Technical Annexe for the article: Towards a tipping point? Exploring the capacity to self-regulate Antarctic tourism using agent-based modelling

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ODD (Overview, Design Concepts and Details)

Overview

Purpose

This model explores how IAATO's self-regulation regime responds to a) changing commitment levels, b) increasing operator numbers, c) operator diversification, and d) accidents. The indicator for self-regulatory success is membership coverage, the percentage of operators who are members at the end of 20 years.

Entities, State Variables, and Scales

The actors and organisation simulated in the model are ship-based tour operators (referred to as sim-ops) and IAATO (sim-IAATO). Sim-ops may differ from each other on six features: ship type (yacht, small ship, large ship, and cruise ship), decision weights (based on a cost-benefit analysis, CBA), membership (yes/no), desired activity level (1:8), activity level ((0:8), this value can be negative in accident scenarios), and commitment level (0:1.00). Ship type, decision weights, and desired activity level remain constant throughout the simulation, whereas membership, activity level, and commitment levels are dynamic.

The model takes the season 2013-2014 as its base year and has a 20 year temporal timeframe (2013-2034). Time in the simulation is not continuous but discrete. Every year (four-month season) consists of 8 time steps. The model is not spatially explicit. It does, however, include an abstract representation of Antarctica's physical environment (torus 21x21, axes wrap) to address crowding and risk of accidents in a rudimentary way. In keeping with the 'one ship, one place, one moment' principle (IAATO, 2015) , sim-ops cannot occupy the same space and attempt to find spaces where no other sim-op is present. The environment shows near accidents (yellow), minor accidents (black) and major accidents (red).

Process overview and scheduling

At the beginning of each time step, sim-IAATO's image is updated and new sim-ops may be added. The maximum number and type of sim-ops added during a scenario are pre-defined by the simulation user (slider). Once the maximum number of new sim-ops is reached, no further sim-ops are added. The user also determines whether accidents are included (slider), with what risk probability (slider), and what membership costs (slider) when they do occur. Then the simulation determines whether an accident occurs in every time step. If an accident does occur, both the sim-op involved and other sim-ops face repercussions. After finishing these system-level updates, each actor performs a series of actions (see Figure 1 of the main document). The order of these actions is fixed, whereas the order of the actors is randomly determined. First, each sim-op tries to operate. If another ship obstructs a sim-op, the sim-op randomly pivots to operate next time step. Otherwise, sim-ops sail (move one step), increase activity level (by one), and commitment level based on experience. At the end of each year (once every 8 time steps), membership decisions are made. After which, the group effect for members and the non-member effects are calculated and sim-ops activity levels are reset unless they are below zero. In that case, activity level remains the same as it is a repercussion of an accident.

Design Concepts

Basic Principles

Basic principles are derived from IAATO documents and scientific literature presented in this article. IAATO documents determine start-up values, sim-op characteristics, and potential growth scenarios (IAATO, 2013, 2014, 2015a, 2015b). The group effect operationalises Ostrom's (2005) basic principles for common pool resource management and Olson's (1965) theory of collective action.

Emergence

The model's main emergent properties are sim-IAATO membership coverage, sim-op types that become members, and sim-IAATO's collective image.

Adaptation

Sim-ops join sim-IAATO if they perceive membership to be beneficial and leave sim-IAATO if they do not. Also, members slightly lower their commitment using the group effect when membership exceeds an optimal group size as they participate and contribute less to the group. If another ship obstructs a sim-op, the sim-op changes course (rotates) in attempt to operate next time.

Objectives

Sim-ops want to operate, maximise their benefits by being members or not, and be as

active as their desired activity level.

Learning

Learning occurs through operating. It increases commitment and makes sim-op, members and non-members alike, more likely to become or remain sim-IAATO members.

Predictions

Sim-ops predict whether being a member is beneficial using CBA. If non-members' activity level is below a desired activity level, then non-members predict that membership may improve their activity level.

Sensing

Sim-ops internally sense membership status, commitment level, activity level, desired activity level, and decision weights. Externally, sim-ops sense sim-IAATO's image (and indirectly membership number), whether another sim-op is in front of them, accidents, and, for members, group effect on their commitment.

Interaction

Sim-ops directly interact through competition for open spaces. This simulates the competition to be at one place at one time. Sim-ops indirectly interact via their membership decisions and sim-IAATO's image. The decisions of others have the largest impact on cruise ship sim-ops.

Stochasticity

Stochasticity describes statuses and processes for which information is unknown or uncertain. Decision weights are partially randomly determined as no specific information exists on how much each sim-op weighs one factor (commitment) over another (image). For initial commitment levels, partial stochasticity represents sim-ops' heterogeneity, although sim-ops with comparable years of experience are assumed to be similar. Changes to commitment level are also partially random to reflect uncertainty. Desired activity level is partially flexible to reflect the activity range observed in the past twenty years. Sim-ops' initial location and (direction of) movement are randomly determined as the model is not spatially explicit.

Collectives

The main collective is whether or not a sim-op is a sim-IAATO member. The second collective is the sim-op's ship type, which influences how sim-ops assess sim-IAATO membership and desired activity level. The different sim-op types are visually represented by different ships. For real operators with more than one ship type, the operator's most commonly used ship type was simulated.

Observation

Experiments using Netlogo 5.0.4 BehaviorSpace varied parameters according to scenarios for a) commitment, b) increasing operator numbers, c) operator diversification, and d) accidents. These tests are expanded below. The test output is sim-IAATO membership coverage at the end of 20 years. Each value for each variable was tested 40 times. Unless otherwise indicated, the values used for each variable are the same as in the base scenario.

a) *Changing Levels of Commitment*

Three model variables were tested for their influence on membership coverage: (i) experience, (ii) optimal group size, and (iii) membership cost. The progressive group effect was applied throughout.

b) *Growth Scenarios: Impact of New Operators*

Sim-IAATO membership implications of three growth scenarios are explored, relating to growth in (i) small ships, (ii) yachts, and (iii) cruise ships. All growth scenarios maximise the probability that sim-ops are added to ensure that the maximum number desired for the scenario is reached within the 20 year timeframe. Both the conservative and progressive group effects are applied to each scenario.

c) *Diversification of Operator Interests*

These scenarios investigate whether diversifying interests and moving away from IAATO's traditional operator type (small ships) affect sim-IAATO membership. The scenarios consider a near doubling of sim-ops compared to the peak season of 2007-2008 (inspired by Haase et al., 2009): fifteen yachts, ten small ships, three big ships, and three cruise ships are added by default. The impact of increasing diversity is explored by varying the number of yachts (i) and cruise ships (ii) relative to the default scenario. These scenarios run with the conservative and progressive group effect.

d) *Impact of Accidents*

The experiments in this category consider the implications of accidents for sim-IAATO membership. First, this is done in a no-growth setting to explore the influence of increased accident risk (i). Next, growth is taken into account; a moderate-cost, moderate-risk accident is combined with cruise ship growth (ii). Both accident scenarios use the conservative group effect to highlight the impact that accidents have on sim-IAATO membership.

Details

Initialisation

Initialisation values use 2013 as a base year. Every initialisation has 63 sim-ops present, of which 48 sim-ops are members. Initial activity level is zero. Desired activity level, sim-op decision-making weights, sim-op location, and commitment level are randomly determined within pre-set parameters. In setting up sim-ops' commitment levels, we assume that past experience is indicative of the commitment level (Antarctica New Zealand, 2000). Membership costs, initial goodwill, activity influence on commitment, the portion of goodwill that determines image, optimal group size, inactivity weight's effect on CBA analysis, new sim-ops, accident risk, and cost per incident are variable and determined by slider values.

Input Data

No input data is used.

Submodels

The model's variables and the sub-models are described below.

Variable table

Variable	Range	Base scenario	Variability	Information	Assumptions
Optimal group size	0:100	50	Fixed	Lowers commitment if optimal group size is exceeded	Only member numbers plays a role
Portion of goodwill	0:1.00	0.50	Fixed	Part of sim-IAATO's image is based on its historical actions and the other part is based on membership coverage	All sim-op members are worth the same. Total image is based on goodwill and membership coverage
Activity influence on commitment	0:0.01	0.0025	Max is fixed, but variable ranges per sim-op each time	Commitment increases the more active sim-ops are	Members' commitment grows faster than non-members. Experience (activity level) is a precursor for increasing commitment
Progressive group effect	0:0.100	Variable	Variable is a fixed multiplier	Effect depends on group size, optimal group size, and randomness	Up until optimal group size, no loss of personal commitment, afterwards commitment decreases (random (1 - (optimal-group-size / sim-IAATO members))

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Conservative group effect	0:0.20	0.025	Fixed ceiling	Effect depends on group size, optimal group size, and randomness	Commitment decrease limited by a factor (random (factor * (members / optimal-group-size))
Inactivity weight	0:0.5	0.2	Fixed	Percent of inactivity weight is added to CBA (if desired activity level < activity level)	If non-members are not able to operate enough, consider membership as a way to improve their activity level
Initial goodwill	0:1.00 (low: high)	0.8	Fixed	Sim-IAATO has been largely commended for work, but not free from errors and scepticism about future abilities	Given the current situation a high starting value of at least 0.75
Membership cost	0:1.00	0.5	Fixed, except in accident scenario	Many costs associated with being a member	Membership cost is relative Accidents increase cost of improving sim-IAATO's image and preventing further accident
Max new yacht sim-ops	0:30	0	Fixed maximum	Randomly determined when sim-ops enter scenario	Growth is expected, but unsure when
Max new small ship sim-ops	0:32	0	Fixed maximum	Randomly determined when sim-ops enter scenario	Growth is expected, but unsure when
Max new large ship sim-ops	0:8	0	Fixed maximum	Randomly determined when sim-ops enter scenario	Growth is expected, but unsure when
Max new cruise ship sim-ops	0:21	0	Fixed maximum	Randomly determined when sim-ops enter scenario	Growth is expected, but unsure when
Accident	True/false	false	Fixed	'True' scenarios include accidents	Costs of prevented accidents are not included
Accident risk	0:0.25	0.05	Fixed	Risk increases probability of accident	Small risk is assumed
Cost per incident	0:0.20	0.05	Fixed	If yachts or small ships cause accidents: cost increases 50% of cost per incident, sim-ops with activity level of 1:4 decrease activity by 0:1, sim-ops with activity level of 5:8 decrease activity by 1:2 If large ships or cruise ships cause accident, 100% of cost per incident, sim-ops with activity level of 1:4 decrease activity by 1:3, sim-ops with activity level of 5:8 decrease activity by 2:4	Smaller ships (yachts and small ships) have less repercussions for sim-IAATO and other sim-ops as sim-op accidents with 200+ passengers Increased cost remains present for the rest of the simulation

Sub-model equations

Concept	Equation	Extra information
Image	Goodwill% x goodwill + (1 – goodwill%) x (sim-IAATO-members / total sim-ops)	Goodwill%: slider value Initial goodwill: slider value
Add new members	Random number drawn, if matches one of the sim-op numbers 50% change that sim-op type created, else another number drawn and other sim-op possibly created	Max new sim-op of each type: slider value Probability: slider value
Update group commitment with progressive group effect	Sim-IAATO: commitment - random-float (1 - (optimal-group-size / sim-IAATO-members))	High scenario: optimal-group-size is 50
Update group commitment with conservative group effect	Sim-IAATO: commitment - random-float (factor * (sim-IAATO-members / optimal-group-size))	Conservative scenario: factor is 0.025 Average scenario: factor is 0.05 Factor: slider value
Decide not to be a member	Commitment – 0.01	
Does an accident occur?	If: random-float 1 <= accident-risk Then: (sim-IAATO-membership + (desired-activity-level/8) + commitment) / 3 > (random-float (1 + accident-risk))	Sim-IAATO membership: 1 if yes, 0 if no Accident-risk: slider value
Accident repercussions	Cost + cost-per-incident Randomly determine activity level within pre-set parameters	(Initial)cost: slider value Cost-per-incident: slider value
Operate	Sim-IAATO: Activity influence on commitment + Random-float (activity influence on commitment) Non-sim-IAATO: Random-float (activity influence on commitment)	If not impeded by other sim-op, moves forward one space Activity increases by one Activity influence on commitment: slider value
Decide to be a member	Sim-IAATO: CBA-commitment + CBA-image ≥ cost Non-sim-IAATO: if activity level > desired activity level CBA-commitment + CBA-image ≥ cost Else CBA-commitment + CBA-image + inactivity-weight * ((desired-activity-level – activity-level) /8) ≥ cost	Cost: slider value Inactivity-weight: slider value Sim-op's personal values: CBA-commitment: Decision-weight-commitment * commitment CBA-image: Decision-weight-image * sim-IAATO's image Activity-level, desired-activity-level

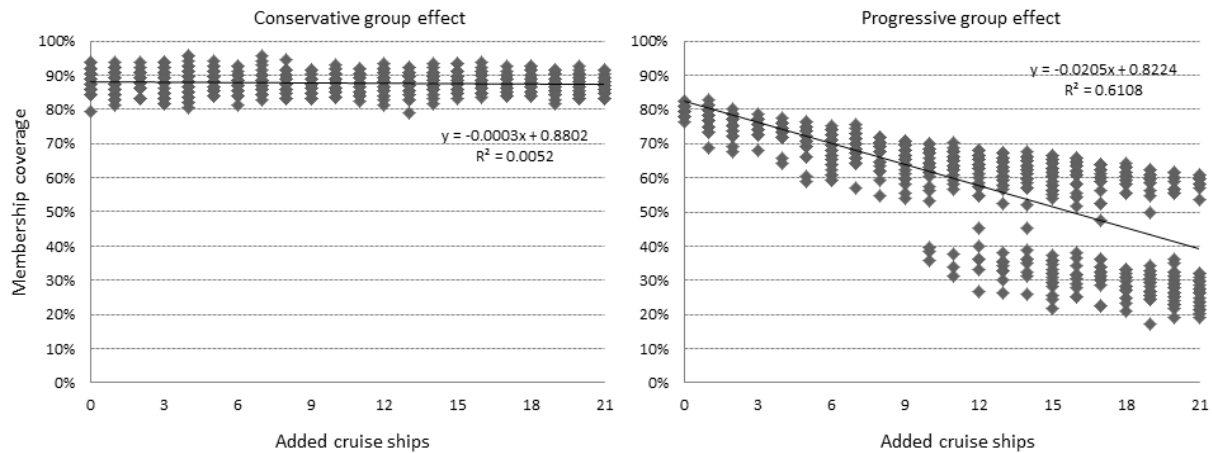# Additional Figures Described in Results Section
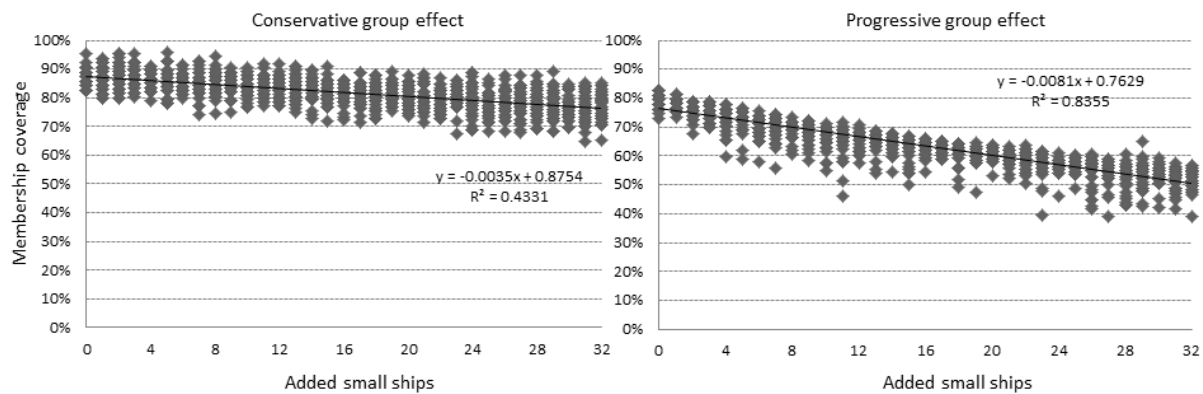
Figure 4. Membership coverage in 2034 as a function of the number of small ships added (conservative and progressive group effects)
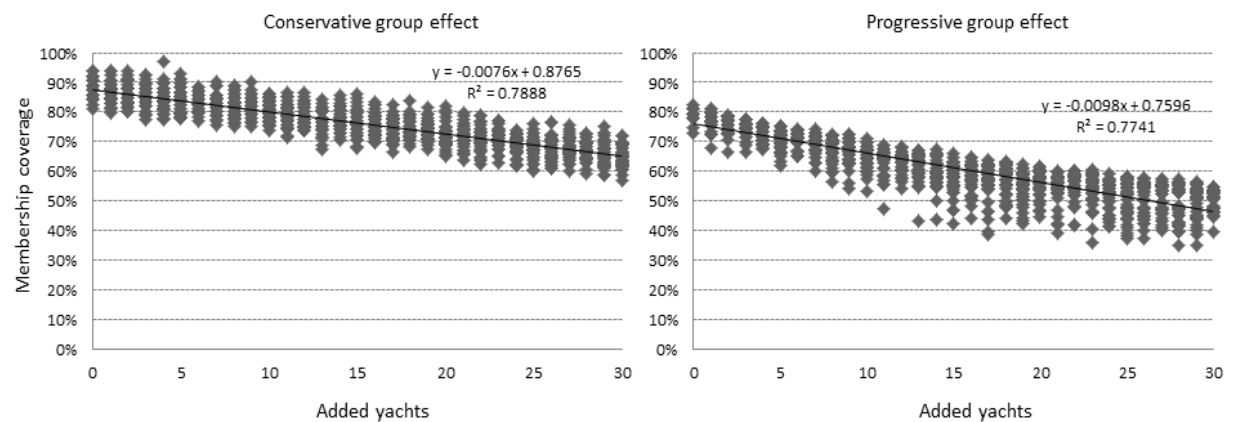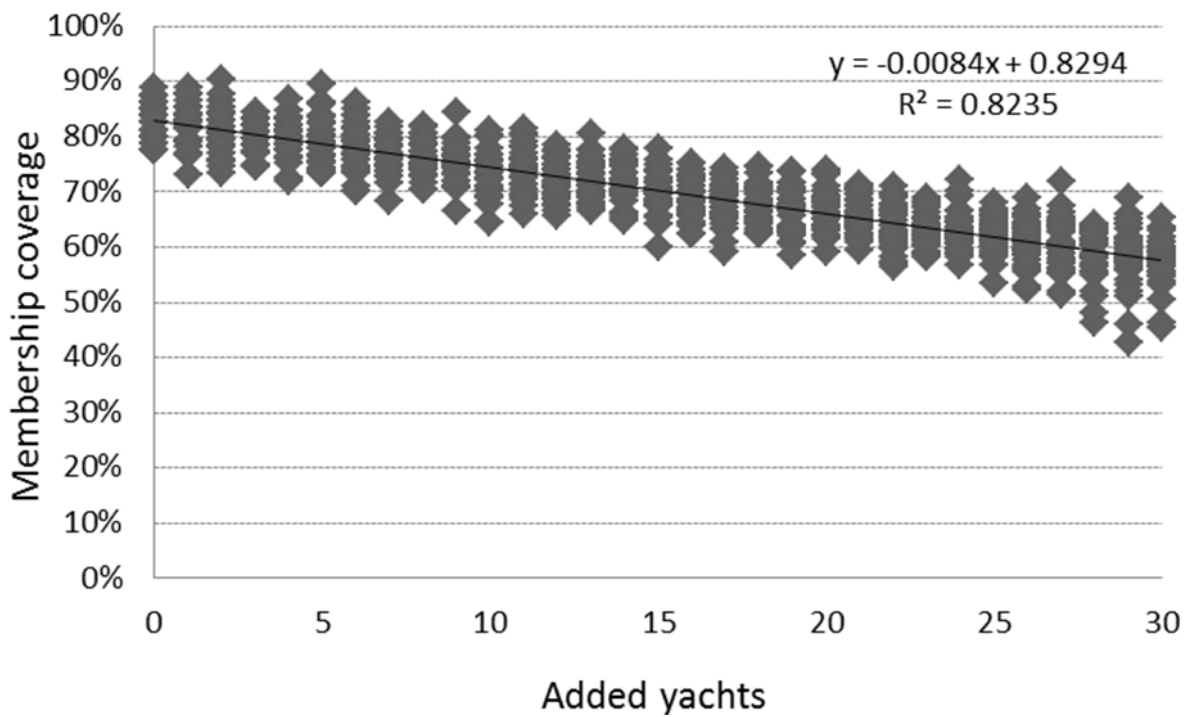

Figure 5. Membership coverage in 2034 as a function of the number of yachts added (conservative and progressive group effects)
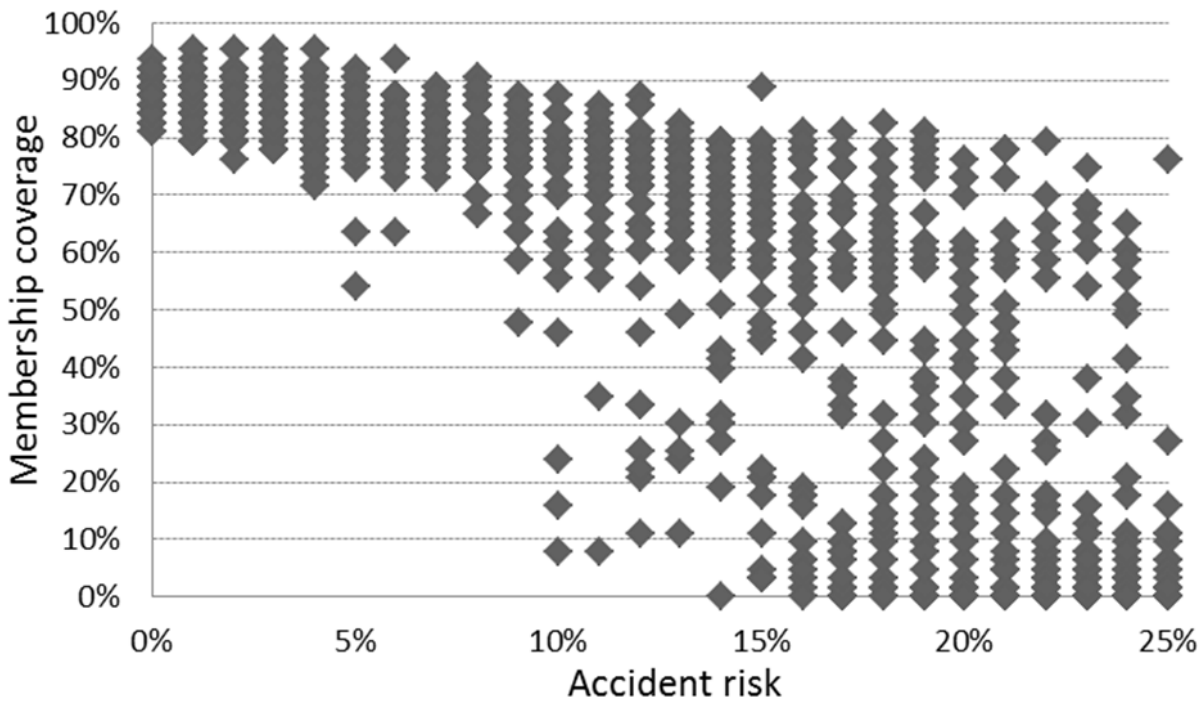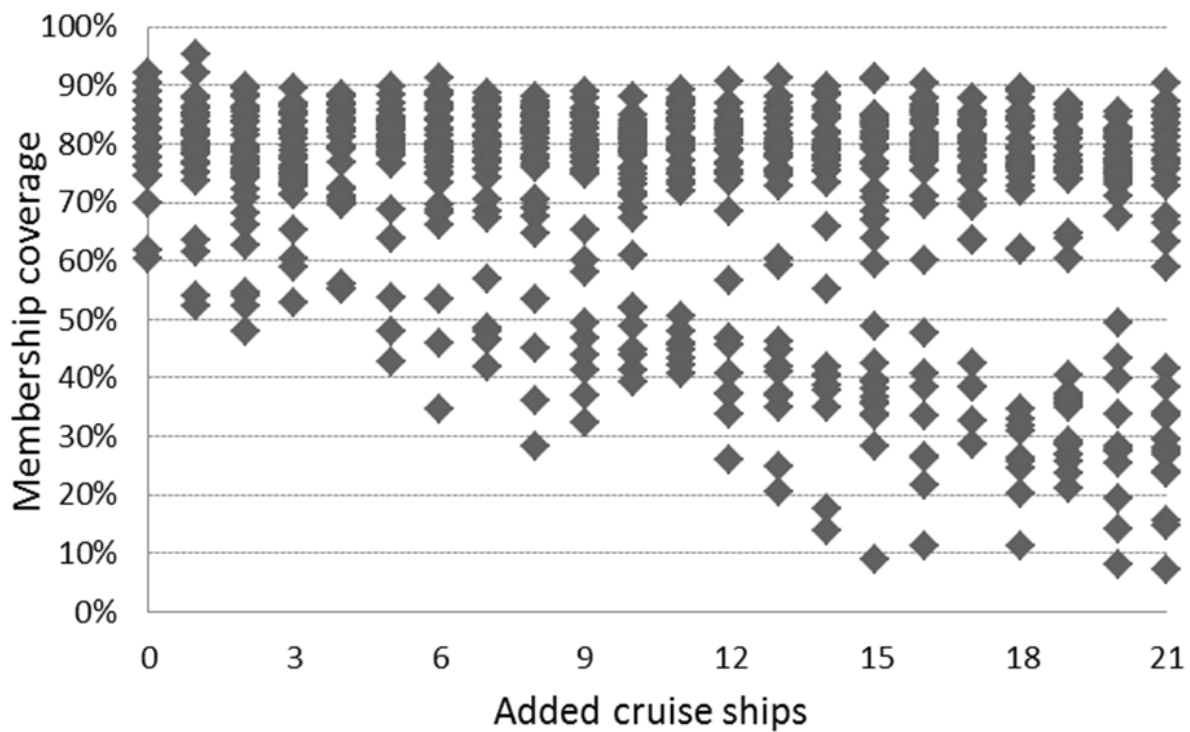
Figure 6. Membership coverage in 2034 as a function of the number of cruise ships added (conservative and progressive group effects)

Figure 7. Membership coverage in 2034 as a function of yacht-led diversification (conservative group effect)

Figure 8. Membership coverage in 2034 as a function of accident risk (small cost per incident)

Figure 9. Membership coverage 2034 as a function of added cruise ships and a moderate-cost, moderate-risk scenario