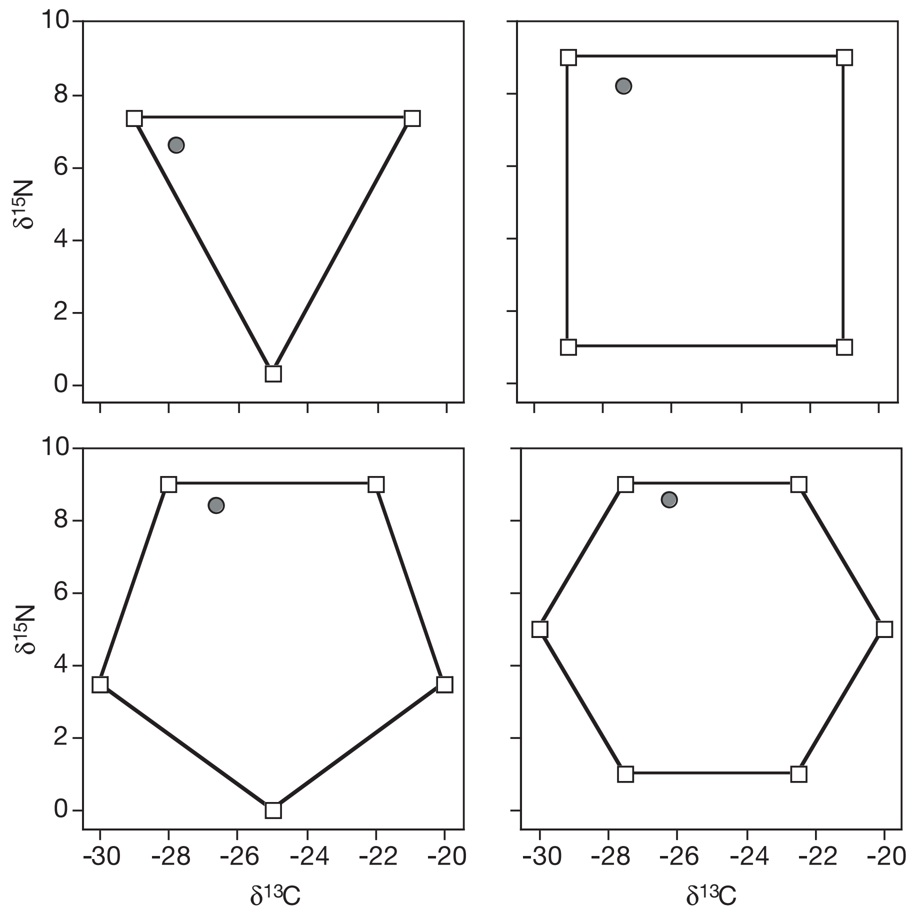

Fig. S2. Regular 3, 4, 5, and 6 end-member polygons tested for this study. Each of these polygons has the same radius (distance from center to a vertex) and the same centroid. The grey dot represents a fixed consumer comprised of 80% of the upper left resource, and 10% of the next 2 resources in a clockwise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

Studies included in the triangular polygon meta-analysis

Two stable isotope polygons

Atwood TB, Wiegner TN, MacKenzie RA (2012) Effects of hydrological forcing on the structure of a tropical estuarine food web. Oikos 121:277–289

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.

Bugoni L, McGill RA, Furness RW (2010) The importance of pelagic longline fishery discards for a seabird community determined through stable isotope analysis. J Exp Mar Biol Ecol 391:190–200

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

Burian A, Kainz MJ, Schagerl M, Yasindi A (2014) Species-specific separation of lake plankton reveals divergent food assimilation patterns in rotifers. Freshw Biol 59:1257–1265

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

Burkholder DA, Heithaus MR, Thomson JA, Fourqurean JW (2011) Diversity in trophic interactions of green sea turtles *Chelonia mydas* on a relatively pristine coastal foraging ground. Mar Ecol Prog Ser 439:277–293

Polygon comprised of macroalgae, seagrass, and gelatinous macroplankton.

Costalago D, Navarro J, Álvarez-Calleja I, Palomera I (2012) Ontogenetic and seasonal changes in the feeding habits and trophic levels of two small pelagic fish species. Mar Ecol Prog Ser 460:169–181

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

Cremona F, Hamelin S, Planas D, Lucotte M (2009) Sources of organic matter and methylmercury in littoral macroinvertebrates: a stable isotope approach. Biogeochemistry 94:81–94

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

Cucherousset J, Boulêtreau S, Azémar F, Compin A, Guillaume M, Santoul F (2012) 'Freshwater killer whales': beaching behavior of an alien fish to hunt land birds. PLoS ONE 7:e50840

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

Cummings BM, Schindler DE (2013) Depth variation in isotopic composition of benthic resources and assessment of sculpin feeding patterns in an oligotrophic Alaskan lake. Aquat Ecol 47:403–414

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

Daly R, Froneman PW, Smale MJ (2013) Comparative feeding ecology of bull sharks (*Carcharhinus leucas*) in the coastal waters of the southwest Indian Ocean inferred from stable isotope analysis. PLoS ONE 8:e78229

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

Eloranta AP, Kahilainen KK, Jones RI (2010) Seasonal and ontogenetic shifts in the diet of Arctic charr *Salvelinus alpinus* in a subarctic lake. J Fish Biol 77:80–97

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

Eloranta AP, Siwertsson A, Knudsen R, Amundsen PA (2011) Dietary plasticity of Arctic charr (*Salvelinus alpinus*) facilitates coexistence with competitively superior European whitefish (*Coregonus lavaretus*). Ecol Freshw Fish 20:558–568

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 Josefv. Polygons comprised of zooplankton, profundal zoobenthos, and littoral zoobenthos.

Francis TB, Schindler DE, Holtgrieve GW, Larson ER, Scheuerell MD, Semmens BX, Ward EJ (2011) Habitat structure determines resource use by zooplankton in temperate lakes. Ecol Lett 14:364–372

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.

Gillespie JH (2013) Application of stable isotope analysis to study temporal changes in foraging ecology in a highly endangered amphibian. PLoS ONE 8:e53041

Polygon comprised of amphipod, planarian, and chironomid.

Glaz P, Sirois P, Nozais C (2012) Determination of food sources for benthic invertebrates and brook trout *Salvelinus fontinalis* in Canadian Boreal Shield lakes using stable isotope analysis. Aquat Biol 17:107–117

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

Hayden B, Massa-Gallucci A, Caffrey J, Harrod C, Mariani S, O'Grady MN, Kelly-Quinn M (2011) Trophic dynamics within a hybrid zone – interactions between an abundant cyprinid hybrid and sympatric parental species. Freshw Biol 56:1723–1735

Lakes Ramor, Corrib, and Ross. Polygons comprised of profundal, littoral, and pelagic prey.

Hayden B, Harrod C, Kahilainen KK (2014) Lake morphometry and resource polymorphism determine niche segregation between cool-and cold-water-adapted fish. Ecology 95:538–552

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

Hopkins JB, Koch PL, Schwartz CC, Ferguson JM, Greenleaf SS, Kalinowski ST (2012) Stable isotopes to detect food-conditioned bears and to evaluate human-bear management. J Wildl Manag 76:703–713

Polygon comprised of plants, animals, and human food.

Jensen H, Kiljunen M, Amundsen PA (2012) Dietary ontogeny and niche shift to piscivory in lacustrine brown trout *Salmo trutta* revealed by stomach content and stable isotope analyses. J Fish Biol 80:2448–2462

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

Kim SL, Casper DR, Galván-Magaña F, Ochoa-Díaz R, Hernández-Aguilar SB, Koch PL (2012) Carbon and nitrogen discrimination factors for elasmobranch soft tissues based on a long-term controlled feeding study. Environ Biol Fishes 95:37–52

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

Kürten B, Al-Aidaroos AM, Struck U, Khomayis HS, Gharbawi WY, Sommer U (2014) Influence of environmental gradients on C and N stable isotope ratios in coral reef biota of the Red Sea, Saudi Arabia. J Sea Res 85:379–394

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

Lavoie RA, Rail JF, Lean DR (2012) Diet composition of seabirds from Corossol Island, Canada, using direct dietary and stable isotope analyses. Waterbirds 35:402–419

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

Madigan DJ, Litvin SY, Popp BN, Carlisle AB, Farwell CJ, Block BA (2012) Tissue turnover rates and isotopic trophic discrimination factors in the endothermic teleost, Pacific bluefin tuna (*Thunnus orientalis*). PLoS ONE 7:e49220

Polygon comprised of sardine, squid, and supplement.

Marchese MR, Saigo M, Zilli FL, Capello S and others (2014) Food webs of the Paraná River floodplain: assessing basal sources using stable carbon and nitrogen isotopes. Limnologica 46:22–30

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.

Masello JF, Wikelski M, Voigt CC, Quillfeldt P (2013) Distribution patterns predict individual specialization in the diet of dolphin gulls. PLoS ONE 8:e67714

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

McCauley DJ, Young HS, Dunbar RB, Estes JA, Semmens BX, Micheli F (2012) Assessing the effects of large mobile predators on ecosystem connectivity. Ecol Appl 22:1711–1717

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

McMeans BC, Arts MT, Lydersen C, Kovacs KM, Hop H, Falk-Petersen S, Fisk AT (2013) The role of Greenland sharks (*Somniosus microcephalus*) in an Arctic ecosystem: assessed via stable isotopes and fatty acids. Mar Biol 160:1223–1238

Polygon comprised of invertebrates, fishes, and mammals.

Mellbrand K, Hambäck PA (2010) Coastal niches for terrestrial predators: a stable isotope study. Can J Zool 88:1077–1085

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

Mellbrand K, Lavery PS, Hyndes G, Hambäck PA (2011) Linking land and sea: different pathways for marine subsidies. Ecosystems 14:732–744

Polygon comprised of *Sargassum*, *Posidona*, and terrestrial plants.

Pacella SR, Lebreton B, Richard P, Phillips D, DeWitt TH, Niquil N (2013) Incorporation of diet information derived from Bayesian stable isotope mixing models into mass-balanced marine ecosystem models: a case study from the Marennes-Oléron Estuary, France. Ecol Model 267:127–137

Polygon comprised of benthic algae, *Zostera*, and phytoplankton.

Quillfeldt P, Schroff S, van Noordwijk HJ, Michalik A, Ludynia K, Masello JF (2011) Flexible foraging behaviour of a sexually dimorphic seabird: large males do not always dive deep. Mar Ecol Prog Ser 428:271–287

Polygon comprised of lobster krill, fish, and squid.

Rigolet C, Thiébaut E, Dubois SF (2014) Food web structures of subtidal benthic muddy habitats: evidence of microphytobenthos contribution supported by an engineer species. Mar Ecol Prog Ser 500:25–41

Amphiura/summer and Haploops/summer. Polygons comprised of POM, SOM, and epiphytes.

Robin F, Piersma T, Meunier F, Bocher P (2013) Expansion into an herbivorous niche by a customary carnivore: black-tailed godwits feeding on rhizomes of *Zostera* at a newly established wintering site. Condor 115:340–347

Polygon comprised of bivalves [mainly *Macoma*], small worms, and *Zostera*.

Ruffino L, Russell JC, Pisanu B, Caut S, Vidal E (2011) Low individual-level dietary plasticity in an island-invasive generalist forager. Popul Ecol 53:535–548

SC May 2006, SC Sept 2006, GI Sept 2006. Polygons comprised of C3 plants, Athropods 1, Arthopods 2.

Ruokonen TJ, Kiljunen M, Karjalainen J, Hämäläinen H (2012) Invasive crayfish increase habitat connectivity: a case study in a large boreal lake. Knowl Manag Aquat Ecosyst 407:08 http://dx.doi.org/10.1051/kmae/2013034

Polygon comprised of littoral, profundal, and terrestrial.

Sellanes J, Zapata-Hernández G, Pantoja S, Jessen GL (2011) Chemosynthetic trophic support for the benthic community at an intertidal cold seep site at Mocha Island off central Chile. Estuar Coast Shelf Sci 95:431–439

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

Semmens BX, Ward EJ, Moore JW, Darimont CT (2009) Quantifying inter-and intra-population niche variability using hierarchical Bayesian stable isotope mixing models. PLoS ONE 4:e6187

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, arthopods, and plants.

Silva-Costa A, Bugoni L (2013) Feeding ecology of Kelp Gulls (*Larus dominicanus*) in marine and limnetic environments. Aquat Ecol 47:211–224

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

Siwertsson A, Knudsen R, Præbel K, Adams CE, Newton J, Amundsen PA (2013) Discrete foraging niches promote ecological, phenotypic, and genetic divergence in sympatric whitefish (*Coregonus lavaretus*). Evol Ecol 27:547–564

Polygon comprised of littoral, profundal, and pelagic.

Stauss C, Bearhop S, Bodey TW, Garthe S and others (2012) Sex-specific foraging behaviour in northern gannets *Morus bassanus*: incidence and implications. Mar Ecol Prog Ser 457:151–162

Polygon comprised of whitefish, garfish, and mackerel.

Tarroux A, Ehrich D, Lecomte N, Jardine TD, Bêty J, Berteaux D (2010) Sensitivity of stable isotope mixing models to variation in isotopic ratios: evaluating consequences of lipid extraction. Methods Ecol Evol 1:231–241

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

Tecchio S, van Oevelen D, Soetaert K, Navarro J, Ramírez-Llodra E (2013) Trophic dynamics of deep-sea megabenthos are mediated by surface productivity. PLoS ONE 8:e63796

Polygon comprised of microplankton, mesozooplankton, and macroplankton.

Vaudo JJ, Heithaus MR (2011) Dietary niche overlap in a nearshore elasmobranch mesopredator community. Mar Ecol Prog Ser 425:247–260

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.

Wyatt ASJ, Waite AM, Humphries S (2012) Stable isotope analysis reveals community-level variation in fish trophodynamics across a fringing coral reef. Coral Reefs 31:1029–1044

Polygon comprised of coral mucus, macroalgae, and zooplankton.

Xu J, Wen Z, Gong Z, Zhang M, Xie P, Hansson LA (2012) Seasonal trophic niche shift and cascading effect of a generalist predator fish. PLoS ONE 7:e49691

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

Yeakel JD, Novak M, Guimaraes PR Jr, Dominy NJ and others (2011) Merging resource availability with isotope mixing models: the role of neutral interaction assumptions. PLoS ONE 6:e22015

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

Three stable isotope polygons

Batt RD, Carpenter SR, Cole JJ, Pace ML, Cline TJ, Johnson RA, Seekell DA (2012) Resources supporting the food web of a naturally productive lake. Limnol Oceanogr 57:1443–1452

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

Cole JJ, Carpenter SR, Kitchell J, Pace ML, Solomon CT, Weidel B (2011) Strong evidence for terrestrial support of zooplankton in small lakes based on stable isotopes of carbon, nitrogen, and hydrogen. Proc Natl Acad Sci USA 108:1975–1980

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

Dibble KL, Meyerson LA (2014) The effects of plant invasion and ecosystem restoration on energy flow through salt marsh food webs. Estuaries Coasts 37:339–353

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

Hondula KL, Pace ML (2014) Macroalgal support of cultured hard clams in a low nitrogen coastal lagoon. Mar Ecol Prog Ser 498:187–201

Polygon comprised of microalgae, macrophytes, and macroalgae.

Solomon CT, Carpenter SR, Clayton MK, Cole JJ and others (2011) Terrestrial, benthic, and pelagic resource use in lakes: results from a three-isotope Bayesian mixing model. Ecology 92:1115–1125

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

Tanentzap AJ, Szkokan-Emilson EJ, Kielstra BW, Arts MT, Yan ND, Gunn JM (2014) Forests fuel fish growth in freshwater deltas. Nat Commun 5:4077

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:

$$d = \sqrt{\left(x_2 - x_1\right)^2 + \left(y_2 - y_1\right)^2 + (z_2 - z_1)^2} \qquad \text{(S1)}$$

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