Determine (1) which models are identifiable for which experimental designs, and (2) what the volume of their parametric domain is given the constraints imposed on the expected count of prey eaten

```
Clear["Global`*"]

AbundSeries = "GoldenRatio";

SetDirectory[FileNameJoin[{NotebookDirectory[], "../results/"}]] ;
DumpGet["Models.mx"]
```

```
In[•]:= GetParams[model_] := DeleteDuplicates@Cases[model, Except[N | P | T | ℯ, _Symbol] , ∞]

AllIdentifiable[model_, Nvals_, Pvals_] :=
 AllTrue[NullSpace[
   Transpose[ArrayReshape[
     Flatten[Grad[model, GetParams[model]] /. N → Nvals /. P → Pvals],
     {Length[GetParams[model]], Length[Nvals] * Length[Pvals]}]]
  ], TrueQ[# == 0] &]
```

```
In[•]:= logGRSpace[a_, b_, n_] := Round[GoldenRatio^Range[a, b, (b - a) / (n - 1)]]

PreyVals[n_, PreyMax_, AbundSeries_] :=
 Which[
  AbundSeries == "GoldenRatio",
  logGRSpace[2, Log[GoldenRatio, PreyMax] + 3, n],
  AbundSeries == "Arithmetic",
  Round[Range[3, Max[logGRSpace[2, Log[GoldenRatio, PreyMax] + 3, n]],
    (Max[logGRSpace[2, Log[GoldenRatio, PreyMax] + 3, n]] - 3) / (n - 1)]]
 ]
PredVals[n_, PredMax_, AbundSeries_] :=
 If[n == 1,
  {1}, (* If only a single level is requested,
  specify a single predator individual *)
  Which[ (* Otherwise, determine predator levels according to GoldenRatio
    or Arithmetic series beginning with 1 predator individual *)
   AbundSeries == "GoldenRatio",
   logGRSpace[0, Log[GoldenRatio, PredMax] + 1, n],
   AbundSeries == "Arithmetic",
   Round[Range[1, Max[logGRSpace[0, Log[GoldenRatio, PredMax] + 1, n]],
     (Max[logGRSpace[0, Log[GoldenRatio, PredMax] + 1, n]] - 1) / (n - 1)]]
  ]]
```

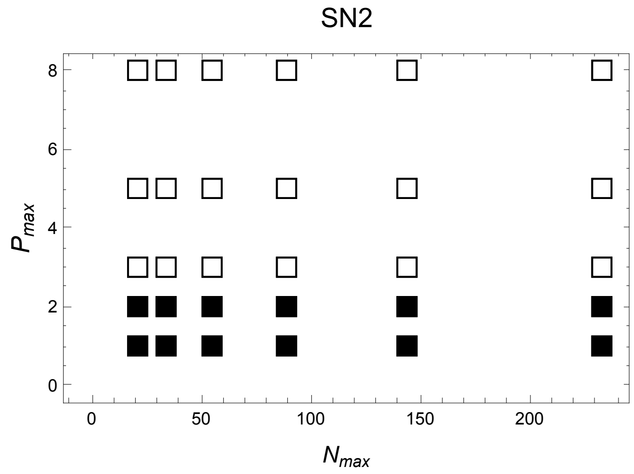
```
In[∘]:= ParamIdent[
          ModelAbb_,
          AbundSeries_] :=
         Module[
          {
           PreyMinLevels = 5,
           PreyMaxLevelsVar = 10,
           PredMinLevels = 1,
           PredMaxLevelsVar = 5
          }
          ,
          Flatten[
           ParallelTable[
            Flatten[{
              Max[PreyVals[i, Fibonacci[i], AbundSeries]], (* Maximum prey level *)
              Max[PredVals[j, Fibonacci[j], AbundSeries]], (* Maximum pred level *)
              Length[PreyVals[i, Fibonacci[i], AbundSeries]],
              (* Number of prey levels *)
              Length[PredVals[j, Fibonacci[j], AbundSeries]],
              (* Number of pred levels *)
              AllIdentifiable[
               ModelAbb,
               PreyVals[i, Fibonacci[i], AbundSeries],
               PredVals[j, Fibonacci[j], AbundSeries]]
             }],
            {i, PreyMinLevels, PreyMaxLevelsVar},
            {j, PredMinLevels, PredMaxLevelsVar}
           ],
           1]
         ]

In[∘]:= ReshapeData[data_] := Flatten[SplitBy[data, Part[#, 1] &][[All, All, {1, 2, 5}]], 1];
```

```
In[∘]:= square[in_, out_ : Black, size_ : 11] :=
          Graphics[{in, EdgeForm[{AbsoluteThickness[1], out}], Rectangle[]},
           PlotRangePadding → 0, ImageSize → size];

        MyListPlot[
          data_,
          plotlabel_,
          axislabels_] :=
         ListPlot[Transpose@{ReshapeData[data][[All, {1, 2}]]},
          PlotMarkers →
           {square[Black], square[White]}[[Boole[ReshapeData[data][[All, 3]]] + 1]],
          PlotStyle → Black,
          PlotLegends → None,
          Frame → True,
          FrameLabel → axislabels,
          ImagePadding → {{60, 5}, {40, 30}},
          PlotRangeClipping → False,
          PlotRangePadding → {Scaled[0.05], Scaled[0.05]},
          Epilog → {Text[Style[plotlabel, 14], Scaled[{0.5, 1.1}]]}
         ]
```

```
In[∘]:= AxisFontSize = 12;
        cm = 72 / 2.54;

        axislabelXY = {
           Style["Nmax", AxisFontSize],
           Style["Pmax", AxisFontSize]};
```

```
In[∘]:= MyListPlot[ParamIdent[SN2, AbundSeries], "SN2", axislabelXY]
```

Out[∘]=



Apply to each model

```
In[∘]:= AllModels = Table[MyListPlot[ParamIdent[models[[i]], AbundSeries],
            modelNames[[i]], axislabelXY], {i, 1, Length[models]}];

        IdentifiablePlot =
          Legended[
           GraphicsGrid[
            ArrayReshape[AllModels, {10, 5}, ""],
            Spacings → {0, -8}],
           Placed[
            SwatchLegend[
             {1, 2},
             {"Identifiable", "Non-identifiable"},
             LegendMarkers → {square[White], square[Black]},
             LegendLayout → "Row",
             LabelStyle → 19 ],
            Above]];
        Export["../figs/Param_Identiability.pdf",
          Show[IdentifiablePlot, ImageSize → 40 cm]];
```